IMPROVING MARINE CONTAINER TERMINAL PRODUCTIVITY:

DEVELOPMENT OF PRODUCTIVITY MEASURES, PROPOSED SOURCES OF DATA, AND INITIAL COLLECTION OF DATA FROM PROPOSED SOURCES

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I. Summary

Containerized trade is a vital part of the U.S. and world economies. The efficiency of containerized trade gives U.S. consumers access to imports, and U.S. exporters access to world markets. That efficiency begins at the ports and marine terminals that handle containers, making their productivity a matter of great concern.

This project was undertaken by The Tioga Group, Inc. on behalf of the Cargo Handling Cooperative Program (CHCP), a public-private partnership sponsored by the United States Maritime Administration. CHCP's mission includes increasing cargo handling productivity through the implementation of focused research and development.

The growth of container volumes has affected U.S. ports on all coasts, rail terminals on trans-continental routes, and key intermodal connectors. In the decade 1997-2006, aggregate U.S. container volumes at the top 10 ports grew by 186 percent to 35.6 million TEU. The downturn after 2006 placed participants in the container shipping industry under pressure to define, defend, and improve their productivity. U.S. container terminals and their workforces are frequently disparaged for being less productive than the leading Asian and European terminals. Given the issues at stake, it is critical for all participants to have a firm understanding of how various productivity measures are properly defined and used, what they do (and do not) imply for terminal operations, and what long-term factors really determine productivity.

The key questions addressed in this study are:

- What is the most useful set of productivity metrics?
- Which productivity concepts are used by key stakeholders?
- How can we collect and analyze the required data?
- What is the best approach to benchmarking?
- How can we identify and encourage productivity improvements?

Underlying these analytic questions are two more fundamental issues facing port authorities and marine terminal operators:

- Who is my customer and what does he want?
- How do I measure what my customer wants?

What is the most useful set of productivity metrics?

Productivity can most usefully be defined as the combined result of resource utilization and operational efficiency. Resource utilization measures output against capacity, and is usually expressed as a percentage. Productivity of a given asset may be increased either by increasing utilization or by increasing operating efficiency. For example, crane productivity could be increased by operating cranes more hours each day (utilization) or by achieving more lifts per operating hour (efficiency).

There are several possible ways to estimate container port capacity, utilization, and productivity. All rely heavily on industry rules of thumb and a variety of assumptions as well as quantifiable relationships. The general approach used in this study was chosen primarily to suit the readily available port and terminal data elements, with the anticipation of regular data collection, analysis, and publication. More precise estimates are possible, but would require a much greater investment in data collection and analysis, and would change frequently as ports and terminals change their facilities and operations.

Data to support productivity metrics can be drawn from a number of sources. As Exhibit 1 indicates, most of the required data come from the ports or published port directories and fall into four groups based on relative availability.

- Data elements that are almost invariably available from ports, public directories, or government agencies such as the Bureau of Transportation Statistics (BTS). These are shown as “Always” data on Exhibit 1.

- Data elements that are often, but not consistently available. These are not typically confidential and help complete the productivity picture. These data elements are shown as “Sometimes” data on Exhibit 1 .

- Data that must ordinarily be estimated are also shown on Exhibit 1. These are not routinely collected or calculated, but are helpful to an understanding of productivity. These estimates will have different values depending on the estimation method used.

- Cost or labor-related data are usually confidential, as shown on Exhibit 1 and rarely made publicly available. Here too, data values can depend upon methodology and assumptions that vary from port to port.

Exhibit 1 also illustrates the differences in availability of data on the port as a whole and on individual terminals. The chief difference is in three data items that are ordinarily available for ports but not for terminals:

- Annual twenty-foot equivalent units (TEU). The lack of terminal-specific annual TEU eliminates many possible productivity measures for individual terminals (except, of course, for ports such as Savannah, New Orleans, Boston, and Portland that have only one container terminal).

- Vessel calls. Vessel call information is collected by estuary or waterway, and is not always port-specific. The most notable example of this is the Delaware River Ports--Philadelphia, Wilmington, and Camden--where data are consolidated by BTS. A similar situation exists for San Francisco Bay.

- Vessel deadweight tons (DWT and TEU capacity). Vessel DWT and TEU data are handled in the same way as vessel calls.

Exhibit 1: Port and Terminal Data Sources

Available Port Data	Source
Always	
Berth Depth	Port, Directories
Berth Length	Port, Directories
Berths	Port, Directories
Channel Depth	Port, Directories
Cranes & Types	Port, Directories
Gross Acres	Port, Directories
Port TEU	Port, Directories, AAPA
Vessel Calls	BTS
Vessel DWT	BTS
Sometimes	
Avg. Crane Moves/hr	Port
CY Acres	Port, Directories
Rail Acres	Port, Directories
TEU Slots	Port, Terminals
Estimated	
Net BGY Acres	Aerial Photos, Terminal Plans
Vessel TEU	DWT/TEU Relationship
Vessel Length	DWT/Length Relationship
Avg. Dwell Time	Benchmarks, Assumptions
Berth Capacity	Benchmarks, Assumptions
Crane Capacity	Benchmarks, Assumptions
CY Capacity	Benchmarks, Assumptions
Confidential	
Costs	Modeling?
Man-hours	Modeling?
Vessel Turn Time	Modeling?
Rates	Modeling?
Working Crane Hours	Modeling?

Available Terminal Data	Source
Always	
Berth Depth	Port, Directories, Terminal
Berth Length	Port, Directories, Terminal
Berths	Port, Directories, Terminal
Channel Depth	Port, Directories, Terminal
Cranes & Types	Port, Directories, Terminal
Gross Acres	Port, Directories, Terminal
Sometimes	
Avg. Crane Moves/hr	Terminal
CY Acres	Port, Terminal
Rail Acres	Port, Terminal
TEU Slots	Port, Terminal
Truck Turn Times	Terminal
Trouble Ticket %	Terminal
Estimated	
Net BGY Acres	Aerial Photos, Terminal Plans
Vessel TEU	DWT/TEU Relationship
Vessel Length	DWT/Length Relationship
Avg. Dwell Time	Benchmarks, Assumptions
Berth Capacity	Benchmarks, Assumptions
Crane Capacity	Benchmarks, Assumptions
CY Capacity	Benchmarks, Assumptions
Confidential	
Costs	Modeling?
Man-hours	Modeling?
Vessel Turn Time	Modeling?
Rates	Modeling?
Working Crane Hours	Modeling?
Terminal TEU	Modeling?
Vessel Calls	Modeling?
Vessel DWT	Modeling?

Which productivity concepts are used by key stakeholders?

Discussions of productivity measures in the literature tend to converge on relatively few metrics, listed below.

- Annual TEU per acre (or hectare)
- Annual TEU per berth (or per foot of berth)
- Crane moves (or TEU) per hour (or year)
- Vessel turn time (in hours or minutes)
- Berth utilization (in percent)
- TEU or crane moves per man-hour

Analysis undertaken suggests that some of these concepts are too limited, and that more insightful productivity, capacity, and utilization metrics can be developed from readily available data.

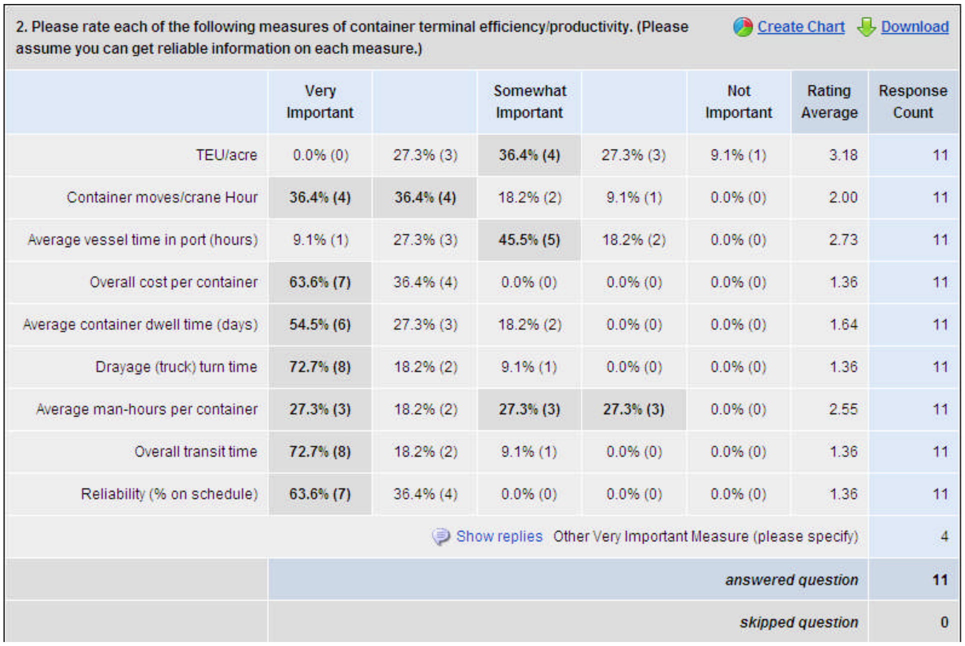
Customer-focused assessments or competitiveness comparisons, tend to focus on a different, but overlapping set of measures.

- Terminal handling cost (or overall cost)
- Cargo velocity, transit time, or dwell time
- Vessel turn time
- Reliability (e.g. % of moves on schedule)

- Crane moves per hour

A customer survey taken in this study (Exhibit 2) found much more emphasis on results, such as overall cost and transit time, than on productivity measures that reflect asset performance. This survey targeted the end customers--importers, exporters, and 3PLs. Those stakeholders do not see the separate cost of marine terminal operations since it is part of the ocean carrier rate. They are likewise insulated from issues such as labor productivity or land use.

Exhibit 2: Results of Customer Survey



2. Please rate each of the following measures of container terminal efficiency/productivity. (Please assume you can get reliable information on each measure.)

	Very Important		Somewhat Important		Not Important	Rating Average	Response Count
TEU/acre	0.0% (0)	27.3% (3)	**36.4% (4)**	27.3% (3)	9.1% (1)	3.18	11
Container moves/crane Hour	**36.4% (4)**	**36.4% (4)**	18.2% (2)	9.1% (1)	0.0% (0)	2.00	11
Average vessel time in port (hours)	9.1% (1)	27.3% (3)	**45.5% (5)**	18.2% (2)	0.0% (0)	2.73	11
Overall cost per container	**63.6% (7)**	36.4% (4)	0.0% (0)	0.0% (0)	0.0% (0)	1.36	11
Average container dwell time (days)	**54.5% (6)**	27.3% (3)	18.2% (2)	0.0% (0)	0.0% (0)	1.64	11
Drayage (truck) turn time	**72.7% (8)**	18.2% (2)	9.1% (1)	0.0% (0)	0.0% (0)	1.36	11
Average man-hours per container	**27.3% (3)**	18.2% (2)	**27.3% (3)**	**27.3% (3)**	0.0% (0)	2.55	11
Overall transit time	**72.7% (8)**	18.2% (2)	9.1% (1)	0.0% (0)	0.0% (0)	1.36	11
Reliability (% on schedule)	**63.6% (7)**	36.4% (4)	0.0% (0)	0.0% (0)	0.0% (0)	1.36	11
				Show replies	Other Very Important Measure (please specify)		4
						answered question	**11**
						skipped question	**0**

As in virtually all industries, cost and labor-related data for marine container terminals are confidential, and are not accessible for public distribution.

Recommended Productivity and Utilization Measures

The value in the productivity, capacity, and utilization measures recommended below is in their combined implications for port and terminal performance.

Each terminal is different. Ports, which are collections of terminals, are more different still. No one measure will suffice, as the differences between ports and the interrelated nature of the metrics create multiple possible interpretations for single data elements. For example, the Port of Houston’s average TEU per acre dropped when the new Bayport terminal opened. The overall capacity and efficiency of the port went up, but, because the new capacity was not immediately filled, a common productivity measure went down. Such instances are common, and dictate the need for multiple metrics.

The study divided container terminal metrics into groups corresponding to the basic assets being used:

- terminal land and container yard

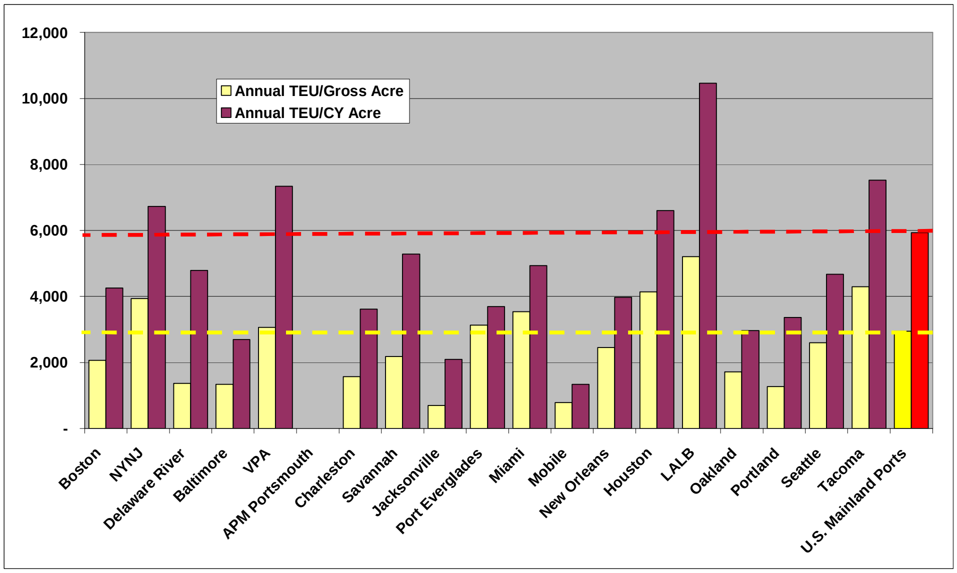
- container cranes
- berths and vessels.

Each proposed metric is discussed below, and graphics provide data and comparisons for U.S. mainland container ports. All data are for 2008, as the extreme recession-induced trade declines in 2009 would drastically skew the metrics.

Land Use and Container Yard (CY) Metrics

Annual TEU per Gross and CY Acre. TEU per acre, meaning gross terminal or port acres, is a commonly used but deceptive metric. Many U.S. container terminals devote substantial portions of their footprint to rail yards or ancillary facilities that would not be present in Asian or European terminals. Annual TEU per CY acre is a much more revealing metric, as it compares throughput (annual TEU) with the inputs directly used (CY acres). Exhibit 3 shows both measures for comparison.

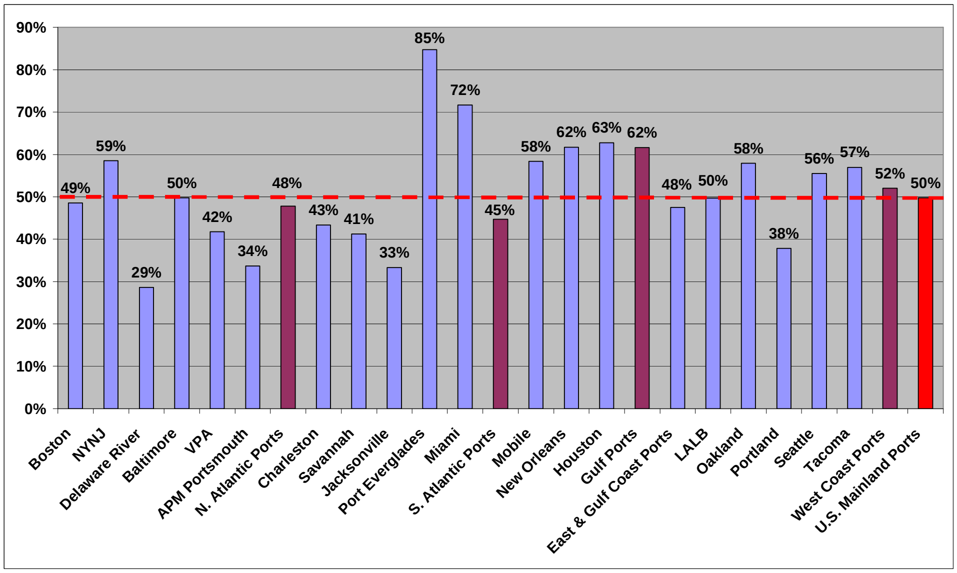
Exhibit 3: Annual TEU per Gross and CY Acre



The highest figures are associated with the busiest, most intensively used ports, notably Los Angeles-Long Beach (LALB); the Virginia Ports (VPA, including Norfolk, Portsmouth, and Hampton Roads); New York-New Jersey (NYNJ); Houston; and Tacoma.

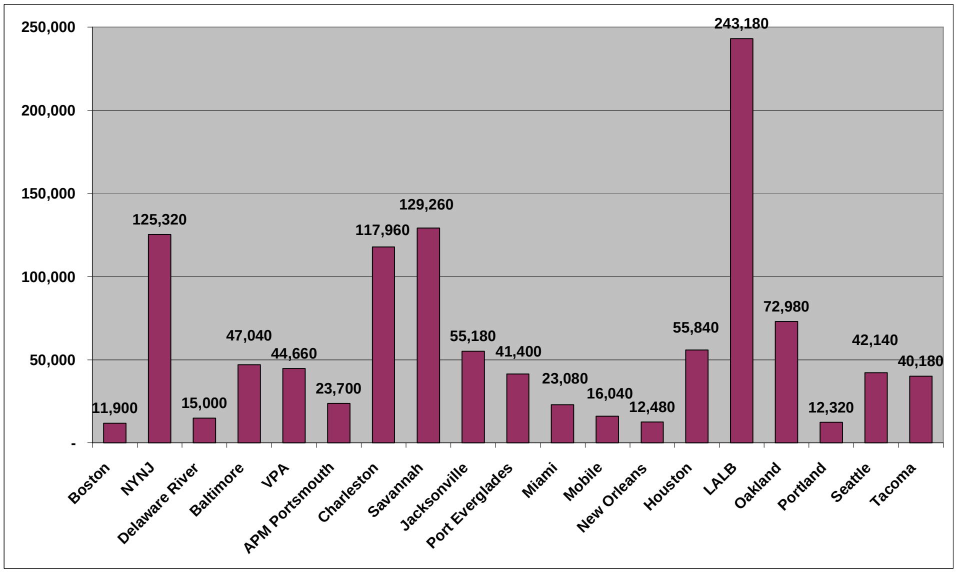
CY/Gross Acreage Ratio. The ratio of CY acres to total (gross) acres helps characterize the port's land use pattern and sheds light on the interpretation of other metrics. Ports and terminals with on-dock rail will have lower ratios, as will legacy or combination terminals that include non-container functions.

Exhibit 4: CY/Gross Acreage Ratio



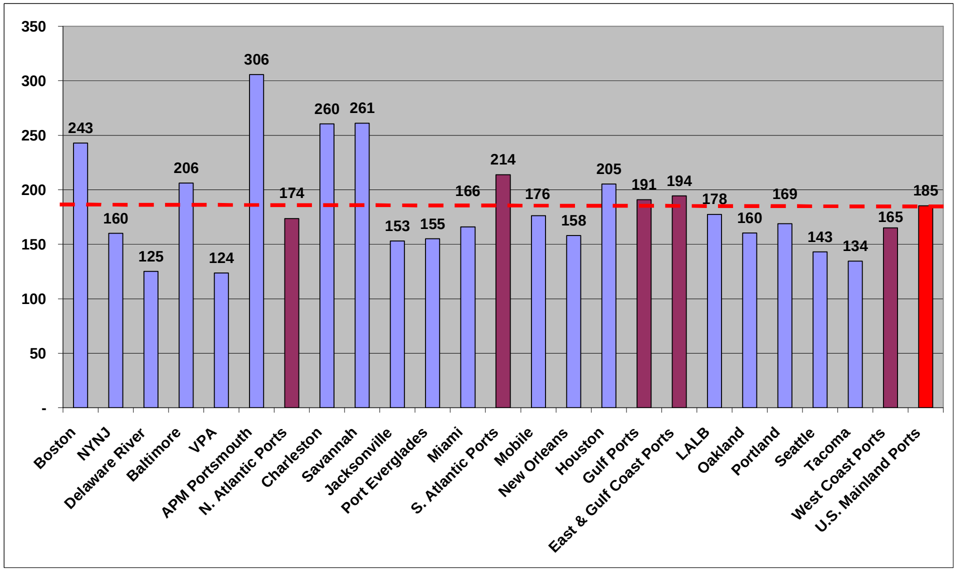
TEU Storage Slots (CY Slot Capacity). The total TEU storage slots in a terminal or port reflects the combination of CY acreage and the CY operating methods in use, and characterizes static storage capacity (Exhibit 5). There are two factors at play: CY acreage and stacking density. The combination highlights the enormous total capacity at the Ports of Los Angeles and Long Beach. Were Seattle and Tacoma combined in the data, the combination would look much larger than the two individual ports.

Exhibit 5: TEU Storage Slots



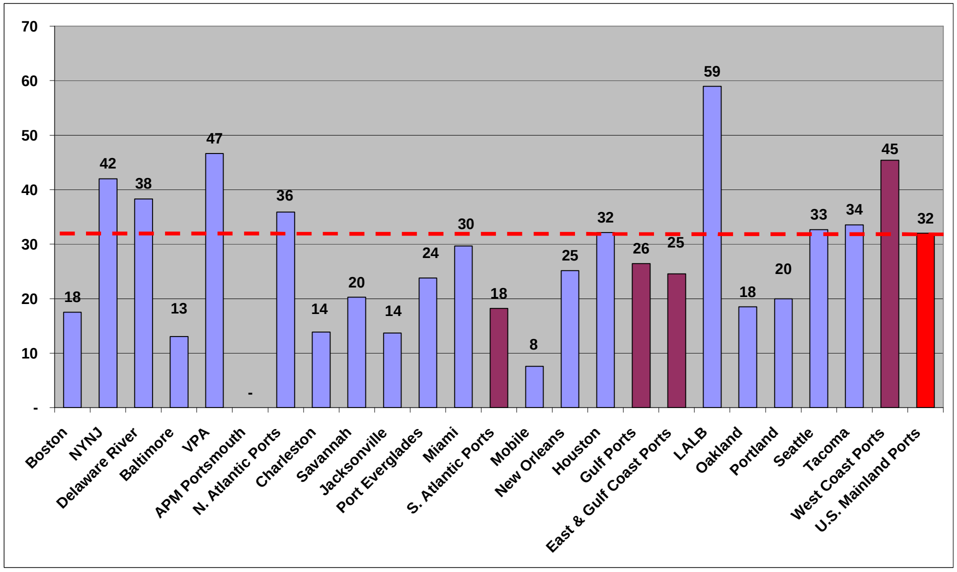
TEU Slots per CY Acre (Storage Density). Storage density is a mid-point in the analysis of capacity and productivity. Storage density (Exhibit 6) reflects the way the terminal space has been allocated among various storage technologies. A higher number indicates that the facility has been configured for high annual throughput, but does not reflect the extent to which that capacity is being used. The very high density figure for the AP Moeller (APM) terminal at Portsmouth reflects its design and configuration as a very high-capacity terminal for future needs. Only a fraction of that capacity is being used at present.

Exhibit 6: TEU Slots per CY Acre (Storage Density)



Annual TEU per Slot (Turns). TEU per slot, or annual slot turns (Exhibit 7), is a productivity measure reflecting the output from the TEU slot "asset." U.S. ports analyzed averaged about 34 annual TEU per CY slot, or about 49% of a benchmark maximum of 70 TEU per slot. (Equivalent to about one turn every five days). The figures are highest at the busiest ports, indicating more intensive use of available capacity.

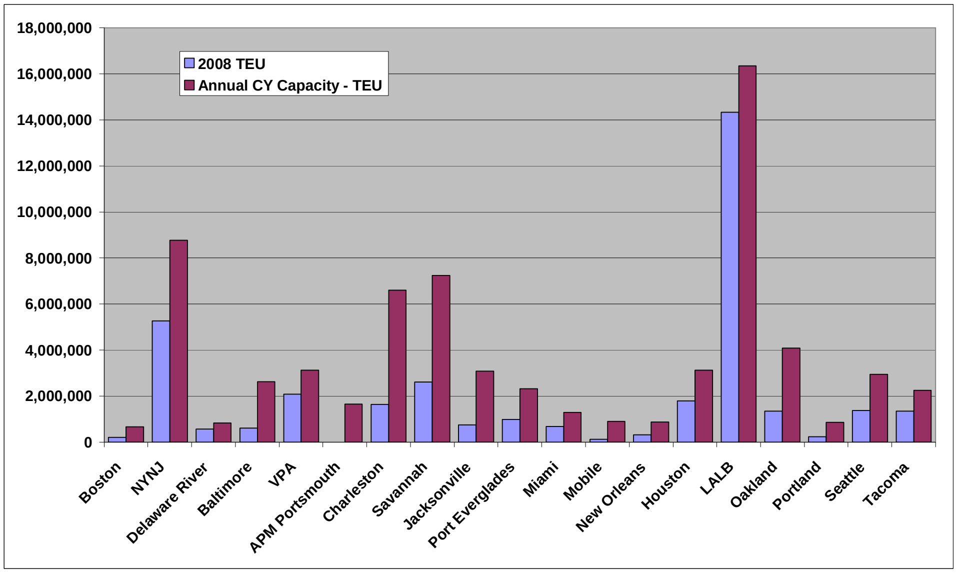
Exhibit 7: Annual TEU per Slot (Turns)



Annual CY TEU Capacity. Annual CY capacity, estimated as the product of TEU slots and a maximum turnover of 70 per year, is a benchmark for the maximum TEU that could be handled.

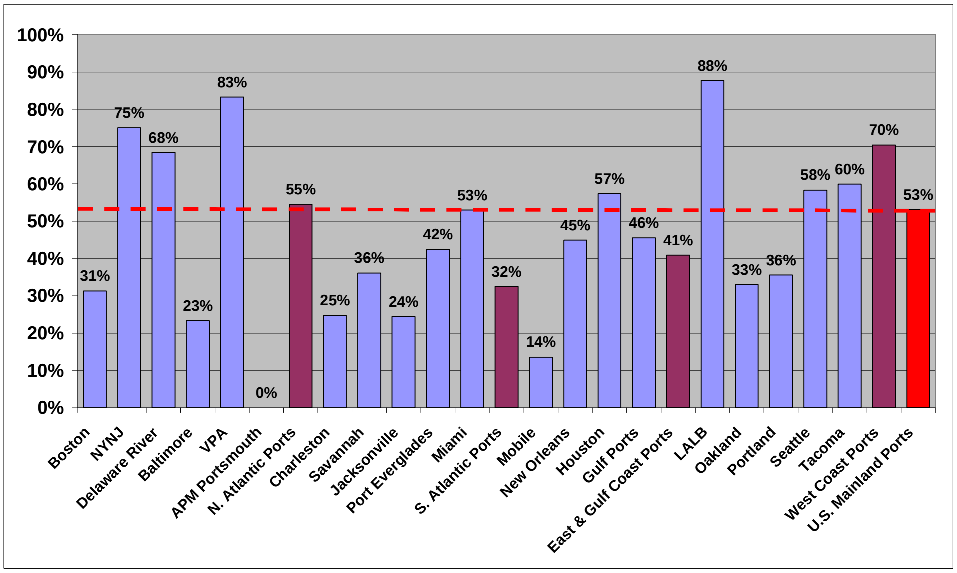
(Exhibit 8) Sustainable capacity can be estimated at 80% of the maximum, allowing for business peaks and valleys and a margin for growth.

Exhibit 8: Annual CY TEU Capacity and 2008 TEU



CY Capacity Utilization. Annual TEU divided by estimated annual TEU capacity (throughput as a percentage of capacity) is a measure of CY capacity utilization (Exhibit 9). The ports shown in Exhibit 9 average 50% CY capacity utilization, indicating substantial latent CY capacity. This is a second reason why U.S. TEU per gross acre looks low compared to crowded Asian and European terminals.

Exhibit 9: CY Capacity Utilization

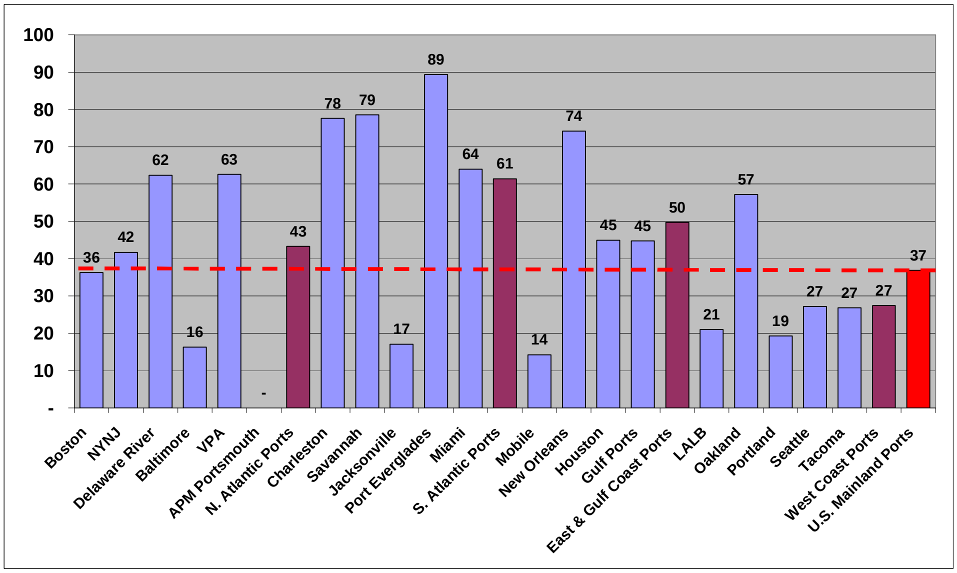


Container Crane Metrics

The following two metrics tell more in combination than either reveals separately.

Annual Vessel Calls per Crane. A marine terminal may use anywhere from one to five cranes to discharge and load a containership. A low number of calls per crane (Exhibit 10) suggests that either there are relatively few vessel calls or that the average call discharges and loads a large number of containers. The low number for LALB is due to the size of the vessels; large vessels require more cranes on each call.

Exhibit 10: Annual Vessel Calls per Crane



Annual TEU per Crane. Annual TEU per crane (Exhibit 11) reflects overall port or terminal performance and balance. A low figure suggests that cranes are being used to handle either relatively few vessels or relatively few TEU from each vessel. The lowest numbers are at Baltimore, Philadelphia, and Portland, which receive relatively few calls. The low figure at Oakland reflects excess crane capacity there.

Exhibit 11: Annual TEU per Crane

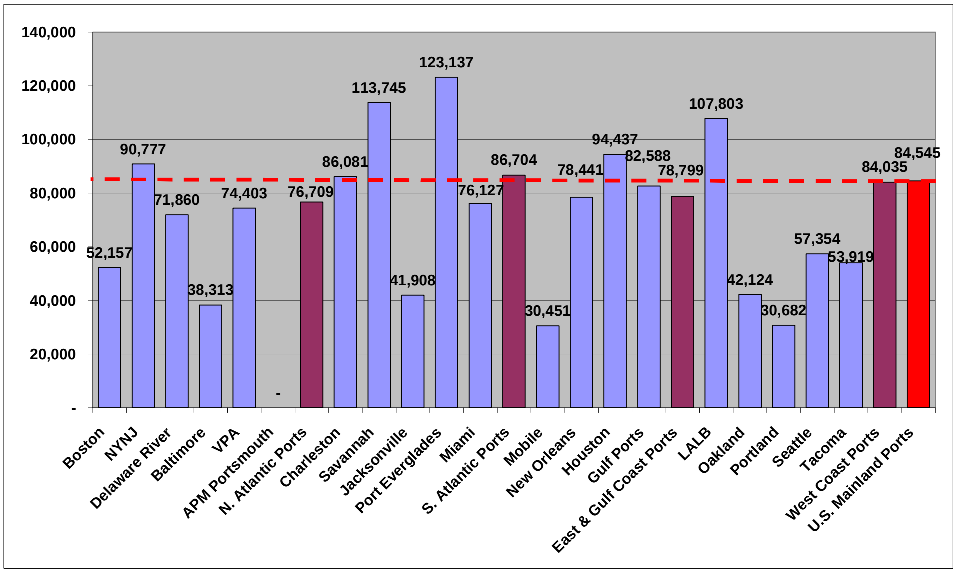
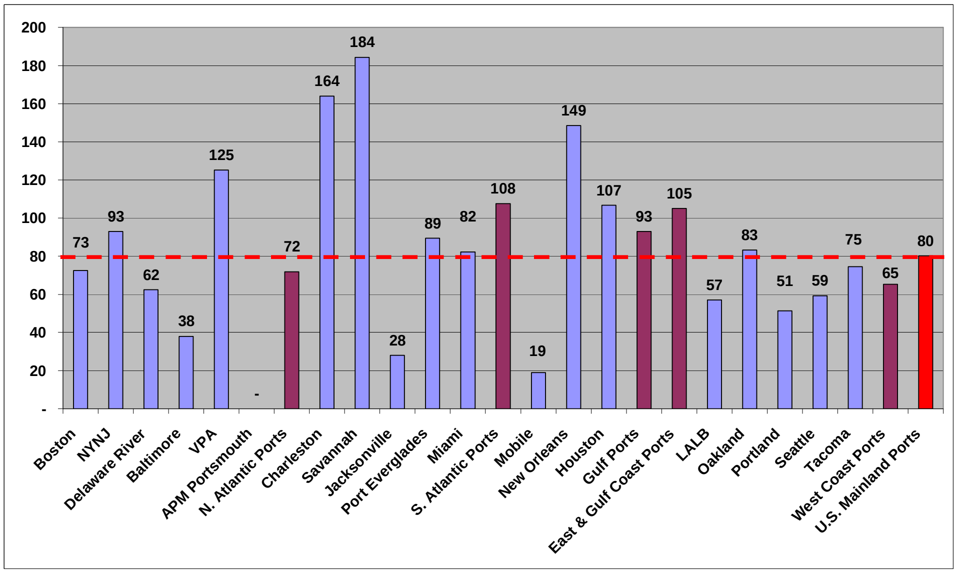


Exhibit 10 and Exhibit 11 together indicate that the ports of Charleston, Savannah, Port Everglades, and New Orleans have very high container-crane productivity. In fact, the situation is more complex, as they combine high crane efficiency (moves per working hour, a metric that is not consistently available) and a large number of calls by smaller vessels. At Port Everglades, the ratios are artificially increased by inclusion in the data of TEU volumes that are handled by barge or self-unloading ships without the use of shore-side cranes.

Berth and Vessel Metrics

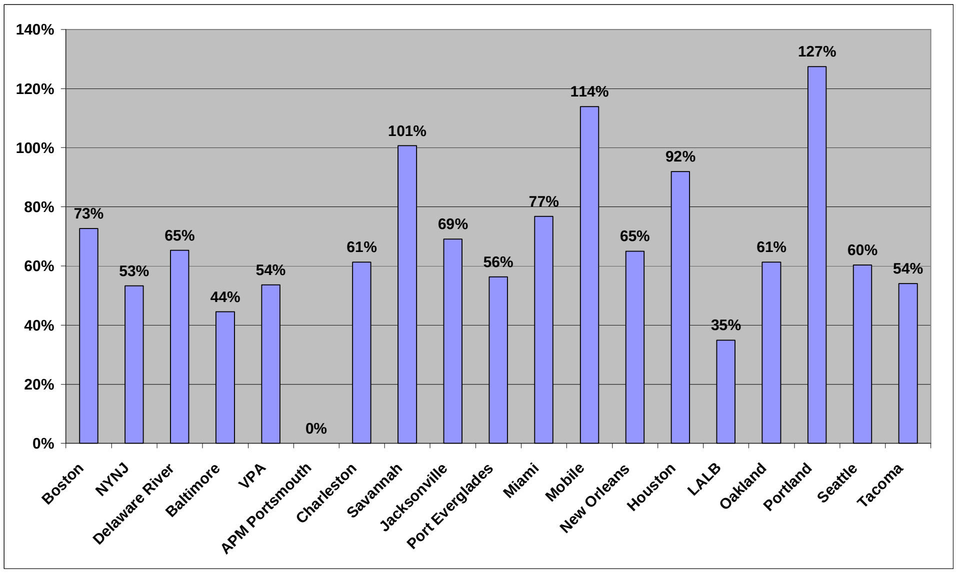
Annual Vessel Calls per Berth. Exhibit 12 displays annual vessel calls per berth, which is the first factor in berth utilization and productivity. There is some ambiguity when terminals have a long berth face that can be divided in different ways, as the number of berths can vary from time to time. These data also show the large number of vessel calls at Charleston, Savannah, and New Orleans, reflected in the crane productivity metrics.

Exhibit 12: Annual Vessel Calls per Berth



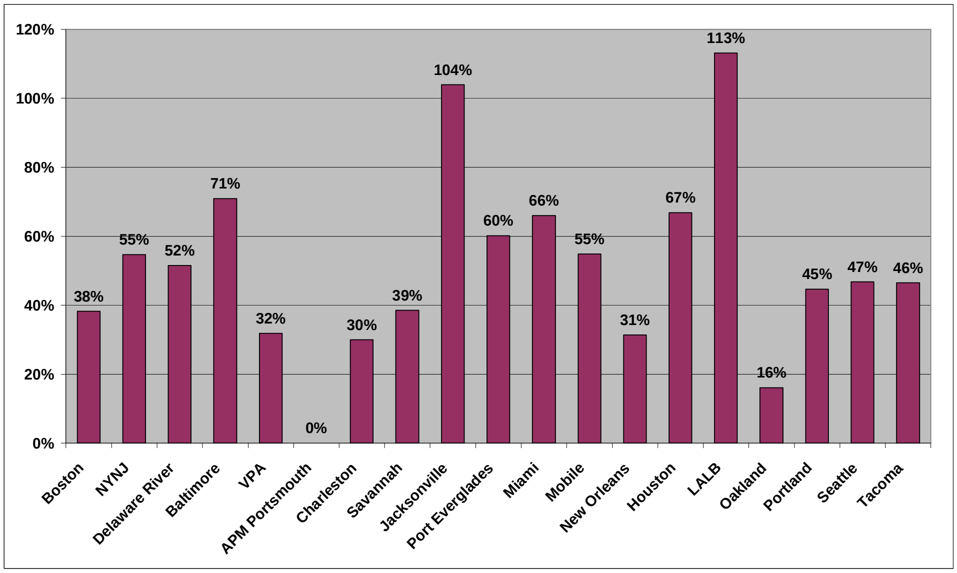
Vessel Size Ratio (Average Vessel TEU Capacity *vs.* Maximum Vessel TEU Capacity). Comparing the average vessel size being handled to the maximum possible vessel size for the available draft (Exhibit 13) indicates how much of the inherent draft and berth length is being used. This ratio can reach 100% if the port is being served by a fleet of maximum-sized vessels, or if tides or light loading are being used to bring in vessels that would otherwise exceed the available draft. Savannah, Mobile, Houston, and Portland show this effect.

Exhibit 13: Vessel Size Ratio - - Average versus Maximum TEU



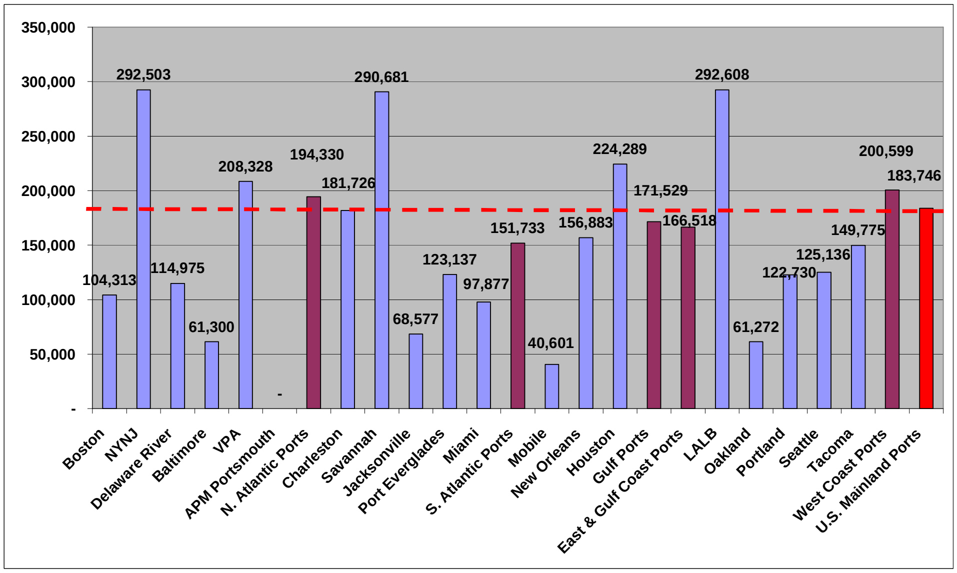
Vessel Size and Load Ratio (Average TEU Discharged and Loaded *vs.* Average Vessel TEU Capacity) (Exhibit 14). Container vessels do not ordinarily sail completely full, or discharge and reload their full capacity at a single port. Ports typically served in rotation on multi-call schedules show lower averages. The high average for LALB is attributable to the numerous "shuttle" services that call there to unload high volumes of intermodal cargo destined for inland markets.

Exhibit 14: Vessel Size and Load Ratio



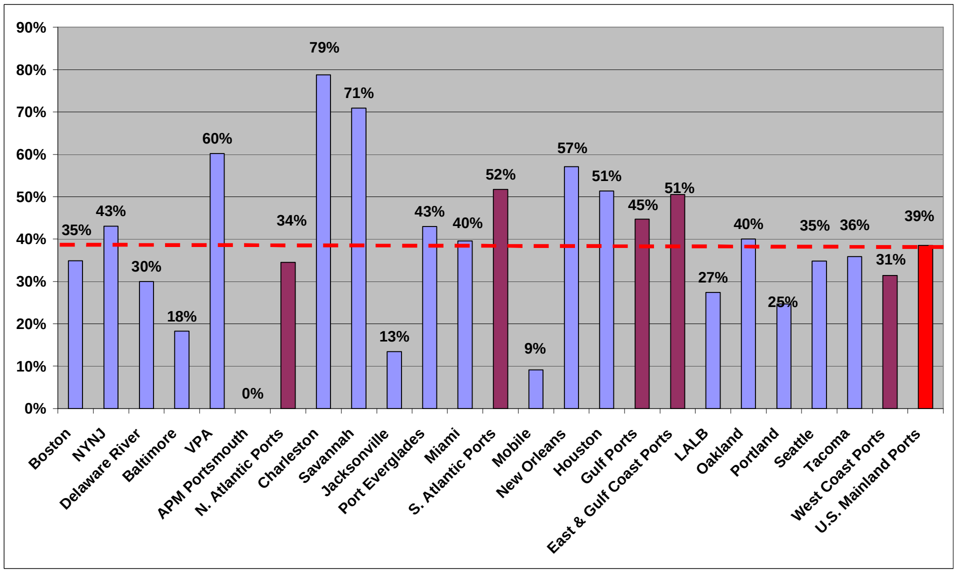
Annual TEU per Berth. If the ultimate function of a marine container terminal is to transfer containers between land and vessel, annual TEU per berth reflects overall productivity (Exhibit 15). The high marks go to NYNJ, Savannah, and LALB, for different reasons: Savannah has a very high number of calls per berth: LALB has fewer calls but much larger vessels and TEU loads on each vessel; and NYNJ has a combination of factors. Ports with a large number of available berths, such as Baltimore and Oakland, show much lower averages.

Exhibit 15: Annual TEU per Berth



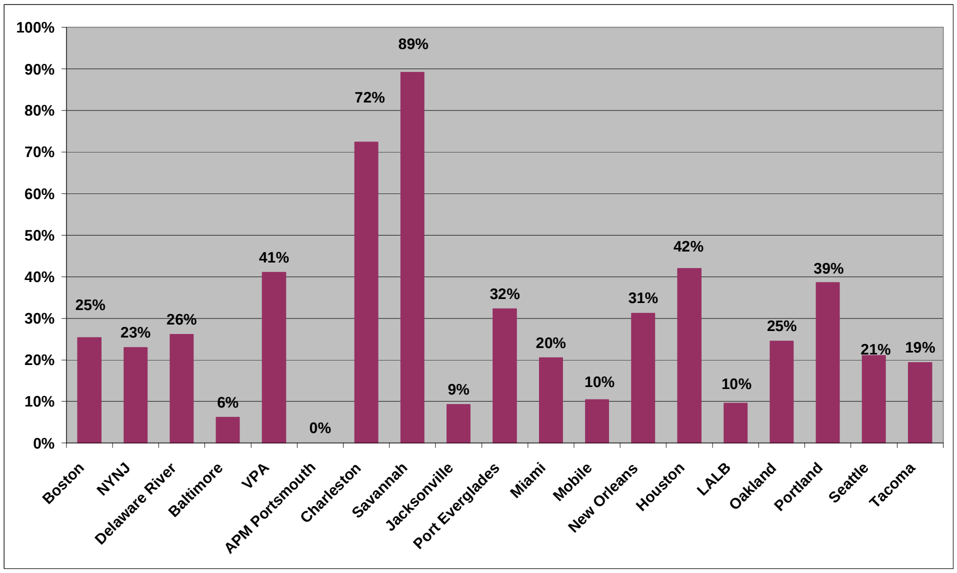
Berth Call Utilization (Vessel calls per berth *vs*. maximum calls per berth). The simplest way to gauge berth capacity utilization is to compare the number of vessels handled (calls) with the maximum that could have been handled (Exhibit 16). The number of vessels that could have been handled must usually be estimated, and is set for this study at 208 per year (80% of a one-per-weekday maximum of 260). The number that can be handled is also affected by the number of containers that must be discharged and loaded for each vessel.

Exhibit 16: Berth Call Utilization



Berth TEU Utilization (Annual TEU per berth *vs*. maximum TEU per berth for maximum vessel size). A more complex look at berth utilization takes into account the maximum TEU that could be handled if the maximum size vessel made the maximum number of calls. (Exhibit 17) This is an aggressive comparison since it measures productivity against a standard that is unlikely to be attained anywhere. The U.S. average is about 34%. Savannah is at 89% because the reported average vessel size is larger than the estimated maximum (due to the use of tides for more draft). The calls per berth measure is high as well. The West Coast ports have low averages because their current average vessel size is well below their maximum vessel size.

Exhibit 17: Berth Utilization - Maximum Vessel Size Basis



Maximum *versus* Sustainable Throughput

Few facilities of any kind can operate at full capacity for an extended period. A general rule of thumb applied in this study is that sustainable throughput (sometimes also called practical capacity, or capability) is 80% of maximum capacity. This is an empirical rather than scientific principle, and applications of this rule of thumb appear in the subject literature. Discounting the maximum capacity in this way implicitly incorporates the following observations.

- Continued operations at or near capacity limits leaves no margin for error or deviation. Marine terminal operations can, as a practical matter, be disrupted by vessel delays, weather, information system outages, or equipment downtime, among other factors.

- A facility operating at its limits has no room for growth, and cargo growth has been more or less continual for most of the last three decades.

- A terminal continually operating at its limits cannot accommodate the seasonal surges that are endemic in containerized transport.

Discounting maximum capacity to 80% allows for these factors without attempting to analyze and incorporate them in detail.

How can we collect and analyze the required data?

The most promising strategy for on-going collection, compilation, and publication of container port productivity data would involve three organizations.

- **American Association of Port Authorities (AAPA).** The AAPA would collect a standardized set of data elements from its members and publish an annual report. The annual report could be a section of *Seaports of the Americas* and/or be available on-line.

- **U.S. Maritime Administration (MARAD).** MARAD would provide financial or in-kind support and technical assistance, and be the U.S. Department of Transportation "customer" for whom productivity data would be provided.

- **The U.S. Army Corps of Engineers Institute for Water Resources/Navigation Data Center (USACE IWR/NDC).** The U.S. Army Corps of Engineers would share the cost with MARAD and be the federal "customer" for port capacity and infrastructure information supported by the same underlying port data.

This approach would offer the distinct advantage of having the leading industry association and the two leading federal organizations working from the same data and definitions while sharing the cost. The resulting data compilations could be made available through AAPA, MARAD, USACE, or the Bureau of Transportation Statistics as required.

Experience in other data collection efforts suggests that an annual update request may be more effective than asking for complete data sets every year. In this approach:

- AAPA would either collect the initial data or use the data from this study as a starting point.

- Each port authority would designate an AAPA contact.

- Each year, the AAPA would send each port a form or electronic file showing the most recent data on record and ask the Port Authority for updates and corrections. These data update requests could be combined with existing data submissions of TEU data to the AAPA.

What is the best approach to benchmarking?

The charts and discussions above, and the more detailed discussions in the body of the report, suggest that great care must be taken in any effort to benchmark productivity, capacity, and utilization of anything so disparate as container ports and terminals. Although each terminal and port uses the same building blocks of land, berths, cranes, etc., they are combined in different proportions to serve different trades and markets.

Where the nature of the data allow computation of U.S. and regional averages, such figures provide at least a starting point for comparisons. U.S. and regional averages are shown in the charts for the following suggested metrics:

- TEU per gross and CY acre (Exhibit 3)
- CY/gross acreage ratio (Exhibit 4)
- TEU slots per CY acre (storage density) (Exhibit 6)
- Annual TEU per slot (turns) (Exhibit 7)
- CY capacity utilization (Exhibit 9)
- Vessel calls per crane (Exhibit 10)
- Annual TEU per crane (Exhibit 11)
- Annual vessel calls per berth (Exhibit 12)
- Annual TEU per berth (Exhibit 14)
- Annual berth call utilization (Exhibit 16)

Estimates of capacity can be made for regions and the U.S. as a whole. These would indicate ability to handle future trade rather than relative efficiency, and so are not shown on the charts. Examples include:

- TEU storage slots (Exhibit 5)
- CY TEU capacity and 2008 TEU (Exhibit 8)

Metrics that relate berth and vessel utilization cannot be reliably defined on a regional basis, in part because maximum vessel sizes are not meaningful. Some metrics, thus lack useable regional or national averages, including:

- Vessel size ratio (average *versus* maximum TEU) (Exhibit 13)
- Vessel size and load ratio (Exhibit 14)
- Berth utilization, maximum vessel size basis (Exhibit 17)

As with all benchmarking exercises, comparison between port data and a national average, or between two sets of port data, is the beginning point of the analysis, not the end.

Some benchmarks highlight differences in utilization:

- CY TEU capacity utilization (Exhibit 9)
- Annual TEU per slot (turns) (Exhibit 7)
- Annual TEU per crane (Exhibit 11)
- Berth call utilization (Exhibit 16)

In these cases low numbers indicate reserve capacity, while high numbers indicate the potential for congestion or the need for investment and expansion.

Some benchmarks also highlight characteristics of the trade being handled:

- Vessel size ratio (Exhibit 13)
- Vessel size and load ratio (Exhibit 14)

These factors are largely external to the ports and terminals, and must be accommodated in terminal design and operation.

Still other benchmarks help describe how ports and terminals are configured and used:

- CY/Gross acreage ratio (Exhibit 4)
- TEU slots per CY acre (storage density) (Exhibit 6)
- Vessel calls per crane (Exhibit 10)

These and other benchmarks can be used by port authorities and marine terminal operators to compare their operations with national averages, and regional competitors to:

- Place their operations in context
- Highlight key differences
- Locate best practices or technologies

Such benchmarks can also be used by regional and national planners and policy makers to:

- Assess the ability of ports, coastal systems, and the nation as a whole to handle expected growth in containerized trade
- Locate available short-term capacity for military deployment, export surges, project cargoes, or other specific needs
- Assess the adequacy of companion infrastructure in waterways, roads, and railroads

How can we identify and encourage productivity improvements?

The development and use of port productivity metrics is an essential part of the process of identifying and encouraging productivity improvements. That process would include:

- Determining what factors of capacity, utilization, and productivity are important
- Developing metrics for those factors
- Benchmarking to locate high-performing ports

- Using multiple metrics to understand variations in performance
- Identifying applicable matrices and technologies that make the difference

Productivity metrics will assist ports and public decision makers with much, but not all, of this process. Port specific analysis will still be needed to place individual metrics in context and to determine why the figures differ.

It is apparent from the productivity metrics and charts presented in this report that "right sizing" is a major factor in high utilization and productivity. Ports, such as LALB and NYNJ, that have been hard pressed to expand their terminal areas, exhibit higher densities and utilization. Ports that have recently added capacity in anticipation of long-term growth, such as Oakland and Mobile, show lower short-term utilization and productivity.

Potential high-productivity port examples would include:

- LALB, on the basis of TEU per CY acre (Exhibit 3), annual TEU per slot (turns) (Exhibit 7), and vessel size and load ratio (Exhibit 14)
- Charleston, on the basis of TEU slots per CY acre (storage density) (Exhibit 6), annual TEU per crane (Exhibit 11), annual vessel calls per berth (Exhibit 12), and berth call utilization (Exhibit 16)
- APM Portsmouth, on TEU slots per acre (density) (Exhibit 6)

Specific productivity factors are also cited in the detailed discussions of potential metrics and port data.

II. Introduction

Background

The U.S. economy has been substantially altered by intermodal transportation, which permits the efficient global movement of trade. Economies of scale in vessel, rail, and port operations have encouraged containerization of a wide variety of import and export commodities. In the decade 1997-2006, aggregate U.S. container volumes at the top 10 ports grew by 186 percent to 35.6 million TEU.

The capacity and productivity of U.S. container ports is the single most critical factor in the nation’s ability to participate in containerized trade. Beginning in the 1950s and accelerating in the decades that followed, containerization transformed both international merchandise trade and the ports that serve it. Efficient handling of containerized trade requires far more than just dockside space and labor; it requires sophisticated facilities, equipment, and systems manned by trained operators. The facilities, equipment, systems, and manpower needed for container terminals are all costly. There is an inherent tension between having enough capacity for trade peaks and expected growth, and creating excess capacity that ties up valuable resources.

Participants in the container shipping industry are under pressure to define, defend, and improve their productivity. U.S. container terminals and their workforces are frequently disparaged for being less productive than the leading Asian and European terminals. Given the issues at stake, it is critical for all participants to have a firm understanding of how various productivity measures are properly defined and used, what they do (and do not) imply for terminal operations, and what long-term factors really determine productivity.

There are few, if any, concerns over container port capacity for the immediate future. The global recession has drastically eroded containerized trade, with most ports seeing 2009 volumes 10-30 percent below the 2006-2007 peaks. Trade began to recover its momentum in early 2010 as this report was being prepared, but it will likely take 5-7 years to regain 2006-2007 volumes.

At those 2006-2007 peaks, there were legitimate concerns over the ability of U.S. container ports to accommodate foreseeable long-term growth. The San Pedro Bay ports were severely congested during the 2004 peak shipping season. Spot capacity shortages have developed from time to time at many ports, and have persisted in some cases despite the recession. Given the high cost and long lead times required to expand container terminal capacity, it is reasonable to ask whether the capacity will be available when it is eventually needed.

The planned opening of the new, higher-capacity Panama Canal locks in 2014 will permit carriers to deploy larger, more economical vessels in Asia-East Coast and Asia-Gulf services, and challenge the productivity of U.S. ports. The increase in vessel sizes is likely to be gradual as vessel fleets adjust and trade volumes grow. While a gradual increase in the size of trans-Panama container vessels will likely give the U.S. ports time to respond to concomitant capacity needs, the response will still be necessary.

Purpose

The Cargo Handling Cooperative Program (CHCP) is a public-private partnership sponsored by the United States Maritime Administration. CHCP's mission statement includes a general objective to increase the productivity of cargo transportation companies through the implementation of cargo handling research and development. This project focuses on establishing an agreed to set of productivity measures for marine terminals. Time-series collection of these measures will permit CHCP to benchmark terminal productivity and promote best practices, allowing CHCP to accomplish its objectives.

The project was completed in two phases. First was the development of the list of measures, and second was the collection of the initial set of data.

Scope

There are five basic contexts in which productivity measures are estimated and used.

- **Port and terminal benchmarking.** The primary goal of this project was to facilitate both cross-section and time-series comparisons. Ports and terminals sometimes conduct their own benchmarking studies or take before-and-after measurements to document the benefits of facility or process improvements.

- **Cost estimation and planning.** From a fiscal standpoint, productivity links investment, operating cost, and revenue. Port and terminal operators use productivity measures to evaluate and prioritize capital investment projects.

- **Research and modeling.** Private-, academic-, and public-sector researchers explicitly or implicitly incorporate productivity measures in their analyses and models. Examples include the San Francisco Bay Seaport Plan, and models used to compare terminal configurations and operating practices.

- **Technology comparisons.** Technology firms, equipment vendors, and their clients all use productivity measures to support decision making.

- **Port choice and cargo routing.** To the extent that carriers and customers consider port productivity in their choice of import and export ports, productivity measures will affect the outcome.

This report does not address the capacity of highways, railroads, and intermodal connectors to move containers to and from the ports. Trade growth through 2006-2007 was creating concern among local, regional, and state transportation officials regarding impacts on road and rail infrastructure. The recession has provided a multi-year reprieve, but the issue will eventually return.

This report likewise does not address the supply of drayage trucks and drivers needed to pick up and deliver more containers. The drayage tractor supply can be increased as required, although meeting stringent emissions requirements will add to the cost. The supply of drivers may be more problematical. Until the recession, motor carriers nationwide were experiencing a persistent driver shortage. Some Southern California drayage firms were offering signing bonuses for new drivers. Transportation Worker Identification Credential (TWIC) requirements have further reduced the pool of drivers eligible for port drayage. As trade recovers, there could be a shortage of drayage drivers.

Finally, this report does not address the need for trained personnel to operate expanded terminals. Labor supply cannot be taken for granted. A major contributor to the 2004 peak season congestion in Southern California was a Longshore labor shortage. The pool of Longshore labor has since expanded, but has shrunk somewhat as Longshoremen idled by the recession have moved to other jobs.

Approach

The study began by simultaneously reviewing the technical and industry literature to determine how port productivity could and should be measured, and assembling the available data into a set of marine terminal profiles. These profiles were assembled to serve as the basis for data analysis, and are presented as a stand-alone report appendix (Appendix C).

The study team also undertook on-line surveys of major customers (importers, exporters, 3PLs), and drew on surveys of drayage drivers and companies being conducted for other projects. The study team also examined parallel metrics for rail intermodal terminals. Analysis of the data focused on port productivity, capacity, and utilization metrics that could be developed from data that were consistently available for major container ports and terminal, or data that is often available and which could become consistently available. This analysis yielded a set of over 15 useable metrics that, together, are far more revealing than global measures, such as TEU per gross acre. These measures can be used to understand the operations of a single port, to understand the differences between ports, to benchmark port performance against U.S. averages or regional revenues, and to locate candidate best practices.

III. Port Productivity Concepts and Data Sources

Working Definition of Productivity

Productivity can most usefully be defined as the combined result of resource utilization and operational efficiency. Resource utilization measures output against capacity and is usually expressed as a percentage.

For example:

A crane is available 24 hours, and used 8 hours - Utilization = 33%

Operational efficiency measures output per unit input, and is usually expressed as a ratio. For example:

A crane averages 24 moves per hour when in use.

Productivity measures output over time. For example:

A crane averages 24 moves/hour, 8 hours/day or – 192 moves/day.

Operational efficiency measures output per unit input, and is usually expressed as a ratio. Crane moves per hour is an *efficiency* measure, while crane operating hours per day is really a *utilization* measure.

Productivity of a given asset may be increased either by increasing utilization or by increasing operating efficiency. Using cranes as an example, crane productivity could be increased by operating cranes more hours per day (utilization) or by achieving more lifts per operating hour (efficiency). This two-part conceptualization of productivity is akin to the DuPont formulation of return on equity (ROE) in corporate finance, where ROE is a function of operating efficiency (profit margin, net profit/sales) and asset efficiency (asset turnover, sales/asset). In both cases, an overall measure is not nearly as useful or revealing as when it is broken into components.

Productivity measures are ordinarily used to compare two methods of obtaining the same throughput, or the relative throughput of two facilities when both are operating at capacity. Productivity is usually expressed as units of output per unit of input.

- TEU per acre/berth/man-hour
- Crane moves per hour/day/shift
- Moves per gang hour
- Cost per TEU/container
- Vessels turns per berth

Capacity measures are usually in units of output per time period and should represent the maximum throughput possible unconstrained by demand or other systems.

- Maximum TEU per hour/day/year
- Maximum crane moves per hour/day
- Yard storage TEU/acre

Utilization is usually defined as current throughput divided by throughput capacity, expressed as a percentage.

- Berth utilization or occupancy
- Crane utilization
- Terminal utilization

Throughput is ordinarily expressed in units of output, such as TEU, lifts, or gate transactions per time period.

- Containers per gate hour
- Crane moves per hour or day
- Vessel turn times
- Container dwell time

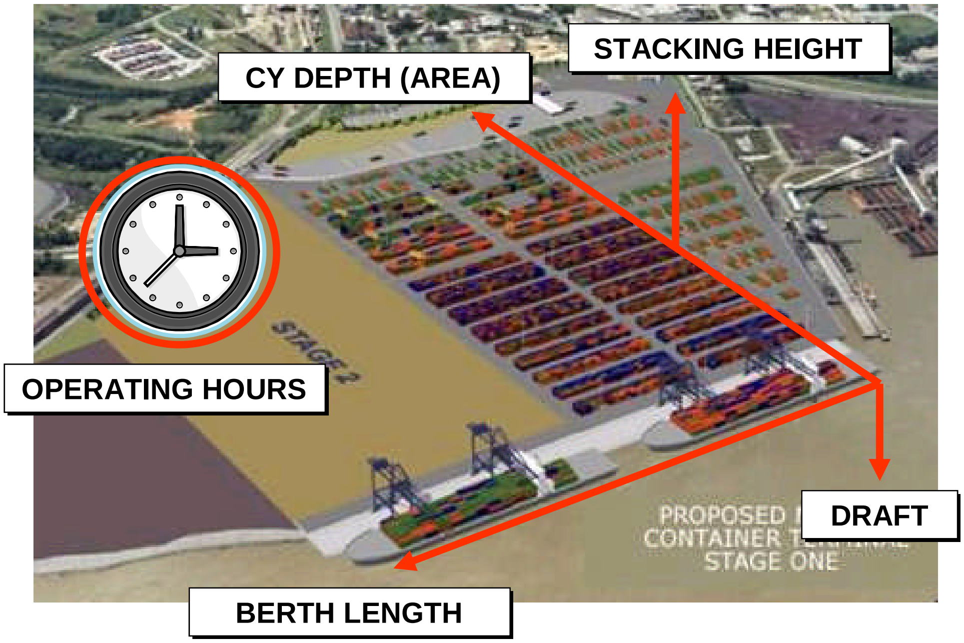
The distinction is also critical from the perspective of an importer, shipper, or military transport command seeking the best way to move cargo. A terminal capable of 10,000 TEU per acre and operating at 9,000 may be more "productive," but has less reserve capacity than a terminal capable of 5,000 TEU per acre but operating at 3,000 TEU.

Marine Terminal Capacity and Utilization

There are several possible ways to estimate container port capacity, utilization, and productivity. All rely heavily on industry rules of thumb and a variety of assumptions as well as quantifiable engineering relationships. The general approach used in this study was primarily chosen to suit the readily-available port and terminal data elements, with the anticipation of regular data collection, analysis, and publication. More precise estimates are possible, but would require a much greater investment in data collection and analysis and would change frequently as ports and terminals change their facilities and operations.

Marine container terminal capacity has five long-term constraints or dimensions, as illustrated in Exhibit 18.

Exhibit 18: Five "Dimensions" of Container Terminal Capacity



Ports and marine terminal operators are continually reviewing and adjusting their capacity, and their operating practices within that capacity. Terminals attempt to balance the five dimensions of capacity.

- Berths long and deep enough for the biggest expected vessel
- Enough berths and cranes to avoid vessel delay
- Enough CY acreage and density to avoid congestion
- Enough hours to turn the vessel

Estimating container terminal capacity, utilization, and productivity along the five dimensions in Exhibit 18 works well for dedicated container terminals that handle vessels with on-shore gantry cranes, which are the subject of this study. The methodology does not work as well with multi-purpose terminals that may also handle autos, breakbulk, neobulk, or project cargoes. In general, there is not, in general, any easy way to divide terminal CY space or other attributes among the uses. Terminals that also handle Ro-Ro vessels (e.g., Seaboard at Miami) or refrigerated vessels with ship's gear (e.g., Freeport, TX) present the same problem. In such cases, the division of terminal space devoted to different cargo types is flexible, and capacity or productivity are not fixed or readily estimated.

In order of their highest to lowest costs, the basic inputs to U.S. container terminal operations are:

- Labor
- Capital equipment

- Land
- Systems and technology

Accordingly, and rationally, the general container terminal development pattern is as follows.

- Terminals start as low-utilization, low-cost operations.
- Terminal operators will first seek systems and technology improvements to take maximum advantage of land, capital equipment, and labor.
- As terminal operators reach the limits of existing systems, technology, land, and capital equipment, they will seek to expand the land available.
- When terminal operators have exhausted systems and technology opportunities and run out of available land, they will invest in capital equipment to minimize labor costs.
- When terminal operators have exhausted the throughput capabilities of system, technology, land, and capital equipment they will engage more labor.

Within this broad pattern there are detailed variations and exceptions. For example, terminal operators may find it more efficient on the margin to engage a small amount of additional labor than to make a large incremental investment in new lift equipment.

Marine container terminals do not ordinarily operate at or near their capacity, nor would we want them to do so. A terminal operating at or near its full capacity is highly vulnerable to the least disruption and lacks the operating resilience to recover. Moreover, a terminal operating at capacity has no room for growth, and despite the current downturn in trade, growth will resume.

Perspectives on Productivity

Criteria. Criteria for useful productivity measures might include:

- **Comparability.** The chosen measures should reflect aspects of port and terminal performance that can reliably be compared across coastal and national geographies.
- **Accuracy.** The measures should be derived through straightforward analysis of reliable, available data.
- **Replicability.** The effects of year-to-year variations in exogenous factors such as rail industry performance or weather should be noted, and ideally it should be possible to correct for such variations.
- **Relevance.** The measures should document factors that will enter into operational choices, capital investments, and cargo routing decisions.

The choice of port productivity metrics should be dictated in large part by their intended use. There are a number of potential users of port performance metrics, including:

- terminal operators
- labor unions
- port authorities
- customers (importers, exporters, third parties)
- ocean carriers
- public agencies

Terminal Operator Perspective. Terminal operators use performance metrics to monitor terminal performance, plan capital expenditures, project revenue, etc. Their primary focus is on the productivity and efficiency of resources and imports under their control:

- labor hours
- container cranes
- yard equipment
- terminal acreage
- operating dollars

The highest day-to-day priority of a marine terminal operator is to service the vessel quickly and efficiently. Pertinent productivity measures would include:

- crane lifts per hour
- crane lifts per man hour
- average cost of crane lifts
- overall vessel discharge and loading rates
- reliability of vessel turn times

High-level measures such as TEU per gross acre are less useful, since they do not translate into management action items. Measures such as container dwell time or storage per acre are more amenable to management initiative and influence. Measures such as TEU/acre require context: a ro-ro terminal operating at 3,000 TEU/acre could be congested while a stacked RTG terminal would be half empty at the same TEU/acre.

The need for management action or capital investment is most likely to be signaled or triggered by complaints about growing congestion, escalating unit costs, or lengthening vessel turn time than by overall throughput or TEU/acre. The most useful metrics would then be those that enabled management to identify the causes of declining performance and choose among possible responses. Rising vessel turn times might be due, for example, to a need for more cranes to handle larger vessels, inefficient crane operations, or yard delays that waste crane operator time.

Management would need to choose between acquiring more cranes, adding yard equipment, or seeking greater crane operator productivity.

The bottom line for terminal operations is cost. In the short run most terminal assets--land, berth space, cranes, yard equipment, and systems--are fixed, and longshore labor hours are the key variable. Man-hours per lift or an equivalent such as gang-hours per vessel is thus the key near-term operating metric.

This observation highlights a key feature of U.S. container terminals: the high cost of labor and low cost of land compared to their Asian or European counterparts. It is axiomatic that commercial operations will be managed to conserve the scarcest resource, and, in the case of U.S. container terminals, the scarcest resource is labor.

The 2003 JWD study for the Port of Houston made a crucial observation regarding the reaction of the privately operated APM (Maersk) terminal to growing trade volumes. Once average throughput at that terminal reached about 4,000 TEU/acre, the terminal operators aggressively sought more space. The terminal expanded, keeping TEU/acre at about 4,000, rather than investing in the capital and labor required to increase productivity. Increasing acreage is, ordinarily, a lower cost alternative compared to increasing throughput per acre.

It is reasonable to ask how much terminal operations rely on performance metrics *versus* the observations and experience of terminal managers. Does the decision to acquire additional reach stackers depend on a numerical benchmark or on the manager's conviction that the supply of reach stackers has become a bottleneck? Industry experience suggests that terminal expansion or capital investment needs are suggested or initiated through management observations, and perhaps vetted or justified by performance metrics.

Carrier Perspective. For marine terminal operators, the primary customers are the ocean carriers. From that perspective:

- The highest priority is turning the ship, on time, at lowest cost.
- Investment in cranes is sized to vessel size and frequency.
- Costs controlled by minimizing labor, particularly second and third shifts.
- Flat, wheeled terminals are less expensive to operate.
- Vessel conflicts due to high berth utilization are highly undesirable.

Terminal operators are trying to strike a balance between cost and service demands rather than trying to maximize productivity of any one asset.

Labor Perspective. The increasing sophistication of labor unions and the increased emphasis on the details of labor union agreements is creating a greater need for labor unions to understand and use productivity measures.

Productivity comparisons between U.S. ports and Canadian, and foreign ports have become part and parcel of longshore contract negotiations. Such comparisons may be used by employer negotiators to support the need for more flexibility in implementing technologies, or to resist demands for greater hourly compensation. The upcoming ILA contract negotiations on the East Coast, for example, have led ILA leadership to investigate industry productivity measures in greater detail.

The measures of greatest relevance to labor unions are those that express outputs--lifts, annual TEU, gate moves, etc.--as a function of man-hours or labor cost.

In the context of negotiations both sides tend to pick and formulate productivity measures to support their position. Comparability and consistency may suffer in the process.

Port Authority Perspective. Port authorities compete for vessel calls and container volume, and productivity metrics have become factors in that competition. The use of productivity measures by port authorities will likely vary widely and depend on the context.

Landlord ports, which include most major U.S. container ports, do not participate in terminal operations management or capital planning for in-terminal equipment. They do, however, negotiate with terminals over lease terms, facility improvements, terminal expansion, and cranes. To the extent that throughput per acre or per crane enters into such negotiations and investment plans, ports need applicable productivity measures. To the extent that port planning and development focuses on physical assets, such as land and cranes, the relevant metrics will be those that express outputs as a function of those inputs. A high level metric such as TEU/acre becomes relevant when terminal operators are negotiating for more acres.

Where port authorities are also terminal operators, such as at Houston, different performance metrics will be applied to different decisions. The case of Barbours Cut at the Port of Houston is particularly notable. As noted earlier, the APM terminal at Houston sought and obtained additional terminal acreage to keep density and unit costs under control as container volumes rose. The APM terminal is adjacent to the Barbours Cut terminal, which is operated by the Port of Houston Authority (POHA). As the APM terminal added acreage, Barbours Cut was correspondingly constrained. As a result, land utilization at Barbour's Cut grew while APM's remained relatively low and constant.

The growing public agency involvement in port planning, access, impacts, and emissions has created a need for port authorities to use productivity metrics in external contexts. There is increasing community concern over port expansion, port truck traffic, port rail traffic, and port emissions. Port productivity has been cited (perhaps unfairly) as an impediment to U.S. export competitiveness. In these circumstances port authorities find themselves compelled to defend their use of land (TEU/acre), their cost structure ($/TEU, TEU/man-hour) and their emissions (carbon lbs/TEU, vessel hours in port).

Industry and Shipper Perspective. Based on Tioga's staff experience and recent research for CIGMA 2008[1], ocean carriers and their customers use the following criteria in choosing between ports and terminals.

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[1] Containerized Intermodal Goods Movement Assessment, 2008

- Capacity – compared to planned shipment volume.
- Transit time – compared to supply chain and competitive standards.
- Reliability – transit time and cost consistency over time, including peak periods.
- Cost – door-to-door cost per unit and in total.

Productivity measures such as lifts per crane hour or TEU/acre are usually relevant to carrier and shipper decisions only to the extent that they affect capacity or cost. A recent OECD report on container port and terminal benchmarking[2] lists the factors below as applying to "total port activities."

- Cost – Cost per TEU
- Productivity – TEU/hectare of land storage, TEU per berth meter, TEU per unit for handling equipment

The report states that: *"The most useful indicators include the total port cost per TEU and the measures of timeliness."*

The carrier customers (importers and exporters) tend to take for granted those terminal performance attributes that are commonly available and focus their choice criteria on "scarce attributes." Until the 2004 peak season congestion in Southern California, adequate terminal capacity (annual TEU or TEU per acre) was usually assumed, and the physical capability of terminals to accommodate new cargo was rarely a differentiating factor. Vessel turn time became a differentiator with the first of the post-Panamax vessels, which had much larger container capacity and a higher daily cost than their predecessors. Rail intermodal capacity became an issue after the 1996-98 Union Pacific "meltdown" that slowed Minilandbridge traffic from the West Coast. Reliability has become increasingly important as supply chains have tightened and inventory levels have been minimized.

Port Productivity Literature Insights

The literature on container terminal productivity measures is highly varied, comprising trade journal articles, research reports, academic papers and articles, and conference presentations. There is a parallel and sometimes interwoven literature on the basis of competition between ports and terminals, and on shipper and carrier criteria for choosing ports and terminals. A formal literature review is presented in Appendix A.

Overall, the available literature provides a strong starting point for CHCP's inquiry into container port and terminal productivity measurement. There is a strong consensus on the desirability of measurement, the importance of productivity, and the potential for improvement. There are also cautions expressed regarding comparability, data adequacy, and interpretation.

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[2] http://books.google.com/books?id=87nEhvBZVwcC&pg=PA59&lpg=PA59&dq=terminal+cost+per+TEU&source=bl&ots=oDLbs3zHvv&sig=Usgq-TqL4l38qlFNku_obPwHa5M&hl=en&ei=32xBSvztF42yswPll7DyCA&sa=X&oi=book_result&ct=result&resnum=9

Technical discussions of productivity measures tend to converge on relatively few metrics, which follow:

- Annual TEU per acre (or hectare)
- Annual TEU per berth (or per foot of berth)
- Crane moves (or TEU) per hour (or year)
- Vessel turn time (in hours or minutes)
- Berth utilization (in percent)
- TEU or crane moves per man-hour

Customer-focused assessments, or competitiveness comparisons, tend to focus on a different, but overlapping set of measures.

- Cargo velocity, transit time, or dwell time
- Terminal handling cost (or overall cost)
- Vessel turn time
- Reliability (e.g. percent of moves on schedule)
- Crane moves per hour

Several sources note differences in perspective. There is a noticeable difference in “outside” viewpoints from academia and the public sector, and “inside” viewpoints from industry participants. “Outside” observers tend to focus on overall throughput and productivity measures such as annual TEU, TEU/acre, and TEU/crane. A good example of such discussions is Le-Griffin and Murphy (2007) which uses TEU/foot of berth, TEU/crane, TEU/crane-hour, and TEU/acre.

A 2009 article by Mongelluzzo reporting on the October 7, 2009, Port Productivity Conference summarizes presentations and remarks made by multiple speakers. The key points made can be summarized as follows:

- Port capacity is currently abundant due to the recession, so the basis of competition will be efficiency rather than capacity.
- Productivity will become a challenge for East Coast ports when the third set of locks allows much larger vessels to transit the Panama Canal starting in 2014.
- From the shipping line perspective, the primary productivity concern is lifts per hour, which translates into vessel time in port.
- Labor efficiency is a crucial concern because labor costs reportedly account for 60-70% of total terminal costs.

Industry participants tend to emphasize either terminal handling costs, vessel turn times, or crane moves per hour as the basis of competition between ports and terminals. Because terminal handling charges and port fees are negotiated between ports, terminal operators, and ocean carriers, they are largely confidential. Vessel turn times or crane moves per hour thus become surrogates for costs. A number of sources note that there are two costs involved: terminal handling charges and the cost of the vessel while in port.

For the current project there are a number of useful sources on container terminal operations and capacity. The work of the JWD Group (now part of AECOM) in Houston, Oakland, and Long Beach is particularly thorough.

A parallel initiative on port productivity measures and benchmarking is currently being undertaken by Transport Canada (Olivier, 2009). The effort is seen as part of an overall inquiry into the reliability and competitiveness of Canadian supply chains. Transport Canada (TC) has identified eight port utilization indicators (PUIs), an example of which is shown in Exhibit 19. TC has secured the cooperation of the four major Canadian container port authorities and is working toward roll-out of the PUIs.

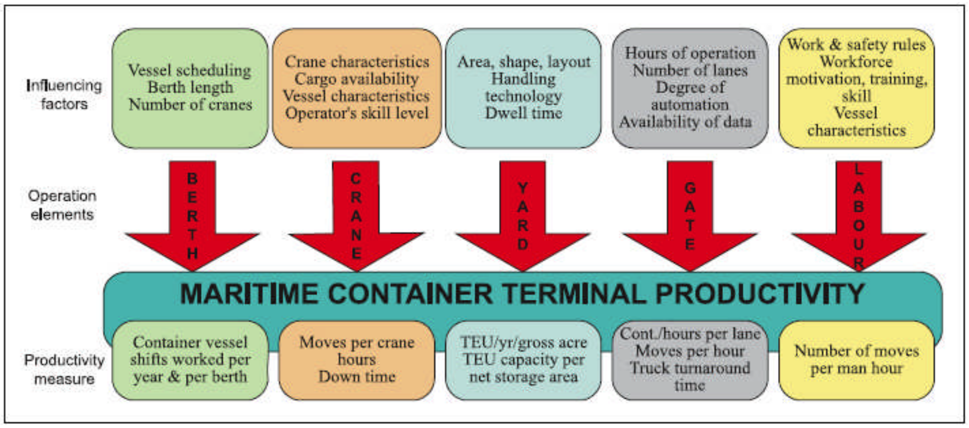
Exhibit 19: Port Utilization Indicators - Canadian Ports

Measure	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09
Gate Fluidity - Minutes	n/a	n/a	12.8	13.8	13.5	12.4	12.2	17
Avg. Truck Turnaround Time - Minutes	n/a	21.9	22.1	22.3	20.4	21.0	20.1	19.4
Berth Utilization - TEU/Meter	60.0	56.6	63.9	67.4	70.5	70.5	71.2	73.0
Vessel Turnaround Time - Seconds/TEU	51	46	45	42	40	41	36	34
Vessel Dwell in Port Waters - Hours/Vessel Call	n/a	31.7	33.2	30.0	30.9	33.4	31.6	31.5
Avg. Container Dwell - Days	3.2	2.7	2.3	3.0	1.8	2.5	2.8	2.0
Port Productivity - TEU/ha	1,286	1,119	1,386	1,375	1,470	1,396	1,465	1,487
Crane Productivity - TEU/STS crane	8,046	7,018	8,676	8,642	9,250	8,796	9,298	9,510
Container Throughput - TEU	179,742	158,305	194,455	195,935	210,095	200,331	213,455	218,717

Source: Olivier (2009)

Among the most insightful formulations of the productivity issue is an article by Beŝkovnik (2008), which includes the diagram below (Exhibit 20), dividing terminal operation into five subsystems.

Exhibit 20: Marine Terminal Productivity Concepts



Source: Beŝkovnik (2008)

A presentation by Rugaihuruza (2007) distinguishes four principle aspects of container terminal performance:

- Service, where the key factors are vessel turn time and container dwell time
- Output, measured by container throughput in TEU
- Utilization, including berth occupancy, equipment utilization, and gate utilization
- Productivity, in terms of efficiency and cost-effectiveness, measured by (for example) cost/ton, labor cost/ton, crane moves/hour, containers/man-hour

Both of these sources link specific productivity measures to specific terminal functions and customer concerns, thus providing a strong rationale for performance measurement.

The sources examined also provided information on best practices, current or proposed. Some, such as improved management-labor relations, have been issues for decades and are unlikely to be easily resolved. Others, such as increased use of recent information and location technology, are a logical extension of current initiatives.

Over the last 15 years, there have been numerous efforts in U.S., European, and Asian academic circles to model container port productivity. The primary technique employed has been Data Envelope Analysis (also referred to as Data Envelopment Analysis), but other econometric techniques have been tried as well. While promising and instructive, these efforts have not yet generated in results useful to port planners or terminal managers.

Long-term versus Near-term Utilization

In principle, every container yard (CY) acre of every U.S. container terminal could be developed to its maximum long-term capacity. Long-term capacity can be defined as annual TEU storage capacity using the operating systems with the highest density. At any given point in time, capital investment in terminal equipment and systems to achieve higher densities must be justified by the expected cargo volumes.

In practice, each terminal is at its own stage of development between the lowest density operations (Ro-Ro or wheeled) and the highest density operations (e.g., automated seven-high stacking). Short-term utilization can be defined as current throughput as a percentage of capacity under the current operating system.

Long-term utilization, in contrast, can be defined as current throughput as a percentage of long-term capacity under the highest density operating system.

With that distinction, container terminals generally fall into three groups.

- **Low short-term utilization.** These terminals have substantial reserve capacity given their existing size, operating system, and throughput. Most ro-ro and combination terminals fall in this category. Such terminals have little or no need to invest in higher productivity systems, although they may risk losing business to competing ports with better scale economies and lower unit costs.
- **Medium short-term utilization.** Most dedicated U.S. container terminals fall into this category, especially given the recession-induced downturn in container

trade volumes. These terminals have no immediate need to expand or invest in higher productivity systems. Given the high cost and long lead times for expansion and investment, many such terminals will have tentative long-term plans to deal with cargo growth.

- **High short-term utilization.** Only a handful of U.S. terminals are intensively utilized under their current operating systems, especially given the current trade downturn. Terminals that were "bursting at the seams" in 2006–2007, now typically have concrete expansion or productivity improvement plans in place.

With trade down in 2009-2010, there are no U.S. terminals approaching their long-term capacity limits. Overall, U.S. container terminals are operating at less than half of their long-term capacity. It would thus be more accurate to describe the U.S. container ports as having high reserve capacity rather than low productivity.

Peak period vs. average productivity

Because port container throughput varies by season, annual productivity measures can conceal important variations. The charts below, for example, illustrate the difference between average and peak TEU per acre for the Ports of Long Beach and Los Angeles. Exhibit 21 shows the normalized month-to-month variation in import TEU, with the annual peak season clearly visible. The same chart also shows the drastic drop in October 2002 due to a labor dispute. Exhibit 22 shows the equivalent annual import TEU per acre for 2005, with the peak in October 11% higher than the annual average. Sailing times between major port pairs and customer preferences for shipping and arrival days lead to a concentration of vessel calls and container handling on certain days of the week; so, more detailed data would reveal even higher productivities for peak days.

Exhibit 21: LALB Cargo Peaking

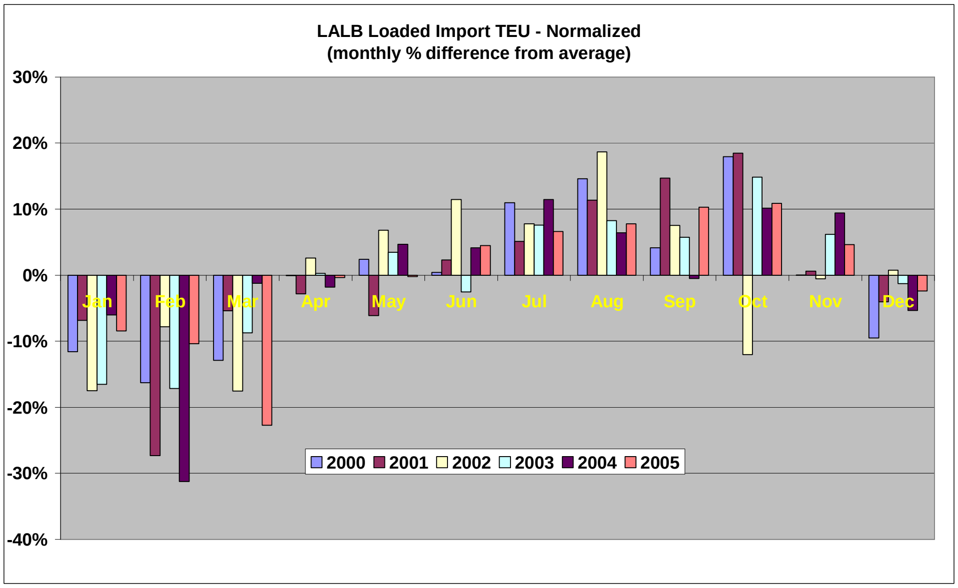
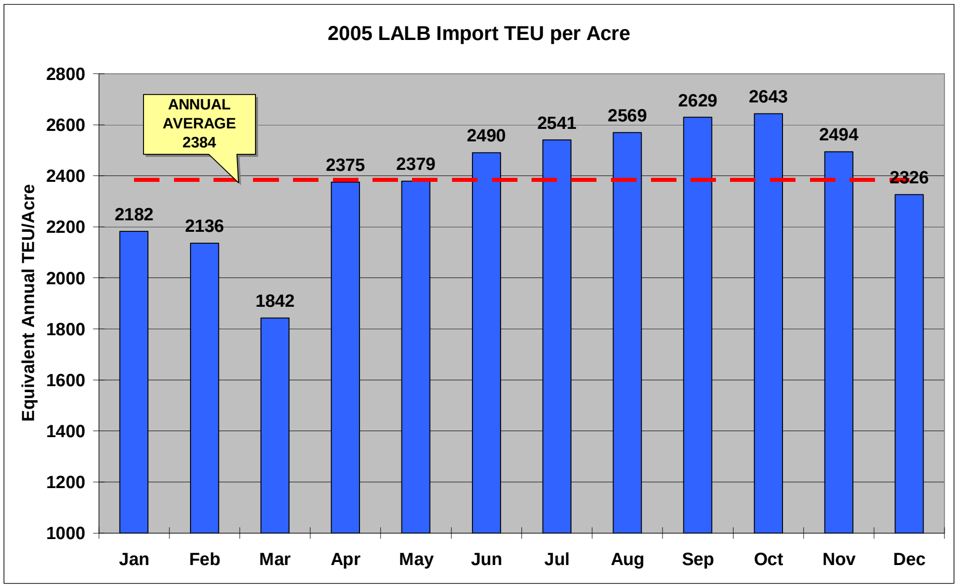


Exhibit 22: Peaking Impact on Productivity



Customer Survey

The ultimate purpose of marine terminal operations and containerized transport is the fulfillment of customer needs for timely and efficient goods movement. one of CHCP’s objectives for this project was to develop metrics that could be used by importers and exporters to plan their supply chains and choose between competing ports and terminals.

The study team designed a brief online survey to determine which potential productivity measures were of most use to the ultimate customers and how likely those customers were to shift business in response to productivity issues. The survey went out to members of the Waterfront Coalition and the National Retail Federation. There were a total of 20 responses (Exhibit 23). Those who responded were key stakeholders in the target audience, the shippers and receivers who control the cargo. It is critical to remember that these are the carrier’s direct customers. For ports and terminals, they are indirect customers.

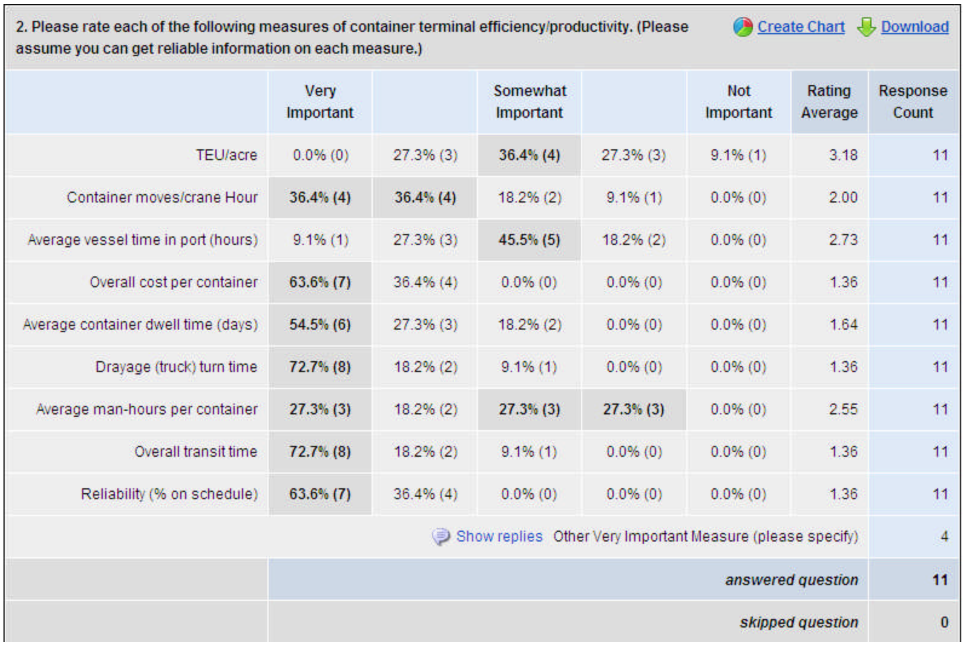
- Respondents were importers, exporters, and intermediaries.
- These are the ocean carriers’ customers, not the direct customers of the terminals or ports.

Exhibit 23: Customer Survey Respondents

What is your company’s role in international container shipping? (check all that apply)		
Answer Options	**Response Percent**	**Response Count**
Beneficial cargo owner (shipper/receiver)	70.0%	14
Importer	80.0%	16
Exporter	15.0%	3
Intermediary/3PL/Forwarder/Agent/Broker/NVOCC	10.0%	2
Port official	0.0%	0
Not involved	5.0%	1
Other (please specify)	5.0%	1

Respondents were instructed to rate various port productivity measures, with 1 being most important and 5 least important. (Exhibit 24) Responses show a clear emphasis on commercial performance, cost, transit time, and reliability. Drayage turn time made it into the top tier. Operational measures are less important, and TEU per acre was ranked lowest of all.

Exhibit 24: Results of Customer Survey



2. Please rate each of the following measures of container terminal efficiency/productivity. (Please assume you can get reliable information on each measure.)

	Very Important		Somewhat Important		Not Important	Rating Average	Response Count
TEU/acre	0.0% (0)	27.3% (3)	**36.4% (4)**	27.3% (3)	9.1% (1)	3.18	11
Container moves/crane Hour	**36.4% (4)**	**36.4% (4)**	18.2% (2)	9.1% (1)	0.0% (0)	2.00	11
Average vessel time in port (hours)	9.1% (1)	27.3% (3)	**45.5% (5)**	18.2% (2)	0.0% (0)	2.73	11
Overall cost per container	**63.6% (7)**	36.4% (4)	0.0% (0)	0.0% (0)	0.0% (0)	1.36	11
Average container dwell time (days)	**54.5% (6)**	27.3% (3)	18.2% (2)	0.0% (0)	0.0% (0)	1.64	11
Drayage (truck) turn time	**72.7% (8)**	18.2% (2)	9.1% (1)	0.0% (0)	0.0% (0)	1.36	11
Average man-hours per container	**27.3% (3)**	18.2% (2)	**27.3% (3)**	**27.3% (3)**	0.0% (0)	2.55	11
Overall transit time	**72.7% (8)**	18.2% (2)	9.1% (1)	0.0% (0)	0.0% (0)	1.36	11
Reliability (% on schedule)	**63.6% (7)**	36.4% (4)	0.0% (0)	0.0% (0)	0.0% (0)	1.36	11
	Show replies Other Very Important Measure (please specify)						4
	answered question						**11**
	skipped question						**0**

Customer are willing to shift to get better terminal performance. Of the respondents, 95% are willing to shift ports, and 100% are willing to shift carriers within a port (Exhibit 25).

Exhibit 25: Customer Survey Results – Shifts

Would you consider shifting volume between ports based on container terminal efficiency/productivity?	
Yes	**60.0%**
It depends on...	**35.0%**
No	**5.0%**

Would you consider shifting import or export volume between ocean carriers at the same port based on container terminal efficiency/productivity?	
Yes	**65.0%**
It depends on...	**35.0%**
No	**0.0%**

Most of the "It depends on…" answers centered on cost. If the costs to the customer are equal, customers are willing to shift to get better terminal and drayage performance.

Drayage Survey

Driver surveys were taken at Houston and LALB under parallel project NCFRP-14. There was a good deal of variation on the numbers attributed to the sources of delay. Overall, marine terminals and container depots, including empty yards, were cited as having the most significant sources of delay.

- The two most frequently cited issues by drivers are the availability and quality of chassis, and the tendency for crane and port personnel to divert attention away from truck operations to ship operations when ships are in port.
- Other frequently listed complaints regarded the number and availability of lift machines to service the trucks, being sent to a lane to pick up a container where no lift machine was available, or several trucks waiting at once for lift machine service.
- Moderate complaints were made about the labor at the ports, especially at LALB. Some drivers pointed to specific issues with port workers on cell phones or who were otherwise distracted, or shutting down for extended breaks. Others made less constructive observations about the port employees being lazy or not sufficiently skilled to do their jobs.
- Wrong information, chassis problems, and empty container problems were cited as the causes of non-revenue trips.
- For trouble tickets, equipment problems and information errors were cited as the major causes.
- The primary thing that draymen have learned from their peers is to be sure that all is in readiness before dispatching a driver to a marine terminal
- The dominant suggestion as to what marine terminals can do differently is to provide more workers and to cover breaks rather than to stop work.

The issues most frequently cited include:

- Availability and quality of chassis
- Time spent locating chassis
- Priority given to ship operations over truck operations when ships are in port
- Number and availability of RTGs
- Being sent to a lane to pick up a container where no RTG was available
- Being assigned to a lane where several trucks are or where several trucks were waiting at once for crane service.

Lesser issues identified include:

- Insufficient Labor
- Distracted workers/extended breaks

A second survey was distributed via the Internet, and was completed primarily by dispatchers.

- Dispatchers echoed drivers in citing the propensity of the port to redirect resources to ship operations when a ship is in port.
- Dispatchers were more likely to cite computer glitches or wrong information regarding container status as a reason for delay.
- Chassis issues were again mentioned by dispatchers as a common problem for the drivers.
- Stacked chassis is sometimes a problem.
- Dispatchers reported that congested conditions required approximately twice the allotted time when compared with uncongested conditions.
- The time differences between congested *vs.* uncongested are more significant than the type of move.

Insights from Rail Intermodal Terminals

The study included a high-level look at rail intermodal terminals, which are in many respects comparable to marine container terminals. The effort produced a separate white paper, presented in Appendix B.

Rail terminal efficiency is measured by *cost per lift*, with a lift being the transfer between rail and highway modes. Measures of physical productivity are subordinate and managed with the goal of influencing the cost per lift.

Lifts. Activity at intermodal terminals is most commonly measured in lifts. A lift is the transfer of a trailer or container from a rail car to the ground/chassis, or from the ground/chassis to rail car. Contract terminal operators are typically paid based on the number of primary lifts they perform.

Gate transactions. While lifts is the measure of activity for the rail side of the intermodal terminal, gate transactions is the measure of activity for the highway mode. Trucks enter and leave the terminal to deliver and pick up loaded and empty trailers and containers. The truck flow through the terminal can be used as a demand/work measure for gate and clerical personnel.

Railroad terminal operators tend to look and measure terminal productivity in a number of different ways based on the time horizon in question. The daily issue at an intermodal terminal is how many people and machines are needed for the next shift. The question is answered based on an estimate of workload for the shift, coupled with knowledge of the equipment and the skill level of individual workers. At this level, productivity measures, such as lifts per man hour and productivity rates for individual operators, are used to size the crews.

Planners with a longer time horizon are typically more interested in longer-term productivity issues involving investments in land, equipment, and facilities. Often these individuals are involved in capital investment decisions.

Data Sources

Data to support productivity metrics can be drawn from a number of sources. As Exhibit 26 indicates, most of the required data come from the ports or from published port directories. The exhibit indicates that the source data fall into four groups based on relative availability.

- "Always" data. Data elements that are almost invariably available from ports, public directories, or government agencies such as the Bureau of Transportation Statistics (BTS).
- "Sometimes" data. Data elements that are often, but not consistently available. These are not typically confidential and help complete the productivity picture.
- Estimated data. Data that must ordinarily be estimated, but are helpful to an understanding of productivity. These estimates are not routinely collected or calculated and will have different values depending on the estimation method used. These estimates often depend heavily on assumptions and industry rules of thumb.
- Confidential data. Cost or labor-related data are usually confidential and rarely made available outside an organization. Here too, data values can depend upon methodology and assumptions that vary from port to port.

Exhibit 26: Port and Terminal Data Sources

Available Port Data	Source
Always	
Berth Depth	Port, Directories
Berth Length	Port, Directories
Berths	Port, Directories
Channel Depth	Port, Directories
Cranes & Types	Port, Directories
Gross Acres	Port, Directories
Port TEU	Port, Directories, AAPA
Vessel Calls	BTS
Vessel DWT	BTS
Sometimes	
Avg. Crane Moves/hr	Port
CY Acres	Port, Directories
Rail Acres	Port, Directories
TEU Slots	Port, Terminals
Estimated	
Net BGY Acres	Aerial Photos, Terminal Plans
Vessel TEU	DWT/TEU Relationship
Vessel Length	DWT/Length Relationship
Avg. Dwell Time	Benchmarks, Assumptions
Berth Capacity	Benchmarks, Assumptions
Crane Capacity	Benchmarks, Assumptions
CY Capacity	Benchmarks, Assumptions
Confidential	
Costs	Modeling?
Man-hours	Modeling?
Vessel Turn Time	Modeling?
Rates	Modeling?
Working Crane Hours	Modeling?

Available Terminal Data	Source
Always	
Berth Depth	Port, Directories, Terminal
Berth Length	Port, Directories, Terminal
Berths	Port, Directories, Terminal
Channel Depth	Port, Directories, Terminal
Cranes & Types	Port, Directories, Terminal
Gross Acres	Port, Directories, Terminal
Sometimes	
Avg. Crane Moves/hr	Terminal
CY Acres	Port, Terminal
Rail Acres	Port, Terminal
TEU Slots	Port, Terminal
Truck Turn Times	Terminal
Trouble Ticket %	Terminal
Estimated	
Net BGY Acres	Aerial Photos, Terminal Plans
Vessel TEU	DWT/TEU Relationship
Vessel Length	DWT/Length Relationship
Avg. Dwell Time	Benchmarks, Assumptions
Berth Capacity	Benchmarks, Assumptions
Crane Capacity	Benchmarks, Assumptions
CY Capacity	Benchmarks, Assumptions
Confidential	
Costs	Modeling?
Man-hours	Modeling?
Vessel Turn Time	Modeling?
Rates	Modeling?
Working Crane Hours	Modeling?
Terminal TEU	Modeling?
Vessel Calls	Modeling?
Vessel DWT	Modeling?

Exhibit 26 also shows the differences in availability of data on the port as a whole and on individual terminals. The chief difference is in three data items that are ordinarily available for ports but not for terminals.

- Annual TEU
- Vessel calls
- Vessel deadweight tons (DWT)

The lack of terminal-specific annual TEU eliminates many possible productivity measures for individual terminals (except, of course, for ports such as Savannah, or New Orleans, Boston, and Portland that have only one container terminal).

Ports are reluctant or unable to provide terminal-specific TEU counts because the data are proprietary to the terminal. The port authority receives terminal data in the course of its business relationship as the basis for terminal and carrier charges. The data, however, are usually considered competitively sensitive, and not made available to the public. Moreover, ports contacted for this study made the valid point that TEU counts can shift rapidly when ocean carriers change terminals, and that terminal productivity tends to even out over time.

Exhibit 27 displays examples of typical container terminal data from terminal websites. Data on physical facilities predominate, while operational data are scarce.

Exhibit 27: Sample Terminal Data

Seaside Transportation Service LLC

Contact: Ben E. Nutter
Marine Container Terminal
5190 7th Street
Oakland, CA 94607
Tel: 510.645.2400

Size: 73.91 acres

Berths: 3 (3,213 ft.)

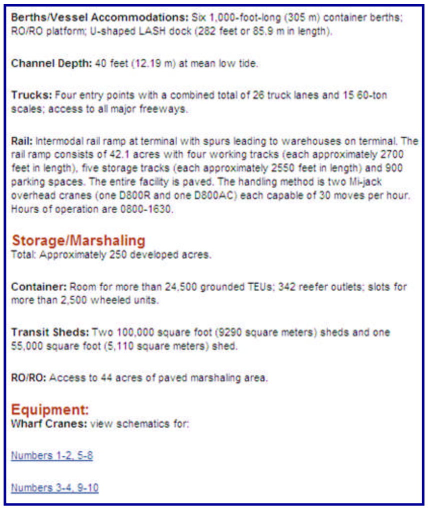
Cranes: 4-Total

3-Low profile

1-Modified A-frame, articulated boom

Access: Near-dock Rail (within 1 mile)

Yard Storage Capacity:
15,628 TEU



Berths/Vessel Accommodations: Six 1,000-foot-long (305 m) container berths; RO/RO platform; U-shaped LASH dock (282 feet or 85.9 m in length).

Channel Depth: 40 feet (12.19 m) at mean low tide.

Trucks: Four entry points with a combined total of 26 truck lanes and 15 60-ton scales; access to all major freeways.

Rail: Intermodal rail ramp at terminal with spurs leading to warehouses on terminal. The rail ramp consists of 42.1 acres with four working tracks (each approximately 2700 feet in length), five storage tracks (each approximately 2550 feet in length) and 900 parking spaces. The entire facility is paved. The handling method is two Mi-jack overhead cranes (one D800R and one D800AC) each capable of 30 moves per hour. Hours of operation are 0800-1630.

Storage/Marshaling
Total: Approximately 250 developed acres.

Container: Room for more than 24,500 grounded TEUs; 342 reefer outlets; slots for more than 2,500 wheeled units.

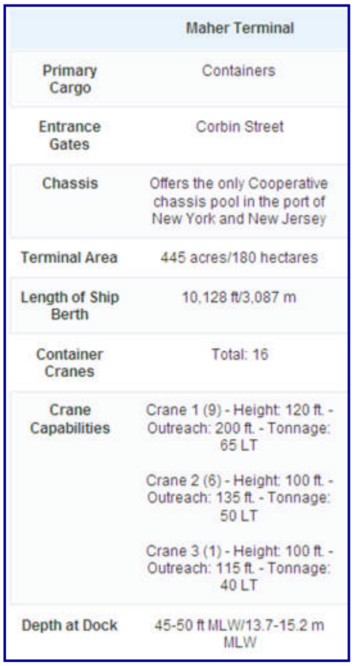
Transit Sheds: Two 100,000 square foot (9290 square meters) sheds and one 55,000 square foot (5,110 square meters) shed.

RO/RO: Access to 44 acres of paved marshaling area.

Equipment:
Wharf Cranes: view schematics for:

Numbers 1-2, 5-8

Numbers 3-4, 9-10



	Maher Terminal
Primary Cargo	Containers
Entrance Gates	Corbin Street
Chassis	Offers the only Cooperative chassis pool in the port of New York and New Jersey
Terminal Area	445 acres/180 hectares
Length of Ship Berth	10,128 ft/3,087 m
Container Cranes	Total: 16
Crane Capabilities	Crane 1 (9) - Height: 120 ft. - Outreach: 200 ft. - Tonnage: 65 LT Crane 2 (6) - Height: 100 ft. - Outreach: 135 ft. - Tonnage: 50 LT Crane 3 (1) - Height: 100 ft. - Outreach: 115 ft. - Tonnage: 40 LT
Depth at Dock	45-50 ft MLW/13.7-15.2 m MLW

The American Association of Port Authorities (AAPA) has port throughput data available on its website (Exhibit 28 and Exhibit 29). The data are submitted by the ports, so the accuracy, timeliness, and completeness of the AAPA data depend on what the ports have sent. The AAPA data are the most comprehensive available on port throughput. The data showing both TEU and container counts, ("boxes") in Exhibit 29, are the only comprehensive sampling for the TEU/box conversion factor.

Exhibit 28: AAPA TEU Data

CANADIAN/U.S. PORT CONTAINER TRAFFIC ANALYSIS (TEUs)								
	Loaded			Empty	Domestic/Transshipment	TOTAL TEUs	Ratios	
	Inbound	Outbound	Total				In/Total Loads	Loaded/Total
Baltimore								
1995	**204,017**	**249,450**	**453,467**	**81,089**		**534,556**	**45.0%**	**84.8%**
1996	**183,441**	**223,710**	**407,151**	**67,665**		**474,816**	**45.1%**	**85.7%**
1997	**189,871**	**220,487**	**410,358**	**65,654**		**476,012**	**46.3%**	**86.2%**
1998	**216,176**	**196,889**	**413,065**	**73,796**		**486,861**	**52.3%**	**84.8%**
1999	**231,900**	**184,144**	**416,044**	**82,064**		**498,108**	**55.7%**	**83.5%**
2000	**239,311**	**181,270**	**420,581**	**87,739**		**508,320**	**56.9%**	**82.7%**
2001	**227,390**	**159,328**	**386,718**	**106,417**		**493,135**	**58.8%**	**78.4%**
2002	**243,488**	**148,419**	**391,907**	**116,161**		**508,068**	**62.1%**	**77.1%**
2003	**253,080**	**161,799**	**414,879**	**114,078**		**528,957**	**61.0%**	**78.4%**
2004	**267,881**	**158,766**	**426,647**	**127,452**	**3,759**	**554,099**	**62.8%**	**77.0%**
2005	**289,743**	**181,366**	**471,109**	**131,335**	**31**	**602,444**	**61.5%**	**78.2%**
2008	**288,996**	**212,831**	**501,827**	**111,006**	**44**	**612,833**	**57.6%**	**81.9%**

Exhibit 29: AAPA Port Data

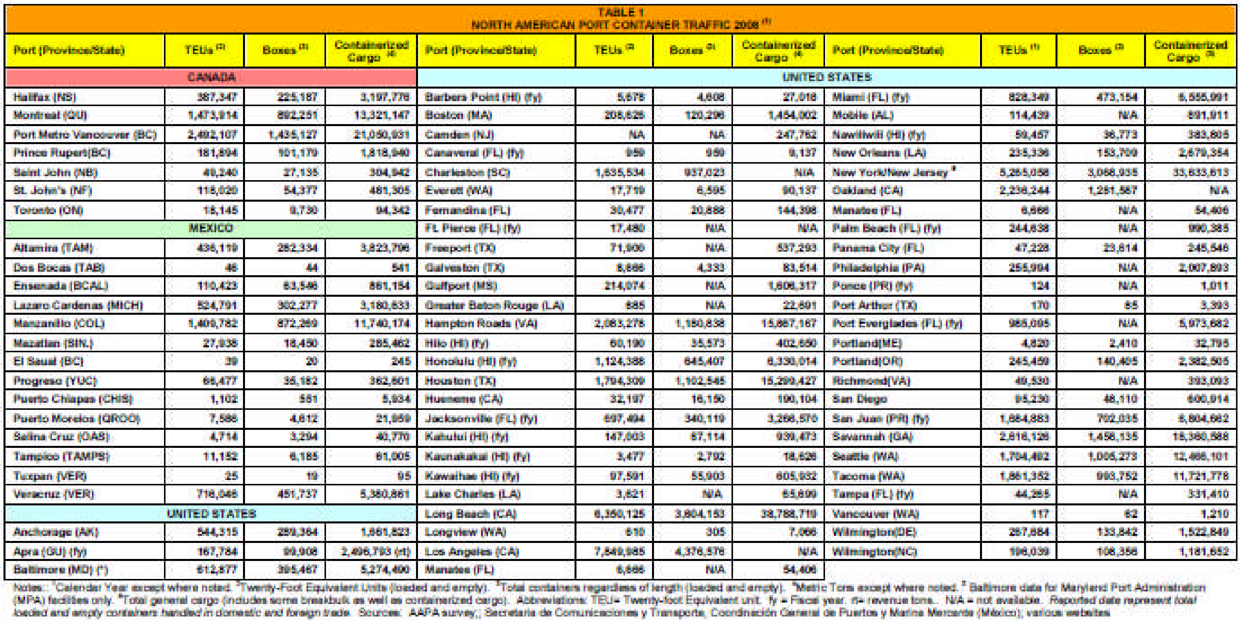


TABLE 1
NORTH AMERICAN PORT CONTAINER TRAFFIC 2008 [1]

Port (Province/State)	TEUs [2]	Boxes [3]	Containerized Cargo [4]	Port (Province/State)	TEUs [2]	Boxes [3]	Containerized Cargo [4]	Port (Province/State)	TEUs [1]	Boxes [2]	Containerized Cargo [3]
CANADA				UNITED STATES							
Halifax (NS)	387,347	225,187	3,197,776	Barbers Point (HI) (fy)	5,678	4,608	27,018	Miami (FL) (fy)	828,349	473,154	6,555,991
Montreal (QU)	1,473,914	892,251	13,321,147	Boston (MA)	208,626	120,296	1,454,002	Mobile (AL)	114,439	N/A	891,911
Port Metro Vancouver (BC)	2,492,107	1,435,127	21,050,931	Camden (NJ)	NA	NA	247,762	Nawiliwili (HI) (fy)	59,457	36,773	383,805
Prince Rupert(BC)	181,894	101,179	1,818,940	Canaveral (FL) (fy)	959	959	9,137	New Orleans (LA)	235,336	153,709	2,679,354
Saint John (NB)	49,240	27,135	304,942	Charleston (SC)	1,635,534	937,023	N/A	New York/New Jersey [5]	5,265,058	3,066,935	33,633,613
St. John's (NF)	118,020	54,377	481,305	Everett (WA)	17,719	6,595	90,137	Oakland (CA)	2,236,244	1,281,587	N/A
Toronto (ON)	18,145	9,730	94,342	Fernandina (FL)	30,477	20,888	144,398	Manatee (FL)	6,666	N/A	54,406
MEXICO				Ft. Pierce (FL) (fy)	17,480	N/A	N/A	Palm Beach (FL) (fy)	244,638	N/A	990,385
Altamira (TAM)	436,119	282,334	3,823,796	Freeport (TX)	71,906	N/A	537,293	Panama City (FL)	47,228	23,614	245,546
Dos Bocas (TAB)	46	44	541	Galveston (TX)	8,666	4,333	83,514	Philadelphia (PA)	255,904	N/A	2,007,893
Ensenada (BCAL)	110,423	63,546	861,154	Gulfport (MS)	214,074	N/A	1,606,317	Ponce (PR) (fy)	124	N/A	1,011
Lazaro Cardenas (MICH)	524,791	302,277	3,180,633	Greater Baton Rouge (LA)	685	N/A	22,691	Port Arthur (TX)	170	85	3,393
Manzanillo (COL)	1,409,782	872,269	11,740,174	Hampton Roads (VA)	2,083,278	1,180,838	15,867,167	Port Everglades (FL) (fy)	985,095	N/A	5,973,682
Mazatlan (SIN.)	27,938	18,450	285,462	Hilo (HI) (fy)	60,190	35,573	402,650	Portland(ME)	4,820	2,410	32,795
El Saual (BC)	39	20	245	Honolulu (HI) (fy)	1,124,388	645,407	6,330,014	Portland(OR)	245,459	140,405	2,382,505
Progreso (YUC)	66,477	35,182	362,601	Houston (TX)	1,794,309	1,102,545	15,299,427	Richmond(VA)	49,530	N/A	393,093
Puerto Chiapas (CHIS)	1,102	551	5,934	Hueneme (CA)	32,197	16,150	190,104	San Diego	95,230	48,110	600,914
Puerto Morelos (QROO)	7,586	4,612	21,959	Jacksonville (FL) (fy)	697,494	340,119	3,266,570	San Juan (PR) (fy)	1,684,883	702,035	6,804,662
Salina Cruz (OAS)	4,714	3,294	40,770	Kahului (HI) (fy)	147,003	87,114	939,473	Savannah (GA)	2,616,126	1,456,135	18,360,588
Tampico (TAMPS)	11,152	6,185	61,005	Kaunakakai (HI) (fy)	3,477	2,792	18,626	Seattle (WA)	1,704,492	1,005,273	12,466,101
Tuxpan (VER)	25	19	95	Kawaihae (HI) (fy)	97,591	55,903	605,932	Tacoma (WA)	1,861,352	993,752	11,721,778
Veracruz (VER)	716,046	451,737	5,380,861	Lake Charles (LA)	3,621	N/A	65,699	Tampa (FL) (fy)	44,255	N/A	331,410
UNITED STATES				Long Beach (CA)	6,350,125	3,604,153	38,788,719	Vancouver (WA)	117	62	1,210
Anchorage (AK)	544,315	289,364	1,861,823	Longview (WA)	610	305	7,066	Wilmington(DE)	257,684	133,842	1,522,849
Apra (GU) (fy)	167,784	99,908	2,496,793 (rt)	Los Angeles (CA)	7,849,985	4,376,576	N/A	Wilmington(NC)	196,039	108,356	1,181,652
Baltimore (MD) (*)	612,877	395,467	5,274,490	Manatee (FL)	6,666	N/A	54,406				

Notes: [1] Calendar Year except where noted. [2] Twenty-Foot Equivalent Units (loaded and empty). [3] Total containers regardless of length (loaded and empty). [4] Metric Tons except where noted. [5] Baltimore data for Maryland Port Administration (MPA) facilities only. [6] Total general cargo (includes some breakbulk as well as containerized cargo). Abbreviations: TEU= Twenty-foot Equivalent unit. fy = Fiscal year. rt= revenue tons. N/A = not available. *Reported date represent total loaded and empty containers handled in domestic and foreign trade.* Sources: AAPA survey,; Secretaria de Comunicaciones y Transporte, Coordinación General de Puertos y Marina Mercante (México); various websites

AAPA also publishes *Seaports of the Americas*, an annual directory of ports in North, Central, and South America. This directory also depends on ports to submit information, and the submissions do not always provide complete or current information.

The Containerisation International (CI) Yearbook, produced annually, is an international compendium on the containerized shipping industry. The section on ports provides basic information similar to that in *Seaports of the Americas*. Date in the *CI Yearbook* are sometimes out of date. Terminal-specific TEU counts may be dated, fragmentary, or rounded. The *CI Yearbook* is also costly, roughly $1,000 annually.

Vessel call data have been made available through MARAD. Exhibit 30 displays 2008 vessel call data, the most recent available at the start of this project. The data of interest for productivity metrics are the number of vessel calls and the average deadweight tons (DWT). Vessel call data are also available directly from Lloyd's List (the original source of the MARAD data shown) but at significant cost.

Exhibit 30: MARAD Vessel Call Data

U.S. Port Calls by Port and Vessel Type, 2008

			All Types		Container		
Port	State	Coast	Calls	Capacity	Calls	Capacity	Capacity (TEU)
Anchorage	AK	PNW	161	3,710,351	75	1,616,230	129,933
Annapolis Anch.	MD	NA	200	10,571,360	7	244,439	17,833
Baltimore	MD	NA	1,870	67,676,024	380	17,153,413	1,263,082
Beaumont	TX	USG	183	8,029,496	3	83,912	3,885
Boston	MA	NA	546	24,954,754	145	7,374,703	545,897
Charleston	SC	SA	2,053	93,336,683	1,475	72,993,121	5,449,509
Columbia River Ports	OR	PNW	2,411	96,330,771	127	6,952,326	553,449
Corpus Christi	TX	USG	1,120	73,344,667	1	36,004	2,411
Dutch Hbr.	AK	PNW	148	6,723,292	137	6,355,764	480,867
Everett	WA	PNW	104	2,646,428	17	433,592	31,841
Fernandina	FL	SA	1	13,671	1	13,671	1,250
Freeport	TX	USG	791	44,320,434	90	1,283,104	88,598
Galveston	TX	USG	560	24,072,927	11	420,554	27,322
Gulfport	MS	USG	16	492,778	9	148,080	8,568
Honolulu	HI	PSW	636	20,962,503	410	13,363,308	946,236
Houston	TX	USG	6,445	273,487,700	854	36,309,947	2,684,246
Ingleside	TX	USG	159	10,918,803	2	104,500	8,076
Jacksonville	FL	SA	1,542	45,860,200	307	9,178,411	725,927
Juneau	AK	PNW	1	21,345	1	21,345	1,712
Kodiak	AK	PNW	88	1,875,203	88	1,875,203	150,656
LA/Long Beach	CA	PSW	4,815	307,277,071	2,795	163,015,941	12,671,344
Lake Charles	LA	USG	705	47,472,997	2	68,713	4,127
Miami	FL	SA	890	28,855,822	576	24,117,943	1,797,792
Mobile	AL	USG	963	51,045,189	57	2,410,054	167,514
Monterey	CA	PSW	1	43,224	1	43,224	3,000
New Orleans	LA	USG	4,328	218,108,130	297	13,159,424	1,000,453
New York	NY	NA	4,823	230,912,536	2,419	128,307,476	9,626,213
Orange	TX	USG	1	19,842	1	19,842	1,446
Palm Beach	FL	SA	127	1,918,648	50	717,398	60,476
Philadelphia	PA	NA	3,006	179,261,511	499	15,440,660	1,114,921
Point Comfort	TX	USG	116	4,305,942	1	20,621	716
Port Angeles	WA	PNW	355	35,210,769	6	274,106	18,759
Port Arthur	TX	USG	1,163	76,615,063	2	55,846	3,857
Port Everglades	FL	SA	1,395	46,370,857	715	21,586,636	1,636,671
Port Laudania	FL	USG	1	30,145	1	30,145	2,046
Port Manatee	FL	USG	113	3,267,679	1	22,778	450
San Diego	CA	PSW	322	5,675,941	55	899,336	51,742
San Francisco	CA	PSW	3,515	198,333,851	1,831	106,823,108	8,382,082
San Juan	PR	PR	836	18,778,221	395	9,108,355	722,772
San Pedro	CA	PSW	4	221,505	4	221,505	18,056
Savannah	GA	SA	2,417	116,004,869	1,659	90,865,274	6,789,479
Seattle	WA	PNW	972	54,231,036	652	36,302,412	2,940,429
Tacoma	WA	PNW	1,244	61,366,440	671	36,615,736	2,900,107
Tampa	FL	USG	710	25,821,405	39	1,521,854	99,472
Texas City	TX	USG	976	65,169,213	1	33,149	2,023
Unalaska	AK	PNW	1	21,291	1	21,291	1,712
Virginia Ports	VA	SA	2,759	146,066,252	1,752	88,065,826	6,540,420
Wilmington	NC	SA	515	20,946,322	112	6,277,279	459,258
Total			60,578	3,182,495,027	18,735	922,007,559	70,138,635

Vessel call data are also potentially available from the Marine Exchange at each port. Contacts with selected marine exchanges suggest that it may be possible to obtain vessel calls by terminal, and to calculate or infer vessel turn times. This approach would apparently entail individual data requests to the marine exchanges at each of roughly 10–20 ports (depending on the coverage of each marine exchange), and a concomitant cost.

Data associated with operating costs or rates are highly sensitive, and will remain so. Marine terminal operators negotiate rates and terms of service with their ocean carrier customers. Those rates are embodied in confidential contracts, just as with many businesses.

Labor data of any kind are highly sensitive and considered proprietary. The wage rates, benefits, and work rules of the longshoreman's union (ILA on the East Coast, ILWU on the West Coast) are highly complex and not easily understood. These rules and contract terms lead to situations that are embarrassing to terminal operators, such as paying workers who actually stay home and hiring several more workers than are actually needed for the job. Revelation of these practices frequently leads to indignation among ocean carriers and customers.

Employer's organizations (e.g., the Pacific Maritime Association on the West Coast) help administer the Longshore contracts and retain data on hours worked, wages paid, etc. These data are available in aggregate on association websites, but are not presented in a way that would allow analysts to distinguish labor at a container terminal from labor at other port operations with the same job classifications.

IV. Proposed Productivity Measures

Approach

Based on the conceptual discussion covered in preceding sections, the study team defined a broad set of potential metrics for port productivity, capacity, and utilization. These metrics were then supported by an initial collection of port and terminal data.

The study team analyzed the following major container ports (Exhibit 31).

Exhibit 31: Major Ports Analyzed

North Atlantic	South Atlantic	Gulf	West Coast
Boston	Charleston	Mobile	Los Angeles/ Long Beach
New York/New Jersey	Savannah	New Orleans	Oakland
Philadelphia	Jacksonville	Houston	Portland
Wilmington	Port Everglades		Tacoma
Baltimore	Miami		Seattle
Virginia			

Data were compiled for each major marine container terminal at these ports in a set of profiles using a common format. The terminals profiles are provide as a standalone appendix (Appendix C). Volume figures used throughout this report are compared to 2008 volumes reported to the American Association of Port Authorities (AAPA). As has been widely reported, 2009 cargo volumes were down 10% to 30% from 2008, so using 2009 volumes would artificially inflate estimates of reserve capacity. It is also likely that the major container ports will have somewhat more reserve capacity than was estimated herein until trade recovers.

Proposed productivity measures as discussed below and illustrated by charts for the initial data collection. Port data values are summarized in a separate section

Land Use Measures

In general, U.S. container terminals handle fewer annual TEU per acre than their European or Asian counterparts. Most of the difference is attributable to lower utilization of land rather than lower productivity of cranes, labor, or other operating inputs. The lower cost and greater availability of land at U.S. ports has enabled terminals and their operators to expand horizontally rather than vertically.

No two container terminals are exactly alike, despite having a great deal in common. Port planners and terminal operators have preferences for different operating types and configurations, and those preferences change over time. Moreover, each terminal design must be adapted to its site. These differences are particularly apparent in the definition and configuration of the container yard (CY). There are frequently disparities between what the port lists as CY acreage and what the consultant team identifies as working CY acreage from aerial photos.

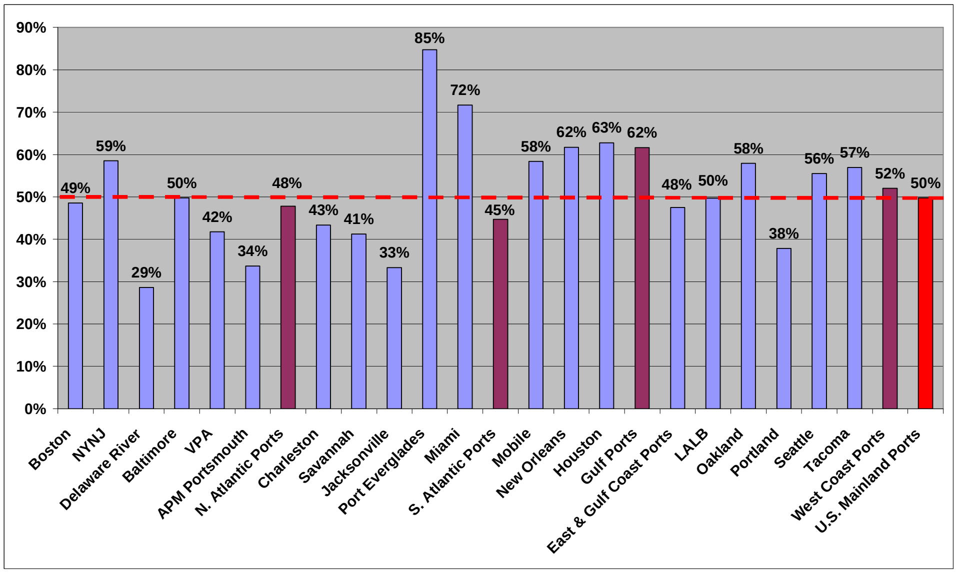
Depending on local practice, land used for chassis storage, land used for equipment maintenance, or land not presently used at all may or may not be included as CY acreage. The study team focused on land being used for container storage, so the figures in this report tend to be conservative.

While the inputs of all terminal types can be generalized as land capital, and labor, data on capital investment and labor man-hours are hard to come by. The issue of land is complicated by the difference between gross and net terminal acres, and because port terminal land is rarely valued at market prices.

CY/Gross Ratio

The first major distinction is between gross acres and CY acres. The study team analyzed the use of space in major U.S. container terminals to distinguish between gross and net acreage, and to develop more accurate and meaningful productivity measures. The ratio of CY acres to total (gross) acres (Exhibit 32) helps characterize a port's land-use pattern and shed light on the interpretation of other metrics. Ports and terminals with on-dock rail will have lower ratios, as will legacy or combination terminals that include non-container functions.

Exhibit 32: CY/Gross Acreage Ratio



U.S. container ports are frequently compared with ports in Hong Kong, Singapore, Rotterdam, and others on the basis of annual TEU per acre. U.S. ports invariably compare poorly. Yet U.S. container ports have lower annual TEU per acre not necessarily because they make poor use of available space, but because they have more space to handle the available cargo.

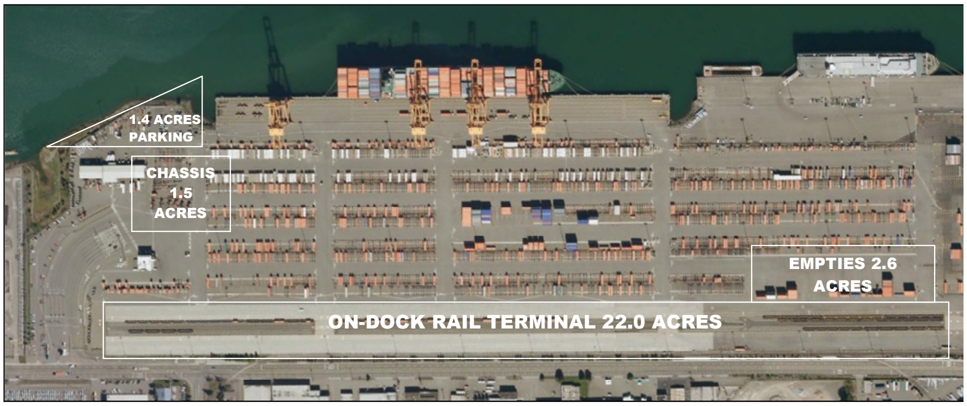
Most foreign terminals use over 75% of their space as container yard. In the US, the average is 49%. Exhibit 33 shows Seagirt in Baltimore, which is fairly typical.

Exhibit 33: Seagirt Terminal

When this photo was taken, the gross acreage included a rail transfer facility, a transloading operation, a chassis lot, and a staff parking area. Those features are not included in high-density Asian terminals

U.S. container terminals typically incorporate functions that use space and reduce the apparent throughput per acre. An apples-to-apples comparison would subtract the acreage used for chassis storage, empty storage, and on-dock rail from the U.S. terminal totals before comparing productivity per acre. The aerial photo below illustrates the difference between gross and net acreage. The Hyundai terminal at Tacoma (Exhibit 34) has a gross area of 80 acres, yet 27.5 acres--34% of the total--are used for non-container yard functions (rail, empties, chassis storage, and parking) that are rarely included in Asian or European terminals. The correction would raise the terminal's TEU per acre by 52%.

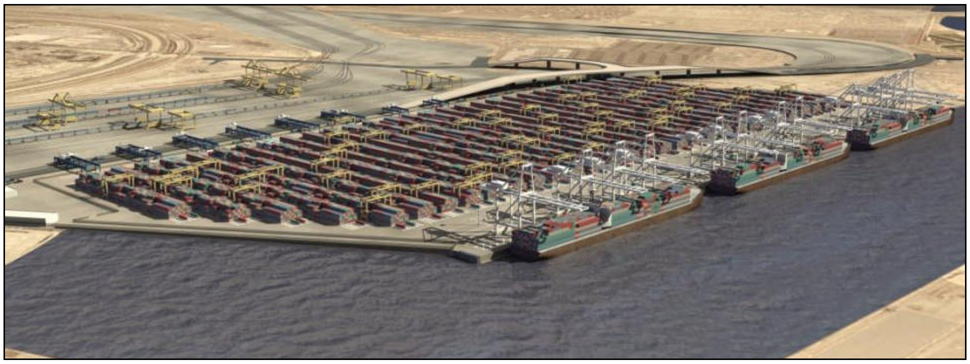
Exhibit 34: Hyundai Terminal, Port of Tacoma



The new Berth 4 at the New York Container Terminal is expected to be able to handle 350,000 to 400,000 lifts per year on 38 acres, the rough equivalent of 8,000+ TEU per acre. A key factor is eliminating chassis storage and stacking instead of parking containers. The Ports America conceptual terminal for Oakland's Outer Harbor (Exhibit 35) has an estimated capacity of 16,600

TEU/acre because it completely eliminates truck aisles in the stacks and relies on an adjacent near-dock rail terminal instead of devoting on-dock space.

Exhibit 35: High Density Outer Harbor Terminal Concept

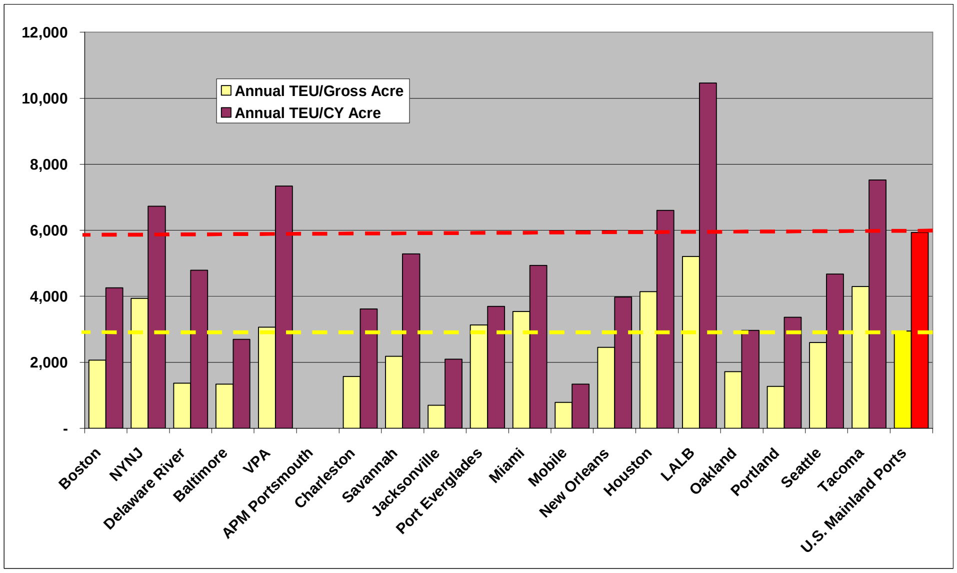


Source: Ports America

TEU per Acre

TEU per acre, meaning <u>gross</u> terminal or port acres, is a commonly used but deceptive metric. Many U.S. container terminals devote substantial portions of their footprint to rail yards or ancillary facilities that would not be present in Asian or European terminals. Annual TEU per CY acre is a much more revealing metric, as it compares throughput (annual TEU) with the inputs directly used (CY acres). Exhibit 36 shows both measures for comparison.

Exhibit 36: TEU per Gross and CY Acre



In 2008, these ports averaged about 2,307 TEU per gross acre. The average throughput for actual CY space was 4,842 TEU per acre, a more accurate basis of comparison. Los Angeles and Long Beach were averaging over 10,000 TEU per CY acre, and several US ports were at 6,000 or more.

Unfortunately, ports and terminals do not always publish their CY acreage. This is an example of the "sometimes" data that would support much better metrics if it were consistently available.

Container Yard Storage Factors

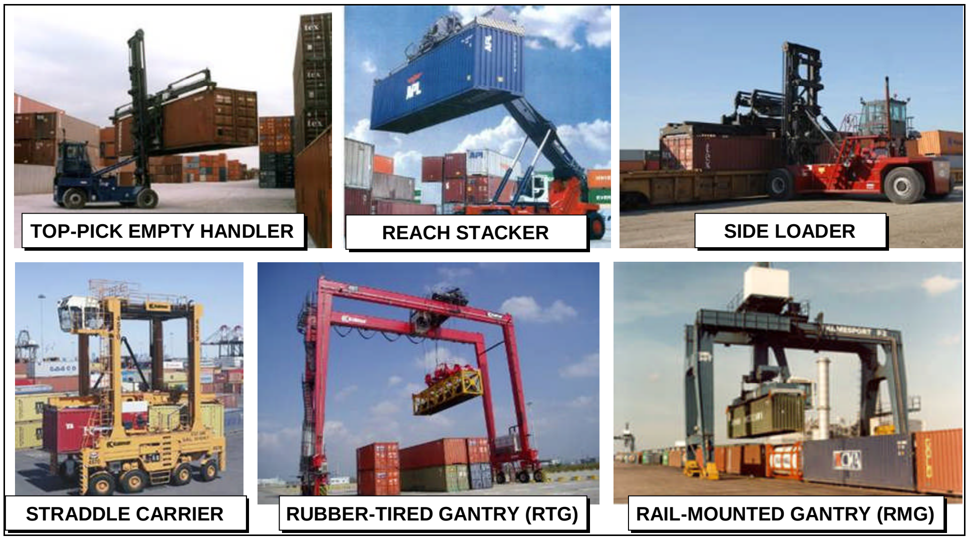
Container Handling Technology

Although marine container terminals all perform similar functions with a limited range of equipment types; in practice, different terminals use different technologies with different production functions.

- Combination container terminals use some of their land, equipment, and labor to handle non-containerized breakbulk cargoes.
- Roll-on/Roll-off (Ro-Ro) terminals do not use mechanical lift equipment and have much lower throughputs per unit of land or berth length.
- Wheeled container terminals transfer containers from vessel to chassis and park them in rows. Such terminals use land as a substitute for capital, and operate at a lower cost.
- Terminals in transition between wheeled and stacked, which include most U.S. terminals, have a mixed production function that may vary with seasonal peaking.
- Stacked terminals vary in density depending on whether they use straddle carriers, RTGs, or RMGs, and on the height and orientation of the stack layout. A straddle carrier terminal, such as Maher at NYNJ, uses a different combination of land, labor, and capital than an RMG terminal such as APM at Norfolk.

Marine container terminal operators adjust container yard (CY) storage density and stacking height by reconfiguring the CY, changing handling equipment, and varying container storage practices. Typical handling equipment types are shown in Exhibit 37.

Exhibit 37: Container Yard Handling Equipment Types



TOP-PICK EMPTY HANDLER

REACH STACKER

SIDE LOADER

STRADDLE CARRIER

RUBBER-TIRED GANTRY (RTG)

RAIL-MOUNTED GANTRY (RMG)

Exhibit 38 displays the progression of terminal handling methods from lowest to highest density. Virtually all U.S. marine container terminals use a mix of the handling methods shown in Exhibit 37 and Exhibit 38, and vary that mix to provide sufficient capacity at minimum cost. Terminal operators gravitate to low-density, low-cost operating methods whenever possible.

Exhibit 38: Progression of Terminal Handling Methods

DENSITY	TYPE	COMMENT
VERY LOW DENSITY	Ro/Ro or Ship's gear	Very small, barge, specialized
	Wheeled Combination	Small, mixed, legacy
	Dedicated Wheeled	Older terminals when new
LOW DENSITY	Wheeled/Top-pick	Transition temrinals
	Top-pick/Wheeled	Transition temrinals
MID DENSITY	**Straddle/Top-pick/Wheeled**	**Hybrid terminal**
	RTG/Top-pick/Wheeled	**Dominant hyrbid type**
HIGH DENSITY	**Straddle Carrier**	**NIT Virginia**
	RTG	**No US Example**
VERY HIGH DENSITY	**Pure RMG**	**APM Portsmouth**

Faced with a need to accommodate more trade, terminals move progressively up the density scale.

- Terminal operators start increasing density by stacking empty containers instead of leaving them parked on chassis. Empties can be handled with inexpensive equipment and stacked first-in/last-out since they are largely interchangeable.

- As additional capacity is required, terminal operators begin stacking loaded export containers. Export containers typically build up over the week prior to vessel arrival and need not be accessed until it is time to load that vessel. Loaded containers are heavier than empties, however, and must be accessed in a sequence tied to vessel loading plans. Loaded export storage, therefore, usually requires more expensive RTGs or straddle carriers.

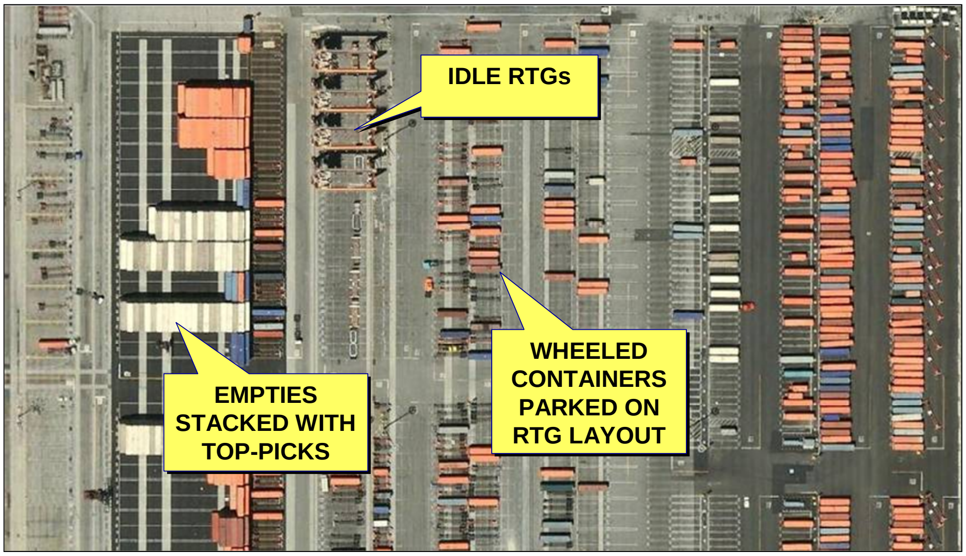
- Terminal operators typically leave loaded import containers parked on chassis ("wheeled") as long as possible to both minimize handling cost and maximize responsiveness to customer needs. When loaded imports are eventually stacked, they require RTG or straddle carriers for flexible access.

- Containers with special requirements are rarely stacked, and most terminals reserve space to keep such movements on chassis. Specialized movements include refrigerated containers, containers with hazardous cargo, over-size or over-weight containers, tank containers, and containers held for CBP inspection.

A wheeled operation in which all containers in the terminal are placed on chassis is the lowest density and most economical operating system. Such an operation requires much more land for parked chassis with and without containers than a stacked system. Yard lift equipment is only required to move containers off the wrong chassis and onto the right one, or to handle containers for maintenance and repair.

In peak periods, such as the annual holiday import surge, terminals shift the balance of operations to higher densities. In slack periods, the operators park more containers on chassis. In protracted downturns, such as the current recession, terminal operators will idle costly handling equipment and revert to wheeled operations, even on space configured for stacking (Exhibit 39).

Exhibit 39: Wheeled Containers on RTG Layout



JWD's white paper (JWD, 2003) points out that three categories of containers are not usually stacked.

- Dangerous or hazardous shipments are typically segregated and kept on chassis
- Outsized or "out of gauge" shipments that extend beyond normal container dimensions cannot be stacked.
- Refrigerated loads that require electrical power are most easily handled on chassis, plugged into yard power "reefer plugs."

There are two other categories of containers that are not usually stacked.

- Tank containers typically carry overweight shipments and require specialized chassis provided by the trucker. Tank containers are, therefore, usually kept on a yard or pool chassis, and subsequently "flipped" to the trucker's equipment.
- Containers held for Customs or USDA inspection are usually placed on chassis and segregated for accessibility.

New terminals that expect a significant volume of refrigerated shipments may install racking systems to hold reefers and supply them with yard power.

Terminal Types and Moves per Box

Each terminal handling method leads to different average moves per container. Wheeled operations are generally preferred in large part because they require only one container lift. The number of lifts, operating cost, and complexity grow as density increases.

- Wheeled – One lift per box
    - Vessel to highway chassis
- Stacked – Three+ lifts per box
    - Vessel to yard chassis
    - Yard chassis to stack
    - Stack to highway chassis (potential stack sorting)
- Straddle Carrier – Two lifts per box
    - Vessel to stack/row
    - Stack/row to highway chassis (minimal row sorting)

Wheeled operations are more labor- and capital-efficient, and average moves per box is an indicator of efficiency and cost. While average moves per box would be a strong indicator of underlying cost, such data require data-links between mobile lift equipment and the terminal's operating system. Even where such links are in place, the data are difficult to collect and analyze, and would be highly confidential.

CY Capacity and Productivity Estimates

The CY capacity and productivity estimation method used in this study is necessarily a compromise, based on a "snapshot" of current stacking density. The team used the most recent aerial photos available on Google Earth and estimated the CY acreage configured for each storage density category. The precision of this method is limited in several respects.

- The latest available aerial photos vary from a few months old to 2 to 3 years old, and terminal configurations and uses can change on short notice.
- Aerial estimates of acreage and uses are imprecise, although probably sufficiently accurate for high-level capacity estimates.

The container yard capacities were estimated by dividing the CY acreage by handling type and applying the storage factors for each to derive estimated TEU slot totals. The typical storage densities for terminal handling methods are shown in Exhibit 40.

Exhibit 40: Typical CY Storage Densities

CY Storage Method	TEU Slots per Acre
Wheeled Chassis	**80**
Grounded Straddle Carrier	**160**
Grounded Stacked	**200**
Grounded RTG	**300**
Grounded RMG	**360**

The focus on capacity, rather than current throughput, led the team to rely more on terminal configuration rather than on current usage or estimates. For example, terminal space configured to use RTGs was assigned an inherent capacity of 300 TEU per acre even though it may currently be used for wheeled storage at 80 TEU per acre. This estimation practice is also necessarily imprecise as the ability to use the full inherent capacity may depend on the availability of handling equipment, operating systems, and other factors beyond the scope of this study.

Exhibit 41 shows an example of CY acreage allocation in which the 79 total CY acres were divided into 20 acres of wheeled storage at 80 TEU/acre, 43 acres of straddle carrier operation at 160 TEU/acre, 8 acres of stacked storage at 200 TEU/acre, and 8 acres of RTG storage at 300 TEU per acre for a total storage capacity of 12,480 TEU slots (Exhibit 42). If the terminal needed more CY capacity, the operator would stack more containers or expand RTG operations at the expense of low-density wheeled storage. The average of 158 slots per acre is between the low density of wheeled operations and the higher density of stacked or RTG operations.

Exhibit 41: CY Acreage Example: Port of New Orleans

Terminal Space	Napolean	Port Total
Total Acres	128	128
Wheeled CY Acres	20	20
Straddle Carrier CY Acres	43	43
Stacked CY Acres	8	8
RTG CY Acres	8	8
RMG CY Acres		-
Total CY Acres	79	79
On-Dock Rail Acres	10	10
Other Non-CY Acres	16	16
Net Berth/Gate/Yard Acres	105	105
Undeveloped Acres	-	-

Exhibit 42: CY Capacity Example: Port of New Orleans

Container Yard Capacity	Napolean	Port Total
Wheeled Chassis Slots	1,600	1,600
Grounded Straddle Carrier Slots	6,880	6,880
Grounded Stacked Slots	1,600	1,600
Grounded RTG Slots	2,400	2,400
Grounded RMG Slots	-	-
TEU Storage Slots	12,480	12,480
Avg TEU Slots/CY Acre	158	158
Maximum Annual Slot Turnover	70.0	70.0
Maximum Annual CY TEU Capacity	**873,600**	**873,600**
Sustainable CY TEU Capacity @ 80%	**698,880**	**698,880**
2008 Annual TEU	313,765	313,765
2008 TEU per CY Slot	**25**	**25**
2008 CY Capacity Utilization	**45%**	**45%**

As Exhibit 42 shows, the team estimated the maximum annual TEU capacity based on a maximum annual slot turnover of 70 turns annually, an aggressive average of more than one turn per week and equivalent to an average container dwell time of slightly over 5 days. While theoretically possible, particularly in periods of peak demand, operation at this level of intensity is unlikely to be sustainable day-in and day-out. Moreover, if this level of density were routine, there would be no reserve capacity to handle the inevitable trade surges. The study team, therefore, also estimated sustainable CY TEU capacity at 80% of the maximum, following a common industry rule-of-thumb. There is only one major container terminal at the Port of New Orleans, so, in the examples above, the port total is the same as the Napoleon terminal total.

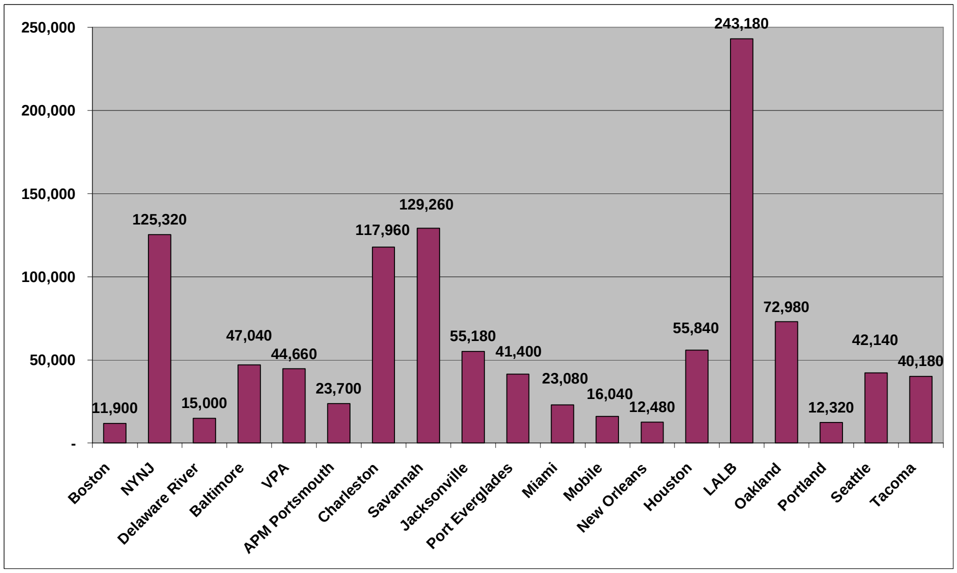
2008 annual TEU counts were compared with the estimated sustainable TEU capacity to estimate the annual TEU per storage slot (25 in the example) and average annual CY capacity utilization (45% in the example).

Under greater pressure, such as was experienced in Southern California before the current recession, marine terminals can also increase capacity by reducing container dwell times. By shortening “free time” allowances and raising or vigorously enforcing charges for excess dwell time, terminal operators have succeeded in reducing dwell times for import loads, thus, increasing storage turnover. On the export side, terminals can limit the time in advance of vessel arrival during which export containers will be accepted. To reduce the dwell time of empty containers, terminal operators and their ocean carrier clients can move empties to off-terminal depots or return leased containers to leasing company depots.

TEU Storage Slots (CY Slot Capacity)

The total TEU storage slots in a terminal or port reflects the combination of CY acreage and the CY operating methods in use, and characterizes static storage capacity (Exhibit 43). There are two factors at play: CY acreage and stacking density. The combination highlights the enormous total capacity at the Ports of Los Angeles and Long Beach. Were Seattle and Tacoma combined in the data, the combination would look much larger than the two individual ports.

Exhibit 43: TEU Storage Slots

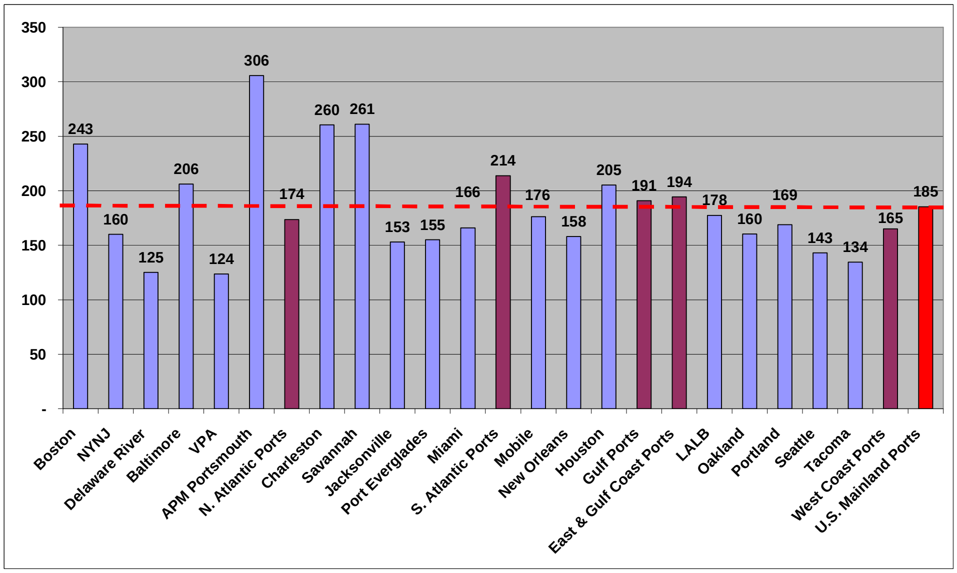


TEU Slots per CY Acre (Storage Density)

TEU slots per acre is a useful measure of CY capacity because it captures the impact of stacking height and technology as well as acreage. US ports average about 190 slots per acre, roughly half way between an all-wheeled terminal at 80 to 100 TEU per acre and an all-RTG terminal at 300 per acre. Almost every US terminal actually has a mix of wheeled, top-pick, and RTG operations. These numbers also indicate substantial room for growth through greater density.

Storage density is a mid-point in the analysis of capacity and productivity. Storage density (Exhibit 44) reflects the way the terminal space has been allocated among various storage technologies. A higher number indicates that the facility has been configured for high annual throughput, but does not reflect the extent to which that capacity is being used.

Exhibit 44: TEU Slots per CY Acre (Storage Density)



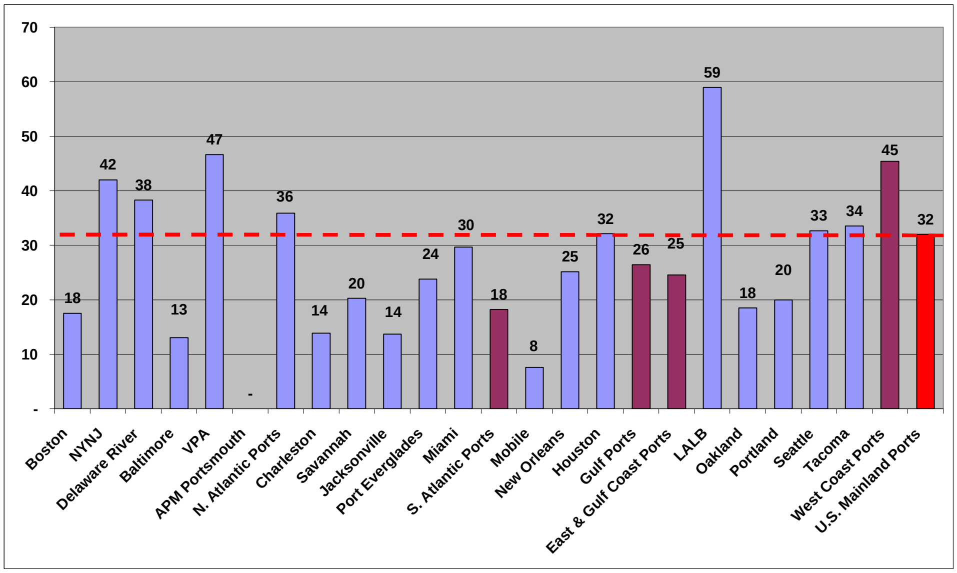
Those terminals with the largest shares of land set up for RTG operations, such as Boston, Baltimore, Charleston, and Savannah, show the highest slot densities, although not all those slots are regularly occupied. The highest density is at the APM Portsmouth terminal, which is the only U.S. terminal using RMGs. The available TEU "slots" were estimated by applying rule-of-thumb storage densities to the acreage used for wheeled, stacked, straddle carrier, RTG, or RMG handling. Annual throughput capacity is therefore a function of TEU slots and annual turnover per slot. The ports analyzed averaged 194 TEU slots per acre against a rough maximum of 300 for all-RTG storage. As the data suggest, almost all the terminals examined use a mix of storage types and densities.

The results shown in Exhibit 44 are examples of "sometimes" data. The team developed its own estimates, but it would be much better if ports and terminals published an official number for TEU slots.

Annual TEU per Slot (Turns)

A more complete picture of CY utilization can be formed by calculating annual TEU per slot (Exhibit 45). TEU per slot, or annual slot turns (Exhibit 45), is a productivity measure reflecting the output from the TEU slot "asset." This measure shows how well the port is using its existing capacity. Not surprisingly, the busiest ports are turning over their capacity more often. U.S. ports analyzed averaged about 34 annual TEU per CY slot, or about 49% of a benchmark maximum of 70 TEU per slot about one turn every five days.

Exhibit 45: Annual TEU per Slot (Turns)

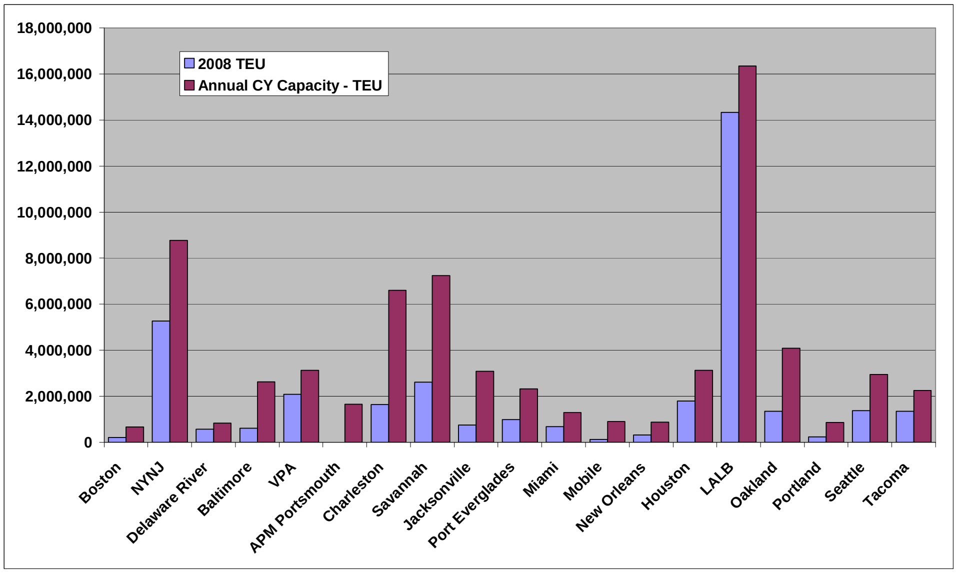


CY Capacity Measures

Annual CY TEU Capacity

Annual CY capacity, estimated as the product of TEU slots and a maximum turnover of 70 per year, is a benchmark for the maximum TEU that could be handled (Exhibit 46). A sustainable capacity can be estimated at 80% of the maximum, allowing for business peaks and valleys and a margin for growth.

Exhibit 46: Annual CY TEU Capacity and 2008 TEU

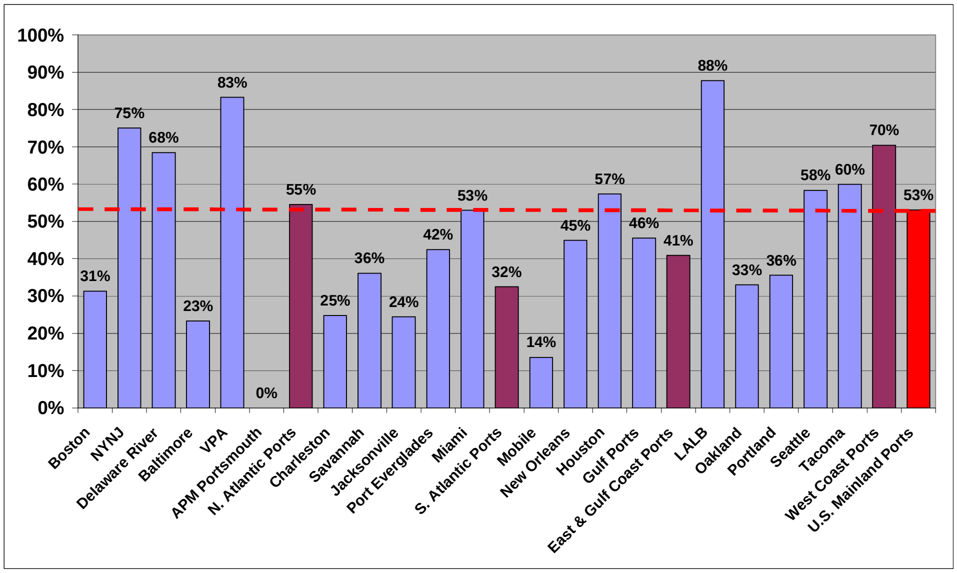


Reserve capacity is greatest at Oakland, NYNJ, Charleston, and Savannah. This chart, however, does not take into account current and announced terminal expansion projects in Mobile, Houston, and elsewhere. In terms of shear size LALB, PANYNJ, Charleston, Savannah, and Jacksonville are the largest ports. The Delaware River Ports include Philadelphia and Wilmington, DE. The Port of Virginia includes Norfolk, Newport News, and Portsmouth terminals.

CY Capacity Utilization

Annual TEU divided by estimated annual TEU capacity (throughput as a percentage of capacity) is a measure of CY capacity utilization. The ports shown in Exhibit 47 average 50% CY capacity utilization.

Exhibit 47: CY Capacity Utilization



Container Crane Measures

Crane utilization metrics present a dilemma. Crane utilization and productivity can be measured in TEU and number of vessels worked.

- Terminals usually have 2-3 cranes per berth.
- They can use up to 5 cranes for large vessels, so they move cranes as needed.
- Most cannot handle multiple large vessels with high discharge/load volumes simultaneously.
- Crane efficiency is measured in moves per working hour, a figure that is not always made available.

There is inherent tension in this approach:

- Annual crane output is higher if fewer cranes work the vessels.
- Vessel turns are faster and more reliable if more cranes are used.

Terminals can maximize crane productivity by using as few cranes as possible, but, by doing this, risk vessel delays. Vessels cost a lot more than cranes, and the primary terminal task is turning the vessel

- Crane utilization and productivity can be measured in TEU and vessels worked.
- Crane efficiency would be measured in moves/hour, but data are seldom available.

There is a critical tradeoff. Annual crane output is higher if fewer cranes work the vessels, yet vessel turns are faster and more reliable with more cranes

The ability to handle a given vessel size depends on the berth length and draft available at the terminal. The ability to handle the cargo from that vessel depends on the number of cranes available, the hourly throughput capability of those cranes, and the hours those cranes are available in a day or week.

The primary goal of terminal operators is to service the vessel on schedule and at minimum cost. The number of cranes installed and used is determined primarily by the need to turn the vessel, with annual crane productivity a secondary consideration. This set of priorities results in relatively low container crane utilization, as suggested by the exhibits that follow. A vessel is far more costly to own and operate than the cranes that serve it, so crane utilization is effectively sacrificed to vessel utilization.

The following metrics tell more in combination than separately.

Average Cranes per Berth

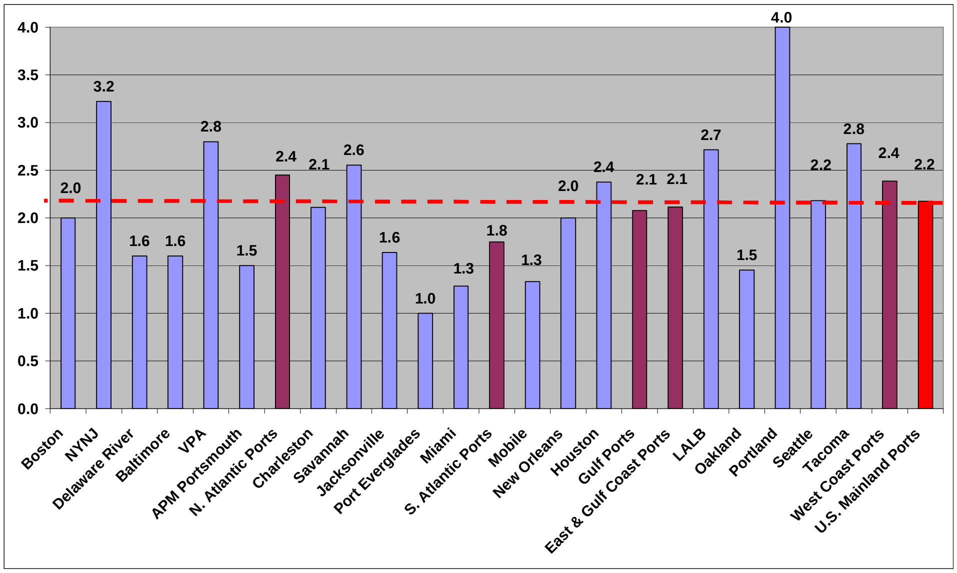
A typical marine terminal, such as the one shown in Exhibit 48, might have two berths and four cranes. This configuration gives the terminal operator the flexibility to assign from one to four cranes to a vessel, as required. as the vessel discharge and load averages increase, the number of cranes may limit the number of vessels that can be handled simultaneously, and therefore annually. As this limit is approached, the port or terminal operator will add cranes.

Exhibit 48: Typical Two-Berth/Four-Crane Terminal

This arrangement lets the stevedore work two small ships at once, or put 3 to 4 cranes against one larger or more heavily loaded ship.

Exhibit 49 shows that the U.S. average is 2.2 cranes per berth and that ports average anywhere form 1.0 to 4.0. Behind the numbers are some important differences. Both Port Everglades and Oakland have lower averages, but Oakland is 4 times the size of Port Everglades. Houston and Portland have high averages, but Houston is 3 times larger than Portland.

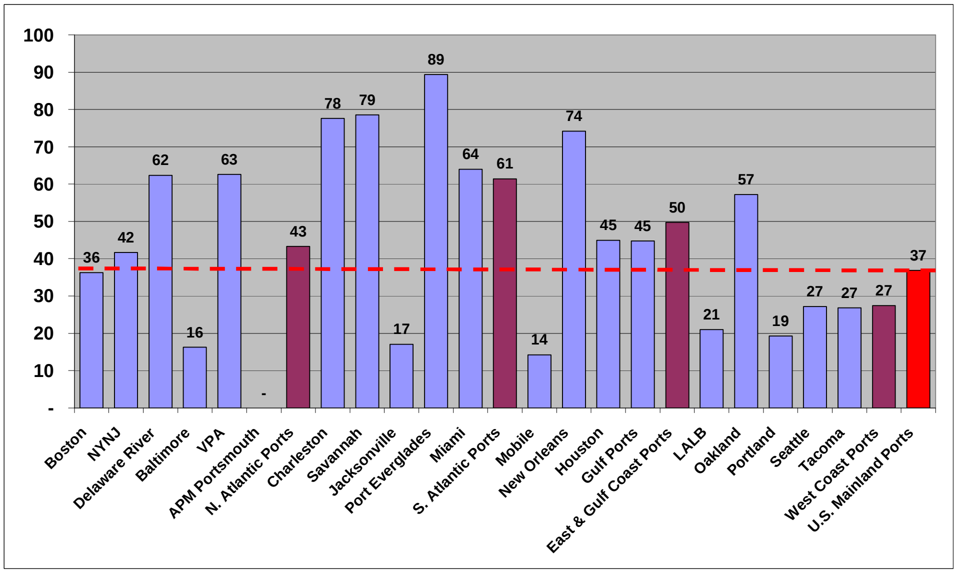
Exhibit 49: Average Cranes per Berth



Annual Vessel Calls per Crane

Annual vessel calls per crane is a productivity measurement, but is driven by the number of calls more than by the number of cranes. A low number of calls per crane (Exhibit 50) suggests that either there are relatively few vessel calls or that the average call discharges and loads a large number of containers. Exhibit 50 shows the lowest annual vessel calls per crane at West Coast ports – LALB, Oakland, Portland, Seattle, and Tacoma. With the exception of Portland, those ports are served by large vessels with large discharge/load totals, so more cranes are needed per vessel. Portland shows a low figure because it has a high ratio of cranes per berth (Exhibit 49).

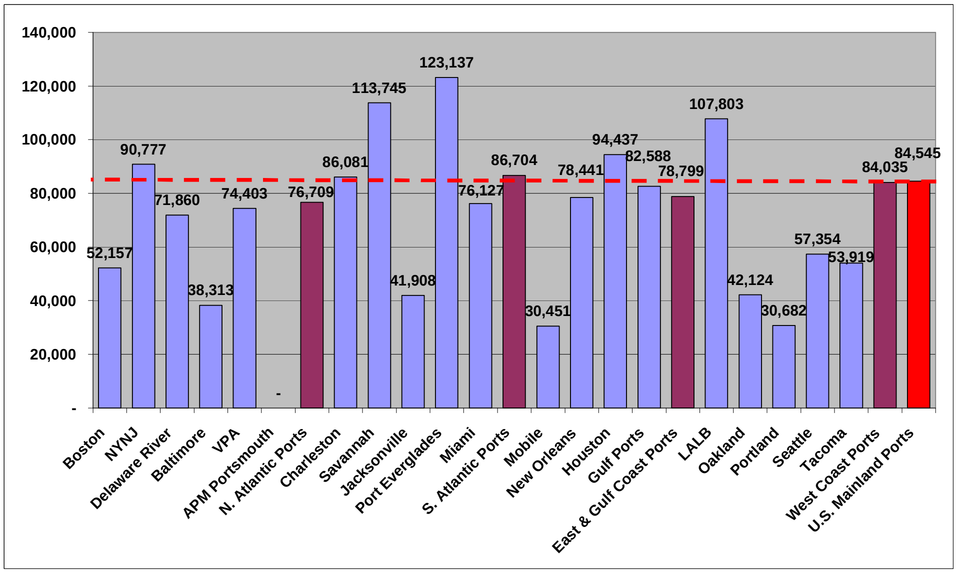
Exhibit 50: Annual Vessel Calls per Crane



Annual TEU per Crane

Annual TEU per crane (Exhibit 51) reflects overall port or terminal performance and balance. A low figure suggests that cranes are being used to handle either relatively few vessels or relatively few TEU from each vessel. The lowest numbers are at Baltimore, Philadelphia, and Portland, which receive relatively few calls. The low figure at Oakland reflects excess capacity there.

Exhibit 51: Annual TEU per Crane



The high figures for Port Everglades are due to inclusion of ro-ro traffic in the data. Other than the Port Everglades anomaly, the highest crane productivities are at LALB (due to large vessels and high discharge/load ratios) and Savannah (due to a large number of vessel calls per berth).

Vessel Measures

Container terminal throughput is limited by the size and utilization of the vessels that call. The average vessel that calls at most ports discharges and loads substantially less than its full capacity. There are two basic reasons for this disparity.

- Vessels almost invariably call at multiple U.S. ports on each voyage, and the vessel’s total cargo discharge and load is split among those ports.

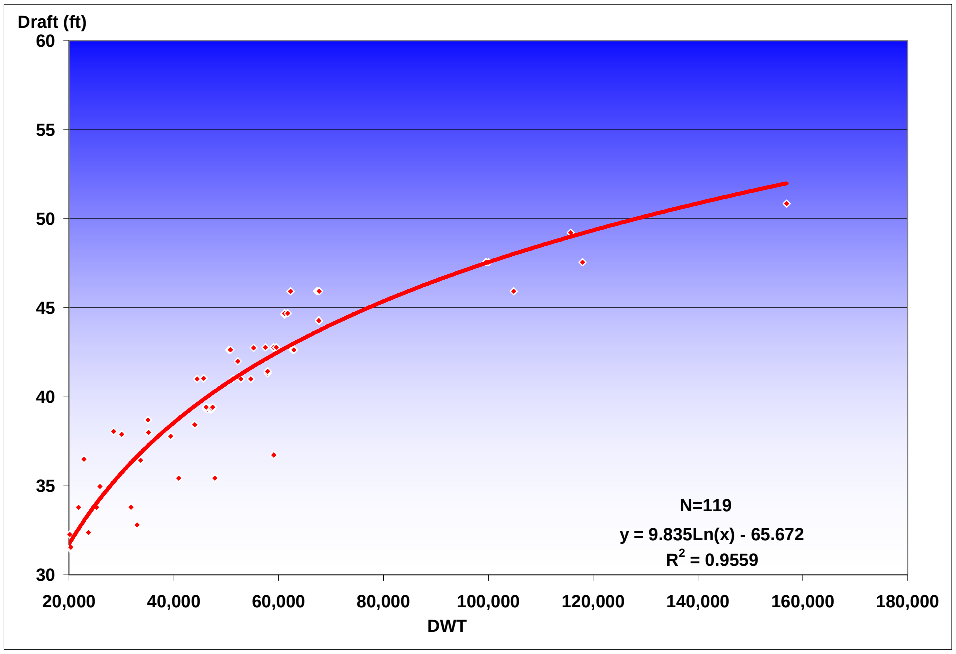
- Ocean carriers, like ports and terminals, offer and deploy sufficient capacity to accommodate growth as well as current cargo volumes. Only in peak periods of peak years will vessels be completely full on every voyage.

Vessel Draft, DWT, and TEU Capacity

The relationship between vessel size measured in deadweight tons (DWT) and in twenty-foot equivalent units (TEU) varies, especially in very large vessels (e.g. over 8,000 TEU). To develop a working relationship the study team assembled a database of 350+ container vessels.

Exhibit 52 shows the relationship between DWT and draft, where both data items were available for a given vessel.

Exhibit 52: DWT vs. Draft



It appears that vessel designers have kept maximum drafts within boundaries, and that the largest vessels are becoming wider rather than deeper.

Vessels rarely sail at their full design draft. To do so would entail a full load of loaded containers, which is uncommon. USACE guidance (Exhibit 53) suggests that maximum effective cargo capacity is typically about 95% of DWT. Applying this ratio to design draft *versus* sailing draft suggests that a vessel designed for 50 feet draft would, for example, usually sail at a maximum of 47.5 feet. While not a precise relationship, this guideline was adopted for the capacity analysis.

Exhibit 53: USACE Guidance on Cargo Capacity as a Percentage of DWT

Adjustments for Estimating Actual Vessel Capacity
Short Tons of Cargo as a Percentage of Vessel DWT

Vessel DWT	% Cargo to DWT
<20,000	90%
20,000 to 70,000	92%
70,000 to 120,000	95%
>120,000	97%

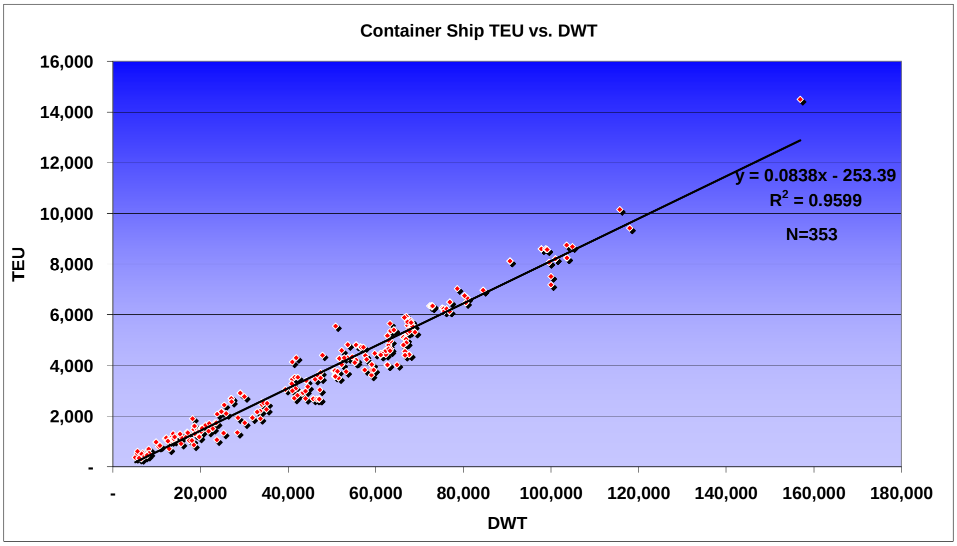
Source: IWR Report 91-R-13, National Economic Development Procedures Manual, Deep-Drat Navigation, November 1991, p. 77.

Likewise, vessels rarely use the full channel depth. For safety reasons, pilot rules and common practice typically require a minimum of 3 feet under keel. This rule is sometimes “bent,” and it is common at some ports to “ride the tide” to gain additional clearance. Taking the long-term view again, the capacity analysis incorporates the 3-foot minimum.

Together, these guidelines imply that a vessel with a 50-foot design draft would have a maximum sailing draft of 47.5 feet and would need a channel depth of 50.5 feet to maintain a 3-foot under-keel clearance.

A second regression analysis yielded the relationship between DWT and TEU capacity (Exhibit 54).

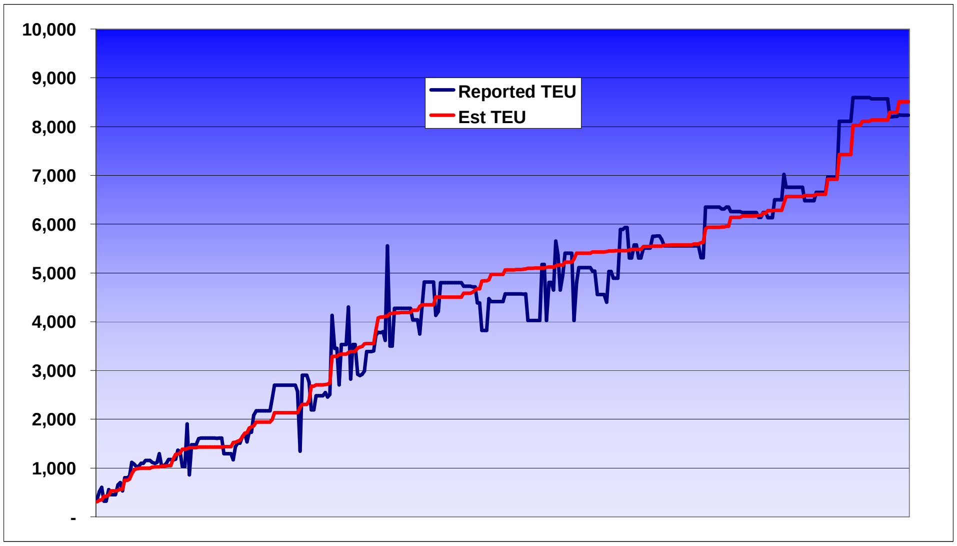
Exhibit 54: Container Vessel DWT vs. TEU Capacity



This analysis is likely to be most reliable in the range of 20,000 to 80,000 DWT or 2,000 to 6,000 TEU, where the most data are available. At the upper end of the range, fewer data are available.

Exhibit 55 compares the reported *versus* estimated TEU capacities where available. Significant differences in reported and estimated TEU capacities should be expected because there are substantial variations in the way the carriers themselves rate vessel capacity. A vessel can hold more containers if they are light or empty, so a TEU capacity based on an illustrative average of 12 metric tons per TEU will be higher than an estimate for the same vessel at 13 or 14 metric tons per TEU. These variations account for much of the disparity between vessels of similar size and tonnage, but different TEU capacities.

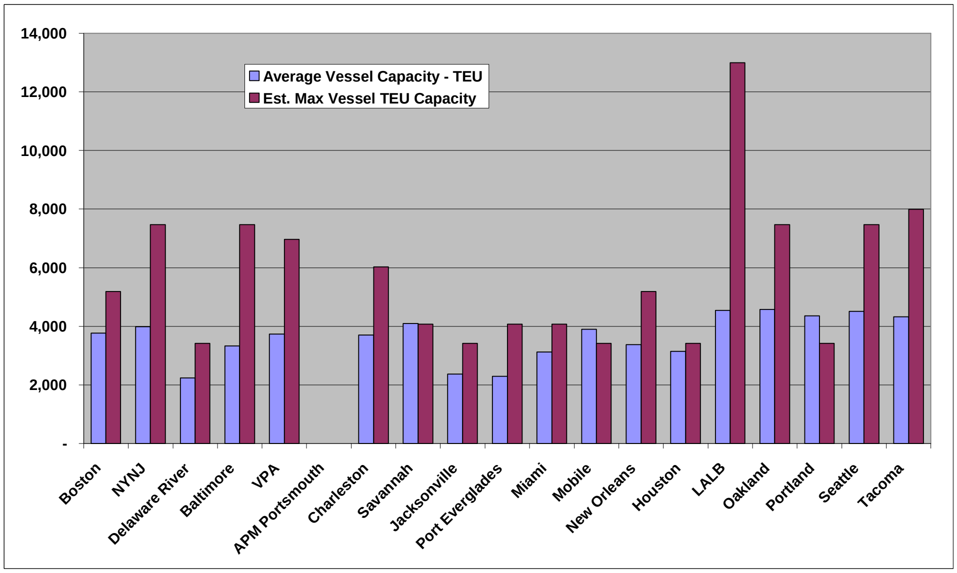
Exhibit 55: Reported vs. Estimated Container Vessel TEU



Vessel Size Ratio

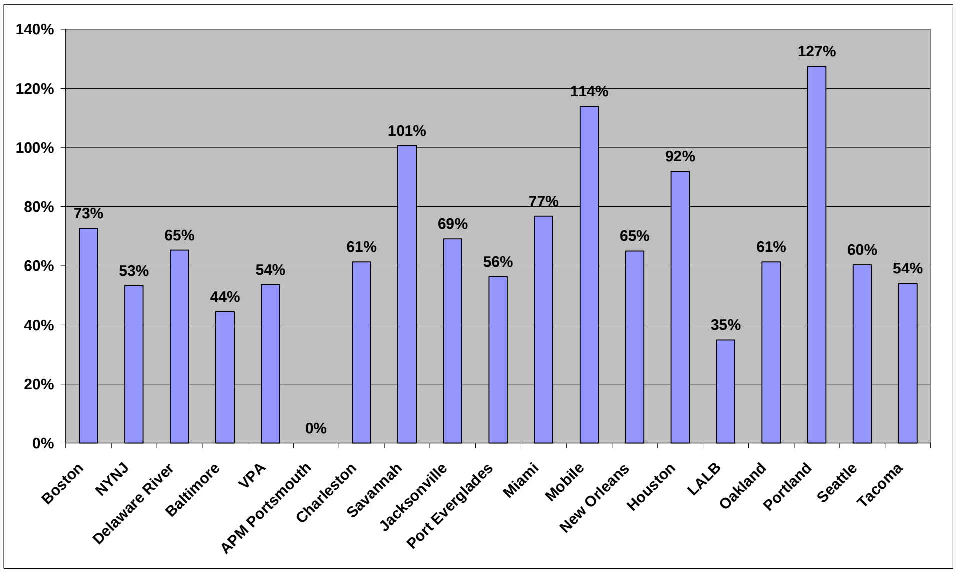
Comparing the average vessel size being handled to the maximum possible vessel size for the available draft indicates how much of the inherent draft and berth length is being used. The series of relationships describe above was used to estimate the largest vessel size in TEU that could be accommodated at each port, and the corresponding berth requirements for length and beam. Exhibit 56 shows the estimated maximum vessel size for each port and the reported average container vessel size for 2007. Most major ports receive a mix of vessels whose average sizes are well below the maximum.

Exhibit 56: Maximum vs. Average Vessel Capacity - TEU



The comparison in Exhibit 56 can also be expressed as a ratio (Exhibit 57). This ratio could reach 100% if the port is being served by a fleet of maximum-sized vessels, or if tide or light loading are being used to bring in vessels that would otherwise exceed the available draft.

Exhibit 57: Vessel Size Ratio - - Average versus Maximum TEU



A comparison between the estimated maximum vessel size and the record of vessel calls revealed some cases where the reported average vessel size was greater than the estimated maximum and the ratio is over 100%. The highest ratios are for three ports with draft restrictions - (Houston, Philadelphia, and Portland). The theoretical maximum there is being reached or exceeded.

- Larger vessels can access these ports if they are “light loaded” and are sailing at less than their design draft.
- Larger vessels can also access these ports by using tides for greater draft.

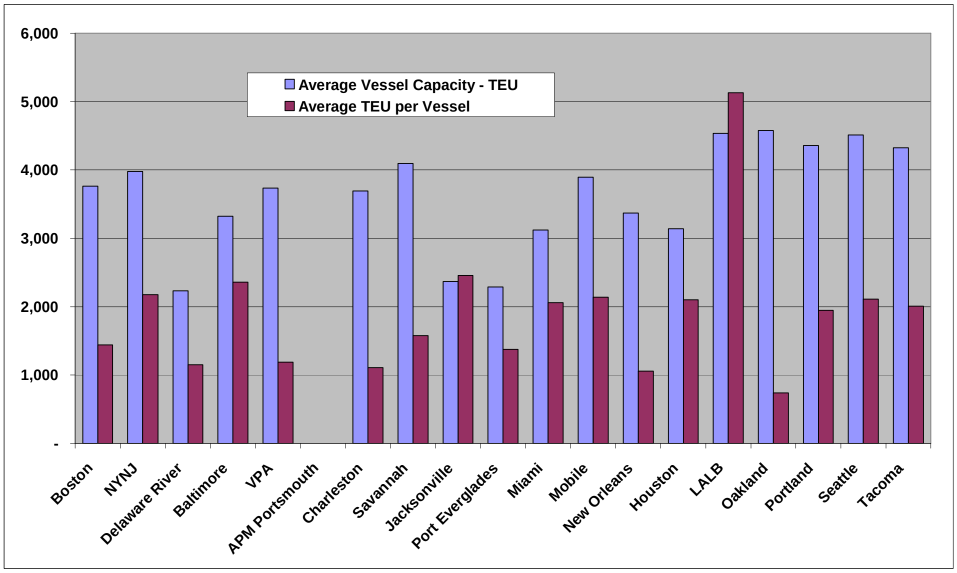
The lowest ratios are at three ports that can accommodate very large vessels (LALB, NYNJ, and Tacoma).

Vessel Size and Load Ratio

Container vessels do not ordinarily sail completely full, or discharge and reload their full capacity at a single port.

Exhibit 58 compares the estimated average vessel TEU capacity with the average TEU discharged and loaded. The differences are substantial. At most East Coast ports the average vessel discharges and loads 1,000–2,000 TEU, less than half the vessel capacity. This apparent low vessel utilization is actually the manifestation of multiple port calls on the East Coast. From Boston to Miami the U.S. East Coast has 10 competing port areas. The U.S. West Coast has 3 (4 if Portland is counted separately from Seattle and Tacoma). The West Coast also has a number of transpacific “shuttle” services that feed intermodal rail movements into Southern California or the Pacific Northwest. As the chart shows, these factors produce larger vessels loaded to a greater fraction of their capacity at West Coast ports.

Exhibit 58: Vessel Size and Load Comparison

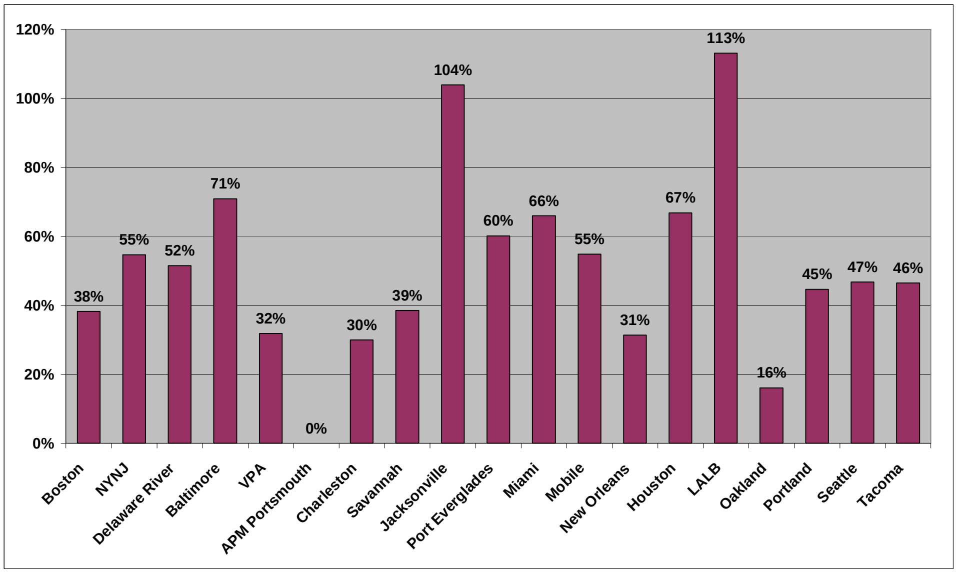


As vessel sizes grew over the preceding decade, concern increased over the potential for “load centering,” the anticipated practice of using large vessels to serve large ports and smaller feeder vessels (or inland truck or rail service) to serve smaller ports. The practice was not widely used in part because carriers formed Vessel Sharing Agreements (VSAs) and alliances, and continued direct service to small ports under competitive pressure.

The data in Exhibit 58, however, suggest that load centering or similar practices may be limiting volumes going through Boston, Philadelphia, Baltimore, and Portland. These ports are all adjacent to major competitors. PANYNJ competes with Boston and Philadelphia; Virginia competes with Baltimore, and Seattle and Tacoma compete with Portland. Philadelphia, Baltimore, and Portland also have the competitive disadvantage of being located some distance from the open ocean.

These data can be expressed as a ratio. The theoretical maximum is 200% of vessel capacity: a vessel completely emptied and reloaded. Exhibit 59 shows that most ports discharge and load an average of 30-40% of vessel capacity. The exceptions are Houston, the dominant port in the Gulf, and LALB.

Exhibit 59: Vessel Size and Load Ratio



Berth Measures

Berth Length

Berth length is published in many places. Berth length also tends to remain stable over long periods, so the sources tend to be accurate. Container terminal berths are typically 600-1,000 feet. At many ports, however, the berth face is continuous across multiple berths or even across multiple terminals. Two 1,000-foot berths on a 2,000-foot face, therefore, can accommodate vessels longer than 1,000 feet, although not two at a time.

As most container vessels in service are less than 1,000 feet long and 1,000-foot berths are common, berth length *per se* has seldom been a limiting factor. That will eventually change as Post-Panamax and Super-Post-Panamax vessels become more common on the East and Gulf Coasts.

- The Panamax length limit is 965 feet and the width limit is 105 feet. Vessels that transit the Panama Canal can be as large as 5,000 TEU, although most are much smaller.
- Typical Post-Panamax vessels are 1000+ feet long and 130+ feet wide. Capacities range up to 10,000 TEU. These are the vessels targeted by the Panama Canal expansion.
- The largest Super-Post-Panamax vessels now being built in the 13,000-15,000 TEU range such as the Maersk E-Class, are 184 feet wide and 1,300+ feet long.

Draft (Berth Depth)

Berth depth (and the depth of the channel required to reach the berth) is also commonly published. It is seldom clear whether the published figure is the authorized depth (which may or may not have been fully maintained) or a measured and maintained depth. Given the long-term outlook of the capacity estimates, it was assumed that the published depths would be maintained. Ports and terminal operators can provide capacity, but throughput is limited by the capacity of the vessels that call and by the percentage of that capacity that is discharged and loaded. Berth depth governs the maximum vessel size that each port and terminal can accommodate.

It should be noted that the current draft limit for the Panama Canal is 39.5 feet, which is more restrictive than most East Coast and Gulf ports. The new Canal locks are expected to allow vessels with drafts of up to 60 feet, widths of up to 180 feet, and lengths of up to 1,400 feet transit the Canal.

Berth Utilization

Berth utilization can be measured in multiple ways:

- Vessel calls per berth
- TEU as percentage of capacity with largest possible vessels and discharge/load
- TEU as percentage with current vessels
- Vessels as percentage of maximum vessel calls with current size and discharge
- Vessel utilization
- Current average vessel size compared to maximum possible for berth and channel depth
- Current average TEU as percentage of maximum discharge load from current average vessel.

The analysis provides two different perspectives on berth capacity:

The Maximum Vessel Basis estimates the potential throughput using the largest vessel for the available draft, and the 2007 ratio of discharge/load total to vessel capacity. In Exhibit 60, an example from Boston (Conley Terminal), the nominal maximum vessel size is 5,183 TEU based on an available draft of 45 feet and a corresponding sailing draft of 42 feet. The current average vessel capacity (2007) is estimated at 3,675 TEU, with a 37% discharge/load rate. At the same rate, a 5,183 TEU vessel would load and discharge 1,930 TEU at Boston. The example is based on a maximum of 260 calls per year per berth (5 per week) and a sustainable estimate of 208 (80%) per berth. The annual TEU capacity would be 803,012.

Exhibit 60: Berth Capacity - Maximum Vessel Basis Example (Boston)

Berth Capacity - Max Vessel Basis	Conley	Boston
Berths	2	2
Berth length	2,000	2000
Berth Depth - Feet	45	45
Max Sailing Draft	42	42
Corresponding Design Draft @ 95%	44	44
Corresponding DWT	63,678	63,678
Nominal Max Vessel TEU	**5,183**	**5,183**
Corresponding Vessel Length - Feet	1,000	1,000
Vessel Spacing (Beam)	140	140
Length requirement	1,140	1,140
Available Berths for Max Vessel	**2.0**	**2.0**
Port average TEU/container	1.73	1.73
2008 TEU	220,339	220,339
Avg. TEU/Vessel	1,439	1,439
Avg. Vessel DWT	50,860	50,860
Average Est. Vessel Capacity TEU	3,765	3,765
Average Discharge & Load %	38%	38%
Average TEU per Max Vessel	1,981	1,981
Max annual calls per berth	260	260
Sustainable Calls per berth @ 80%	208	208
Total Sustainable Vessel Calls	416	416
Annual Berth Capacity TEU	**823,934**	**823,934**
2008 Annual TEU	208,626	208,626
Berth Utilization, Max Vessel Basis	**25%**	**25%**

The Vessel Call Basis estimates berth capacity more conservatively using the current average vessel size by simply maximizing the number of calls (Exhibit 61).

Exhibit 61: Berth Capacity Estimate- Vessel Call Basis Example

Berth Utilization - Vessel Call Basis	Conley	Boston
Max Calls per berth 5 / wk	260	260
Available Berths	2.0	2.0
Sustainable Calls per berth @ 80%	208	208
Total Sustainable Vessel Calls	416	416
2008 Vessel calls	145	145
2008 Berth Utilization	**35%**	**35%**

Annual Vessel Calls per Berth

Exhibit 62 displays annual vessel calls per berth, which is the first factor in berth utilization and productivity. There is some ambiguity when terminals have a long berth face that can be divided in different ways, as the number of "berths" can vary from time to time.

Exhibit 62: Annual Vessel Calls per Berth

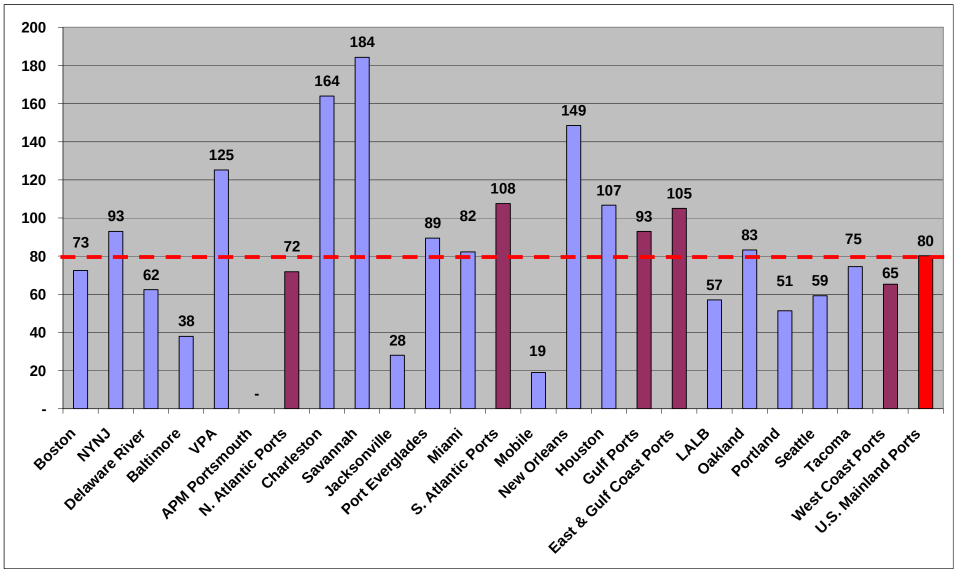
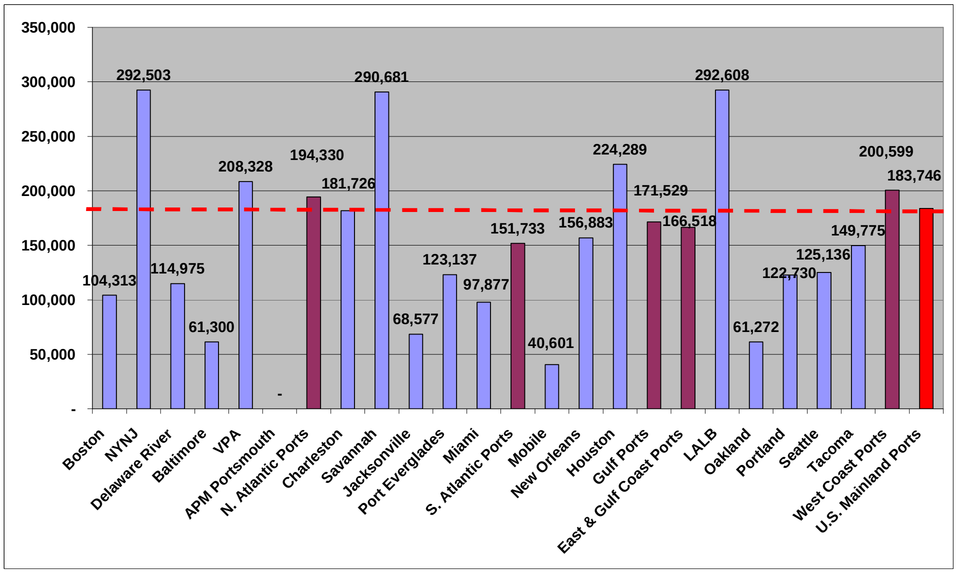


Exhibit 62 shows considerable variation. At the low end is Oakland. Although Oakland is one of the nation's busier ports, it has an unusually large number of berths at its terminals. At the high end are Savannah and Charleston, which receive a large number of calls from smaller vessels in the Atlantic and South American trades.

Annual TEU per Berth

If the ultimate function of a marine container terminal is to transfer containers between land and vessel, annual TEU per berth reflects overall productivity (Exhibit 63). The high marks go to Savannah and LALB, for different reasons: Savannah has a very high number of calls per berth, while LALB has fewer calls, but much larger vessels, and fewer TEU on each vessel.

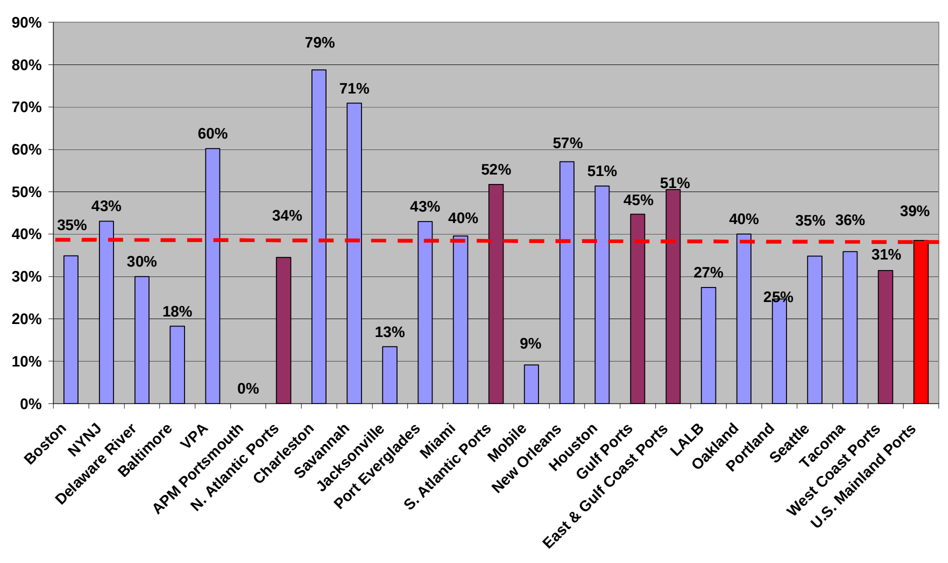
Exhibit 63: Annual TEU per Berth



Berth Call Utilization (Vessel calls per berth *vs.* maximum calls per berth)

The simplest way to gauge berth capacity utilization is to compare the number of vessels handled (calls) with the maximum that could have been handled (Exhibit 64). The number that could have been handled must usually be estimated. The number that could be handled is also affected by the number of containers discharged and loaded on each one.

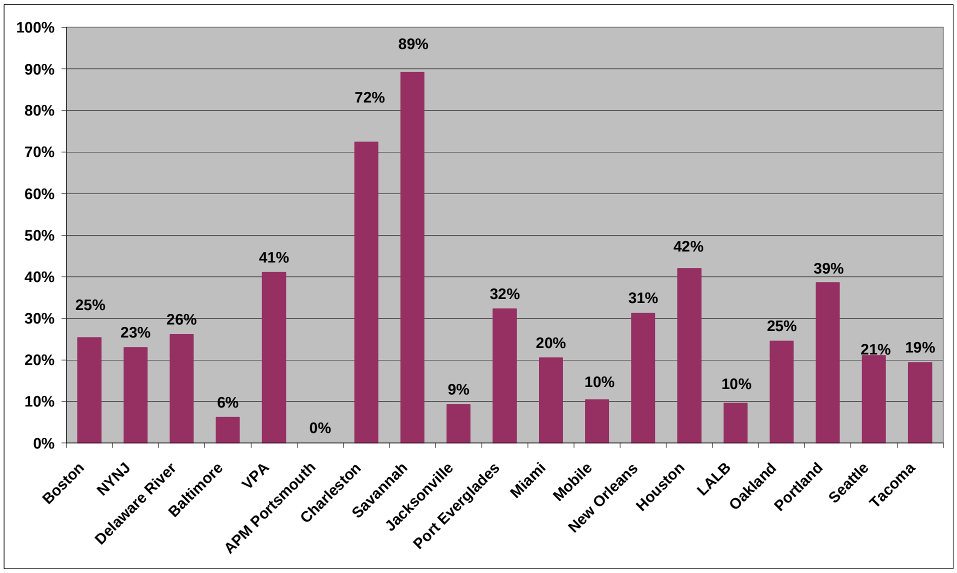
Exhibit 64: Berth Call Utilization



Berth TEU Utilization (Annual TEU per berth *vs.* maximum TEU per berth for maximum vessel size)

A more complex look at berth utilization takes into account the maximum TEU that could be handled if the maximum-size vessel made the maximum number of calls (Exhibit 65). This is an aggressive comparison, since it measures productivity against a standard that is unlikely to be attained anywhere. The U.S. average is about 34%. Savannah is at 103%, because the reported average vessel size is larger than the estimated maximum (due to the use of tides for more draft) and the calls per berth measure is high. The West Coast ports have low averages because their current average of vessel size is well below their maximum vessel size.

Exhibit 65: Berth Utilization - Maximum Vessel Size Basis



Productivity Implications

Port and terminal throughout could be increased by using larger vessels for the same number of calls, making more calls with the same vessels, discharging and loading more of the vessel capacity at each call, or any combination of these changes. In each case more container cranes and/or crane time would be required to handle the increased cargo while keeping the vessel on schedule. The crane capacity estimates are based on availability for two shifts per day, 250 days per year (4,000 annual hours). The cranes are, in fact, available 24 hours per day if the terminal operator needs the additional shifts to turn the vessel on schedule and is willing to pay for overtime.

Berth length and draft determine the size of vessels the terminal can handle and how heavily they can be loaded. The terminal storage capacity depends on the area available and how high the containers can be stacked. The other variable is operating hours. Most terminals will operate a second shift as required to turn the vessel, but second shifts are expensive, and third shifts are still more expensive. Most terminals still open the gates for just one shift.

Port authorities are commonly charged by their communities, regions, or states with promoting growth of trade, economic development, and jobs. To do so, port and terminal operators attempt to build and maintain sufficient capacity for foreseeable and attainable growth. Most container terminal parameters that would allow for growth can only be adjusted through large, costly, and time-consuming long-term commitments. Development of new terminals, expansion of berths, and dredging are multi-year, multi-million dollar projects. Expansion of existing terminal space can be undertaken more easily and inexpensively, but can still take months or years in congested seaport areas.

In the shorter term, ports and terminals can add container cranes at a cost of $5-$10 million each, with a lead time of multiple months rather than multiple years. In the very short term, ports and container terminals can adjust capacity along two dimensions: container yard stacking density and operating hours. These are also ordinarily the only means by which container terminals *reduce* capacity. Except in rare circumstances, terminal areas do not shrink, berths do not get shorter, channels do not become shallower, and the number of cranes does not decline. During seasonal or economic trade downturns, however, marine terminal operators can reduce operating hours, reduce manning during operating hours, and revert to low-density, low-cost container yard operations.

Operating Hours

Port terminals occasionally vary operating hours to handle additional vessels or cope with trade surges. Marine container terminals typically maintain full cargo handling and gate functions for a single shift five to six days per week. Additional shifts are often added to handle arriving or departing vessels and to complete loading or unloading, even if full gate and truck handling functions are not supported. In peak periods, terminals will extend gate hours to handle inbound and outbound truck movement. At the busiest ports, such as NYNJ or LALB, extended gate hours are a regular feature.

Labor agreements specify the options available to terminal operators and the attendant costs. Marine terminal operators attempt to match labor supply and costs with vessel and trade requirements. The rigidities of these agreements make it difficult and costly for terminal operators to extend operating hours or to match labor supply closely with trade and vessel requirements. So, although container terminal throughput and capacity could be greatly increased by adding shifts, that option is usually the last choice for any extended period.

Coastal Port Summaries

North Atlantic Ports

Exhibit 66 summarizes estimates of North Atlantic port capacity and utilization along multiple dimensions. North Atlantic container trade is dominated by the Port Authority of New York and New Jersey (60% of the 2008 TEU total) and the Port of Virginia (Virginia Port Authority, 24% of the 2008 TEU total). The Ports of Boston and Philadelphia (Delaware River) must compete with NYNJ. The other Delaware River port, Wilmington, DE, is a specialized facility handling imported bananas. Baltimore must compete with the Port of Virginia. In addition to its own seaport terminals, VPA operates the Virginia Inland Port, a satellite terminal in Baltimore's market area. Philadelphia and Baltimore have the additional competitive disadvantage of being located a significant distance from the open ocean with channel draft restrictions. The new APM Portsmouth terminal is shown separately.

Exhibit 66: North Atlantic Capacity and Utilization Summary

Container Yard	Boston	NYNJ	Delaware River	Baltimore	VPA	APM Portsmouth	N. Atlantic Ports
2008 TEU	208,626	5,265,058	574,876	613,000	2,083,278		8,744,838
Gross Acres	101	1,338	420	458	680	230	3,227
CY Acres	49	783	120	228	284	78	1,542
CY/Gross Ratio	**49%**	**59%**	**29%**	**50%**	**42%**	**34%**	**48%**
Annual CY Capacity - TEU	666,400	8,772,400	840,000	2,634,240	3,126,200	1,659,000	17,698,240
Annual TEU/Gross Acre	2,066	3,935	1,369	1,338	3,064	-	2,918
Annual TEU/CY Acre	4,258	6,724	4,791	2,689	7,335	-	5,973
Est. CY TEU Slots	11,900	125,320	15,000	47,040	44,660	23,700	267,620
Avg. CY Slots/ Acre - Density	243	160	125	206	124	306	174
Avg. Annual TEU/CY Slot (Turns)	18	42	38	13	47	-	36
CY Utilization	**31%**	**75%**	**68%**	**23%**	**83%**	**na**	**55%**
Container Cranes	**Boston**	**NYNJ**	**Delaware River**	**Baltimore**	**VPA**	**APM Portsmouth**	**N. Atlantic Ports***
Cranes	4	58	8	16	28	6	120
Cranes per Berth	2.0	3.2	1.6	1.6	2.8	1.5	2.4
Annual Crane Capacity - TEU	971,192	14,616,000	2,016,000	3,471,202	7,056,000	1,512,000	29,642,395
Annual TEU/Crane	52,157	90,777	71,860	38,313	74,403	na	76,709
Annual Moves/Crane	30,074	50,432	39,922	24,723	41,335	na	43,137
Annual Vessel Calls/Crane	36	42	62	16	63	na	43
Crane Utilization	**21%**	**36%**	**29%**	**18%**	**30%**	**na**	**30%**
Berths and Vessels	**Boston**	**NYNJ**	**Delaware River**	**Baltimore**	**VPA**	**APM Portsmouth**	**N. Atlantic Ports**
Berths	2	18	5	10	10	4	49
Berth Feet	2,000	27,421	5,300	8,819	11,460	3,200	58,200
Annual Vessel Calls	145	2,419	499	380	1,752	na	5,195
Annual Vessel Calls per Berth	73	93	62	38	125	na	72
Berth Utilization - Vessel Call Basis	**35%**	**43%**	**30%**	**18%**	**60%**	**na**	**34%**
Annual TEU per Berth	104,313	292,503	114,975	61,300	208,328	na	194,330
Annual TEU/Foot of Berth	104	192	108	70	182	na	159
Average Vessel Capacity - TEU	3,765	3,979	2,234	3,324	3,733	na	3,675
Est. Max. Vessel Capacity - TEU	5,183	7,470	3,420	7,470	6,967	na	na
Avg. vs. Max. Vessel Capacity	**73%**	**53%**	**65%**	**44%**	**54%**	**na**	**na**
Average TEU per Vessel	1,439	2,177	1,152	2,358	1,189	na	1,683
Avg. Vessel Ute. - % Discharge/Load	**38%**	**55%**	**52%**	**71%**	**32%**	**na**	**46%**
Berth Capacity - Avg. Vessel Basis	598,541	12,223,467	1,437,766	4,413,600	2,720,628	na	21,394,001
Berth Utilization - Avg. Vessel Basis	**35%**	**43%**	**40%**	**14%**	**77%**	**na**	**41%**
Avg. Discharge/Load per Max. Vessel	1,981	4,086	1,764	5,299	2,219	na	na
Berth Capacity - Max. Vessel Basis	823,934	22,948,363	2,200,890	9,918,893	5,077,716	na	na
Berth Utilization - Max. Vessel Basis	**25%**	**23%**	**26%**	**6%**	**41%**	**na**	**na**

As the summary data show, reserve capacity in the North Atlantic is substantial, in part because of the shear size of NYNJ and Virginia (particularly if the APM terminal is included) and in part because Boston, Philadelphia, and Baltimore are underutilized.

South Atlantic Ports

Exhibit 67 displays the capacity and utilization estimates for the major South Atlantic ports. Savannah is the busiest at 39% of the 2008 TEU total, but the shares are more evenly distributed than in the North Atlantic. The Miami total shown in Exhibit 67 excludes barge traffic through the Seaboard terminal. All of these ports have significant reserve capacity, although Charleston and Savannah could become berth-constrained if the average size stays low. Most of the reserve capacity is at Charleston and Savannah.

Exhibit 67: South Atlantic Capacity and Utilization Summary

Container Yard	Charleston	Savannah	Jacksonville	Port Everglades	Miami	S. Atlantic Ports
2008 TEU	1,635,534	2,616,126	754,352	985,095	685,139	6,676,245
Gross Acres	1,045	1,200	1,085	315	194	3,839
CY Acres	453	495	361	267	139	1,715
CY/Gross Ratio	**43%**	**41%**	**33%**	**85%**	**72%**	**45%**
Annual CY Capacity - TEU	6,605,760	7,238,560	3,090,080	2,318,400	1,292,480	20,545,280
Annual TEU/Gross Acre	1,565	2,180	695	3,127	3,532	1,739
Annual TEU/CY Acre	3,610	5,285	2,090	3,689	4,929	3,893
Est. CY TEU Slots	117,960	129,260	55,180	41,400	23,080	366,880
Avg. CY Slots/ Acre - Density	260	261	153	155	166	214
Avg. Annual TEU/CY Slot (Turns)	14	20	14	24	30	18
CY Utilization	**25%**	**36%**	**24%**	**42%**	**53%**	**32%**
Container Cranes	**Charleston**	**Savannah**	**Jacksonville**	**Port Everglades**	**Miami**	**S. Atlantic Ports**
Cranes	19	23	18	8	9	77
Cranes per Berth	2.1	2.6	1.6	1.0	1.3	1.8
Annual Crane Capacity - TEU	4,642,917	5,777,192	4,536,000	2,016,000	2,205,877	19,177,987
Annual TEU/Crane	86,081	113,745	41,908	123,137	76,127	86,704
Annual Moves/Crane	49,317	63,397	23,282	68,409	43,484	48,739
Annual Vessel Calls/Crane	78	79	17	89	64	61
Crane Utilization	35%	**45%**	**17%**	**49%**	**31%**	**35%**
Berths and Vessels	**Charleston**	**Savannah**	**Jacksonville**	**Port Everglades**	**Miami**	**S. Atlantic Ports**
Berths	9	9	11	8	7	44
Berth Feet	7,940	9,693	9,850	6,125	6,500	40,108
Annual Vessel Calls	1,475	1,659	307	715	576	4,732
Annual Vessel Calls per Berth	164	184	28	89	82	108
Berth Utilization - Vessel Call Basis	**79%**	**71%**	**13%**	**43%**	**40%**	**52%**
Annual TEU per Berth	181,726	290,681	68,577	123,137	97,877	151,733
Annual TEU/Foot of Berth	206	270	77	161	105	166
Average Vessel Capacity - TEU	3,695	4,093	2,365	2,289	3,121	3,466
Est. Max. Vessel Capacity - TEU	6,031	4,067	3,420	4,067	4,067	**na**
Avg. vs. Max. Vessel Capacity	**61%**	**101%**	**69%**	**56%**	**77%**	**na**
Average TEU per Vessel	1,109	1,577	2,457	1,378	2,059	1,411
Avg. Vessel Ute. - % Discharge/Load	**30%**	**39%**	**104%**	**60%**	**66%**	**41%**
Berth Capacity - Avg. Vessel Basis	1,383,828	2,952,012	5,622,011	1,719,439	2,570,079	14,247,368
Berth Utilization - Avg. Vessel Basis	**118%**	**89%**	**13%**	**57%**	**27%**	**47%**
Avg. Discharge/Load per Max. Vessel	1,810	1,567	3,553	2,448	2,683	na
Berth Capacity - Max. Vessel Basis	2,258,566	2,933,090	8,129,312	3,054,850	3,348,897	na
Berth Utilization - Max. Vessel Basis	**72%**	**89%**	**9%**	**32%**	**20%**	**na**

Gulf Ports

Exhibit 68 summarizes capacity and utilization estimates for the three major Gulf Coast container ports. Houston dominates the region with 80% of the total, and has most of the reserve capacity. New Orleans suffered a setback from Hurricane Katrina and has a competitive disadvantage from being located roughly 100 miles upriver from the Gulf of Mexico. Mobile, however, has a new terminal and significant reserve capacity for post-recession growth.

Exhibit 68: Gulf Coast Capacity and Utilization Summary

Container Yard	Mobile	New Orleans	Houston	Gulf Ports
2008 TEU	121,803	313,765	1,794,309	2,229,877
Gross Acres	156	128	433	717
CY Acres	91	79	272	442
CY/Gross Ratio	**58%**	**62%**	**63%**	**62%**
Annual CY Capacity - TEU	898,240	873,600	3,127,040	4,898,880
Annual TEU/Gross Acre	781	2,451	4,141	3,109
Annual TEU/CY Acre	1,338	3,972	6,597	5,045
Est. CY TEU Slots	16,040	12,480	55,840	84,360
Avg. CY Slots/ Acre - Density	176	158	205	191
Avg. Annual TEU/CY Slot (Turns)	8	25	32	26
CY Utilization	**14%**	**45%**	**57%**	**46%**
Container Cranes	**Mobile**	**New Orleans**	**Houston**	**Gulf Ports**
Cranes	4	4	19	27
Cranes per Berth	1.3	2.0	2.4	2.1
Annual Crane Capacity - TEU	1,008,000	1,008,000	4,788,000	6,804,000
Annual TEU/Crane	30,451	78,441	94,437	82,588
Annual Moves/Crane	16,917	43,579	52,465	45,882
Annual Vessel Calls/Crane	14	74	45	45
Crane Utilization	**12%**	**31%**	**37%**	**33%**
Berths and Vessels	**Mobile**	**New Orleans**	**Houston**	**Gulf Ports**
Berths	3	2	8	13
Berth Feet	2,900	2,000	8,000	12,900
Annual Vessel Calls	57	297	854	1,208
Annual Vessel Calls per Berth	19	149	107	93
Berth Utilization - Vessel Call Basis	**9%**	**57%**	**51%**	**45%**
Annual TEU per Berth	40,601	156,883	224,289	171,529
Annual TEU/Foot of Berth	42	157	224	173
Average Vessel Capacity - TEU	3,895	3,369	3,143	3,234
Est. Max. Vessel Capacity - TEU	3,420	5,183	3,420	na
Avg. vs. Max. Vessel Capacity	**114%**	**65%**	**92%**	**na**
Average TEU per Vessel	2,137	1,056	2,101	1,846
Avg. Vessel Ute. - % Discharge/Load	**55%**	**31%**	**67%**	**57%**
Berth Capacity - Avg. Vessel Basis	1,333,422	549,353	3,933,193	5,815,968
Berth Utilization - Avg. Vessel Basis	**9%**	**57%**	**46%**	**38%**
Avg. Discharge/Load per Max. Vessel	1,876	1,625	2,286	na
Berth Capacity - Max. Vessel Basis	1,170,658	1,003,765	4,279,510	na
Berth Utilization - Max. Vessel Basis	**10%**	**31%**	**42%**	**na**

West Coast Ports

Exhibit 69 summarizes capacity and utilization estimates for the major West Coast container ports. LALB dominates the West Coast with 77% of the total, due to both a huge local import market and the practice of moving most intermodal imports bound for the Midwest and beyond through LALB. Within California, the Port of Oakland has substantial reserve capacity due to heavy terminal investments in the last decade. In Oregon, the Port of Portland has struggled to attract and maintain multiple competing services, and is handicapped by both its position 100+ miles up the Columbia River and the proximity of the Puget Sound ports. Not surprisingly, Portland remains underutilized. Seattle and Tacoma should probably be considered one port, for comparison purposes, like Los Angeles and Long Beach, although they are physically separated competitors and their data are shown separately.

Exhibit 69: West Coast Capacity and Utilization Summary

Container Yard	LALB	Oakland	Portland	Seattle	Tacoma	West Coast Ports
2008 TEU	14,337,801	1,347,975	245,459	1,376,496	1,347,975	18,655,706
Gross Acres	2,757	786	193	531	525	4,792
CY Acres	1370	455	73	294.75	299	2,492
CY/Gross Ratio	**50%**	**58%**	**38%**	**56%**	**57%**	**52%**
Annual CY Capacity - TEU	16,341,696	4,086,880	862,400	2,949,800	2,250,080	26,490,856
Annual TEU/Gross Acre	5,201	1,715	1,272	2,592	4,286	3,893
Annual TEU/CY Acre	10,466	2,963	3,362	4,670	7,525	7,487
Est. CY TEU Slots	243,180	72,980	12,320	42,140	40,180	410,800
Avg. CY Slots/ Acre - Density	178	160	169	143	134	165
Avg. Annual TEU/CY Slot (Turns)	59	18	20	33	34	45
CY Utilization	**88%**	**33%**	**36%**	**58%**	**60%**	**70%**
Container Cranes	**LALB**	**Oakland**	**Portland**	**Seattle**	**Tacoma**	**West Coast Ports**
Cranes	133	32	8	24	25	222
Cranes per Berth	2.7	1.5	4.0	2.2	2.8	2.4
Annual Crane Capacity - TEU	33,130,563	7,817,162	2,016,000	5,697,053	6,576,824	55,237,602
Annual TEU/Crane	107,803	42,124	30,682	57,354	53,919	84,035
Annual Moves/Crane	60,587	24,141	17,046	33,826	28,694	7,502
Annual Vessel Calls/Crane	21	57	19	27	27	27
Crane Utilization	**43%**	**17%**	**12%**	**24%**	**20%**	**34%**
Berths and Vessels	**LALB**	**Oakland**	**Portland**	**Seattle**	**Tacoma**	**West Coast Ports**
Berths	49	22	2	11	9	93
Berth Feet	57,053	19,150	1,946	12,810	10,260	101,219
Annual Vessel Calls	2,795	1,831	127	652	671	6,076
Annual Vessel Calls per Berth	57	83	51	59	75	65
Berth Utilization - Vessel Call Basis	**27%**	**40%**	**25%**	**35%**	**36%**	**31%**
Annual TEU per Berth	292,608	61,272	122,730	125,136	149,775	200,599
Annual TEU/Foot of Berth	251	70	126	107	131	184
Average Vessel Capacity - TEU	4,534	4,578	4,358	4,510	4,322	4,518
Est. Max. Vessel Capacity - TEU	13,000	7,470	3,420	7,470	7,997	na
Avg. vs. Max. Vessel Capacity	**35%**	**61%**	**127%**	**60%**	**54%**	**na**
Average TEU per Vessel	5,130	736	1,949	2,111	2,009	3,070
Avg. Vessel Ute. - % Discharge/Load	**113%**	**16%**	**45%**	**47%**	**46%**	**68%**
Berth Capacity - Avg. Vessel Basis	52,282,959	3,368,833	810,576	3,952,148	3,760,669	64,175,186
Berth Utilization - Avg. Vessel Basis	**27%**	**40%**	**30%**	**35%**	**36%**	**29%**
Avg. Discharge/Load per Max. Vessel	14,708	1,201	1,529	3,497	3,717	na
Berth Capacity - Max. Vessel Basis	149,907,029	5,497,117	636,062	6,546,180	6,958,498	na
Berth Utilization - Max. Vessel Basis	**10%**	**25%**	**39%**	**21%**	**19%**	**na**

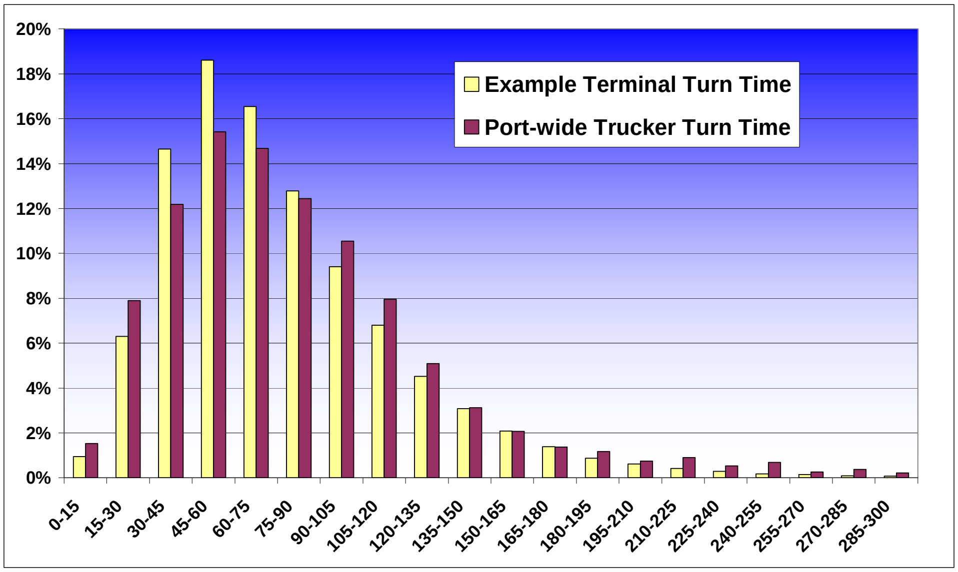
Drayage Measures

Turn Time

The most important measure of drayage productivity is "turn time," the time the motor carrier requires to conduct a transaction or set of transactions at the marine terminal. The portion of the turn time that is spent inside the marine terminal is regularly measured by the terminal operators and is sometimes available. The portion of the turn time that is spent outside the gate is seldom measured.

Tioga recently conducted a study where both elements were measured. The results are displayed in Exhibit 70, which shows the difference between inside the gate turn times and total turn times. In this case a Qualcomm equipped motor carrier geofenced the marine terminals and was able to provide total turn time information.

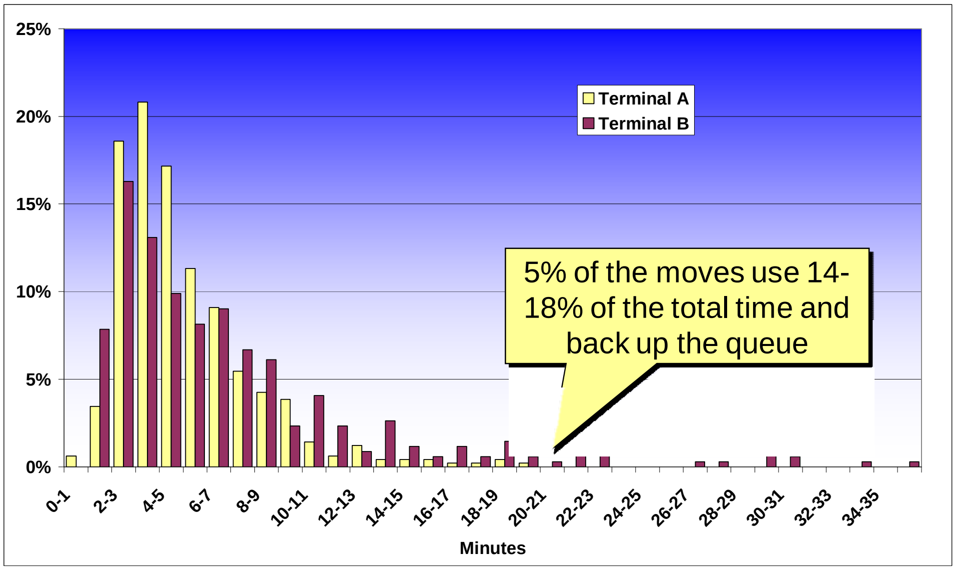
Exhibit 70: Example of Drayage Turn Times



Marine terminals may collect detailed turn time information by type of transaction. This is important because all "turns" are not equally difficult. Some visits to a marine terminal may involve a "double move," that is dropping an export container and picking up an import. Conversely, a transaction may be as simple as delivering an empty container to a marine terminal and bobtailing away. The data in Exhibit 70 do not distinguish between simple and complex transactions.

Another way to analyze turn times is to measure and manage how long each step in the process takes. The gate process is one example. Exhibit 71 shows a frequency distribution at two marine terminals for which process times were measured using gate cameras. It illustrates that, while most gate transactions are handled in under 5 minutes, there are a significant number of longer transactions. The implication is that attacking the exceptionally long transactions will not only improve average turn time, but also make queue time more predictable for motor carriers who sometimes wait in line behind unusually long transactions.

Exhibit 71: Gate Process Time



Trouble Ticket Share

This measure compares the number of transactions involving trouble tickets to the total number of transactions. A typical trouble ticket share is 5%. Trouble tickets measure the ability of the customer, line, terminal, motor carrier, and regulatory agencies to communicate effectively. The large majority of this communication is routine, repetitious, and electronic. For the 5% of the transactions that the systems mishandle, expensive human intervention is necessary. Each trouble ticket typically costs the motor carrier approximately an hour ($50-$60) to resolve. Exhibit 72 is a list of causes for trouble tickets at one terminal Tioga recently studied.

Exhibit 72: Causes of Trouble Tickets

BOOKING PROBLEMS	**28%**
Booking does not match equipment type	10%
Booking is not on file	7%
Booking tally has already been reached	7%
Missing notice for hazardous cargo	3%
Booking quantity exceeded for equipment type	3%
DISPATCH PROBLEMS	**29%**
Cargo not yet released	8%
Driver or motor carrier credential problem	7%
Empty Container/chassis not allowed	6%
Past cargo cutoff	3%
Demurrage due (unpaid bills)	3%
Container exceeds maximum safe weight	2%
SYSTEM PROBLEMS	**22%**
Container/chassis not recognized	18%
Duplicate transaction	2%
Container not found in yard	2%
Other	20%
TOTAL	**100%**

In the study mentioned above, Tioga observed that inexperienced drivers and motor carriers have much higher trouble ticket rates than firms and drivers for whom marine drayage is a primary business.

Best Drayage Practices

The study team attempted to identify best practices to mitigate drayage bottlenecks, delays, and extra trips. There are a number of industry practices and trends that can be expected to improve overall drayage/marine terminal performance, such as having remote container yards, neutral chassis pools, trucker-supplied chassis, or automated gates. There is a second category of practices that focus on information flow, business strategies, and problem solving.

Remote Container Yards. Recently the Uniform Intermodal Interchange Agreement was modified to permit marine terminals to direct motor carriers returning empty containers to container yards in the region rather than bringing them back to the marine terminal of origin.

This change was made to accommodate the current empty equipment management practices, which reflect the increasing ability of the lines and terminals to more intensely manage empty equipment using Internet postings and e-mail to expedite communications with motor carriers. In this case, the practice permits the seamless integration of less expensive container yards in equipment management strategies, particularly for drop off, storage, and pick up of empty equipment.

This practice has a number of advantages and disadvantages for both motor carrier and terminal:

- The marine terminal obtains extra CY and gate capacity, as every movement and function handled at the Polaris Street Yard makes additional capacity at PNCT.
- The motor carrier seeking to drop off and/or pick up an empty container should enjoy a faster gate and overall faster turn times as he is not standing in line behind more complex transactions.
- Conversely, the motor carrier seeking to drop an empty box and pick up a load has extra work. The motor carrier does not know exactly what service will be required when the price is established. As a result, this provision only applies to regional container yards and instructions posted before the close of business the previous day.

Neutral/Cooperative Chassis Pools. Use of neutral chassis pools is expanding, although success has not been uniform. Just as the legacy system of chassis supply is seen as a major obstacle to drayage and terminal productivity, neutral chassis pools are seen as a near-term solution and candidates for best practices. Neutral chassis pools appear to have the greatest benefits at multi-carrier marine terminals and off-dock rail terminals where the need to match chassis and container ownership leads to delays, exceptions, and large on-site chassis fleets. Neutral chassis pools reduce the total number of chassis required and typically reduce the frequency of roadability issues. Typically, pools are located at marine terminals, and involve several marine and rail facilities in a region.

Customer/Trucker-Supplied Chassis. In the long term, the system would benefit greatly if ocean carriers exited the chassis supply function entirely and chassis were supplied by either drayage firms or customers. Such an industry-wide change would eliminate on-terminal chassis searches, trouble tickets, and disputes related to chassis conditions, the need to inspect and interchange chassis at terminal gates, and the need for chassis flips.

Maersk recently took a step in this direction by establishing a practice in which the motor carrier was made responsible for providing the chassis. It established a chassis leasing company, Direct Chassis Link to manage Maersk's fleet of chassis and provide them to the motor carriers that service Maersk's (and other) customers. The operating practice now covers most of Maersk's operations in the United States and is being implemented nationwide. Direct Chassis Link charges the motor carrier $11/day for the chassis. When Maersk is responsible for a door delivery, Maersk pays for the chassis, including any associated customer free time, as part of the motor carrier's rate.

The practice is designed to reduce the on-terminal chassis storage and chassis management requirements in a number of ways:

- by providing an incentive for the motor carrier to make double turns with the same chassis, thereby reducing the number of chassis transactions and increasing utilization,
- by providing room in the market for other pool operators to underbid and gradually replace Maersk's chassis fleet, and
- by encouraging the use of motor carrier owned and provided chassis.

Appointment Systems. Appointment systems are largely confined to Southern California at present. They have a mixed record there, but hold the potential for wider application to other ports and operators, where they are of interest. Appointment systems have a two-fold purpose:

- to allow drayage firms to make efficient dispatching plans with reduced driver queue times; and
- to let marine terminals control workloads, thereby reducing drayage congestion and delay.

Several Southern California appointment systems were tried in response to threats of legislation over driver queue times. Some have fallen into disuse, but the remaining systems have been improved and refined. Drayage firms were particularly interested in appointment systems as ways of dealing with:

- morning queues waiting for gates to open; and
- Southern California queues waiting for the 6 PM PierPASS changeover.

Successful appointment systems can be regarded as candidates for best practices. Truckers noted, however, that appointment systems sometimes do not have enough slots to handle all the containers their customers want on the designated day. This observation is symptomatic of the problems posed by peaking. Motor carriers are also concerned that terminal and customer inefficiencies, as well as variable traffic conditions, may make narrow appointment windows impractical, particularly for short- or medium-haul motor carriers that make several trips to marine terminals daily.

Roadability Canopies. Well-organized, well-supplied, and well-manned "roadability canopies" at or near terminal export gates can quickly remedy minor chassis problems and are regarded as candidate for best practices. Formerly, it was typical for marine terminals to locate all repair functions in a distant corner, forcing drivers to bring problem chassis (or containers) to the repairmen and then back to the exit queue. The practice of locating a "roadability canopy" in line with or in parallel to the exit queue allows drivers to have minor chassis problems remedied with minimal delay. Well-run roadability operations can deal with typical problems such as broken light lenses, burnt-out bulbs, missing mud flaps, or low tire pressure in just a few minutes. The ability to have minor problems corrected quickly reduces the driver's need to search for a chassis in perfect working order or to incur a large delay for repair. It is also likely that quick attention to minor problems keeps the chassis fleet in better overall condition than having drivers reject imperfect chassis.

Driver Flexibility/Cutting Losses. Drivers with trouble tickets will typically "cut their losses" after 30 minutes and go on to another transaction rather than wait indefinitely to have a problem resolved. This finding is critical for the correct interpretation of "trouble ticket" data. The time required to resolve and close out a trouble ticket is often shared with other driver tasks. The driver has not always been fully delayed. Systems that facilitate the driver's ability to shift from one problem transaction to other successful ones can be regarded as a candidate for best practices. Barriers to switching, such as customer insistence that drivers wait for a problem container or long queues at trouble windows tend to exacerbate delays.

Problem-solving Groups. Regular problem-solving sessions involving marine terminal operators and drayage firms could make significant progress in dealing with avoidable delays and trouble tickets. The nature of the working relationship between the parties involved determines their ability to exchange information, find common ground, and implement solutions. Facilitating such problem-solving groups could be a useful role for port authorities, who do not directly participate in drayage operations but are held publicly responsible for congestion and emissions.

New Driver/Company Orientation. There is a need to help new drivers and firms learn the port, the terminals, and their systems. Some ports, notably Houston and Tacoma, have brochures aimed at orienting new truck drivers. Useful information would include maps and terminal diagrams, operating hours, information and documentation requirements, CBP and other regulations, and key contact information. Most marine terminals provide similar information on their websites, but new drivers or firms may not know where to look or what to look for. The universal use of cell phones by drayage drivers may allow the dissemination of such information via text messaging or other media.

Effective Two-Stage Gates. The ability to identify exceptions and turnaways early and segregate them from routine transactions is a key factor in reducing gate congestion and queue times. Two-stage gate systems in which the driver, tractor, and transaction are identified and screened at a first-stage pedestal allow marine terminal operators to turn away unprepared drivers or direct them to a separate "trouble window". The gate configuration must have enough distance between first and second stages to take the offending tractor and chassis out of line without further disrupting the queue.

RFID for Driver and Tractor. The consistent use of RFID systems to identify drivers and tractors can reduce transaction times and error rates at terminal gates. While it is conceivable that RFID tags could also be used to identify chassis, it is not practical to consider their use for containers due to the enormous size of the world fleet.

Gate Hours and Breaks. As expected, some of the longest gate queues form at the start of the day before the gates open, and during closures for coffee breaks, lunch breaks, and shift changes. Gate hours and break policies vary between ports, but those ports and terminals where labor agreements allow for complete gate closures for scheduled breaks and lunch could reduce average turn time, congestion, emissions, and drayage cost by negotiating staggered breaks or other means of achieving continuous and extended gate hours.

APM Portsmouth, VA. The most technically advanced gate observed by the study team was at APM Portsmouth, VA (Exhibit 73). The goal of the gate operation is to identify motor carriers with "clean" transactions early and process them quickly. There is an appointment system with a four hour window. Truckers tell the terminal when they are coming—mostly the day before. 70% of the trucks have appointments. Only 3% get trouble tickets. The average turn time is less than an hour.

Each truck coming to the terminal must be equipped with an RFID tag or it is not permitted to enter. The RFID readers are located on the Western Freeway interchange. As the trucks pass the reader, a computer is activated and the terminal prepares for the truck's arrival.

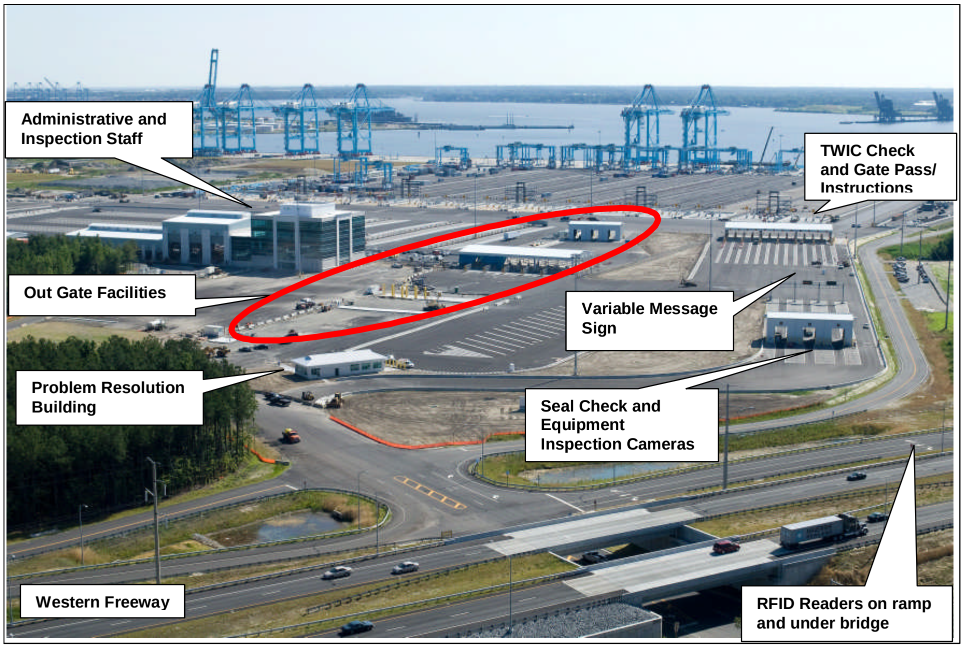
The first step in the process is a seal check, which is done for all trucks entering. This is done by a clerk in a pickup before arriving at the first building. The data go into a handheld, if necessary. The truck then proceeds to the first small building where a physical inspection is done by camera while the truck moves through. During the trucker's transition to the next station, an inspector located in the headquarters building reads the inspection photos. About a third of the way to the next building there is an overhead message sign which tells the trucker which of three sets of lanes he should go to. (One set of lanes is for trucks with no problems, another set is for trucks without appointments and those with trouble tickets, and another returns rejected trucks to the beginning.)

At the second building, the driver swipes his TWIC. If he has an appointment and all is in order, the driver receives his entry permit and instructions. If he has an empty, the driver must get out and open the back door for an inspection by camera. This is a 2 minute process, on average.

If the driver does not have an appointment, a more conventional process is conducted in the lower part of the second building. It takes 6 minutes, on average, a very typical process time. If there is any kind of trouble, the driver deals with the problem at the trouble building—a small building located between the in/out gates. The parking area is the most visible aspect of Exhibit 73. At times a queue develops between the first and second inbound buildings.

The process is repeated at the out gate with the radiation monitor being an additional step at the very end.

Exhibit 73: APM Portsmouth Gate

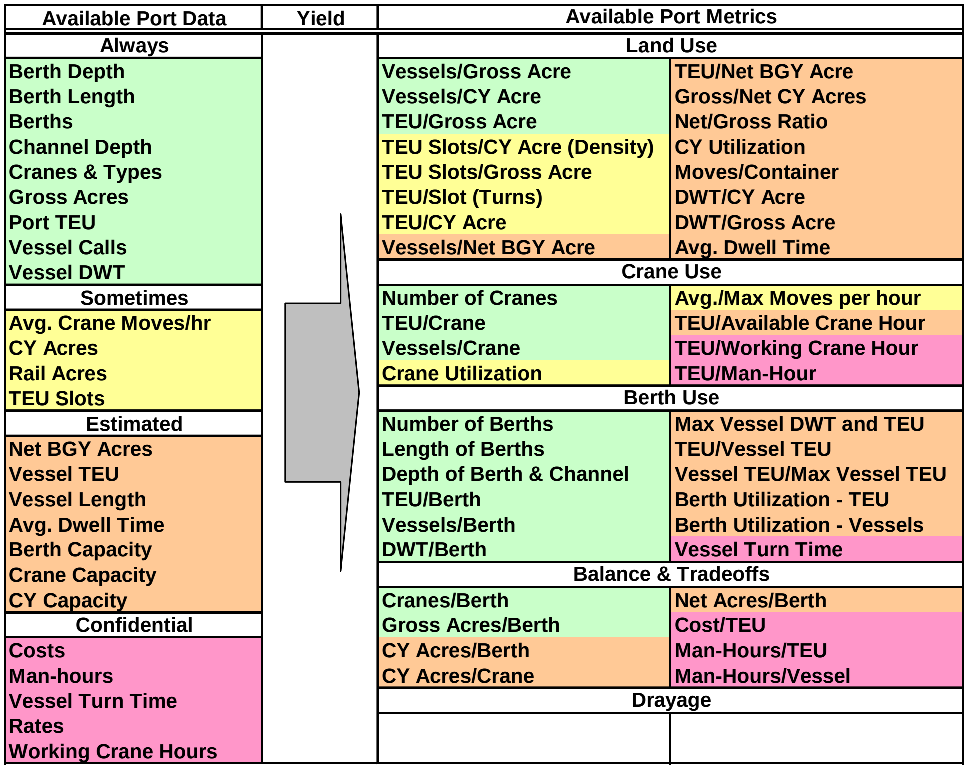


V. Proposed Data Collection Strategy

Data Requirements

Exhibit 74 summarizes port data items and their uses in port metrics. The entries are color-coded to show relative availability of data.

Exhibit 74: Data for Port Metrics



Available Port Data	Yield	Available Port Metrics	
Always		**Land Use**	
Berth Depth		Vessels/Gross Acre	TEU/Net BGY Acre
Berth Length		Vessels/CY Acre	Gross/Net CY Acres
Berths		TEU/Gross Acre	Net/Gross Ratio
Channel Depth		TEU Slots/CY Acre (Density)	CY Utilization
Cranes & Types		TEU Slots/Gross Acre	Moves/Container
Gross Acres		TEU/Slot (Turns)	DWT/CY Acre
Port TEU		TEU/CY Acre	DWT/Gross Acre
Vessel Calls		Vessels/Net BGY Acre	Avg. Dwell Time
Vessel DWT		**Crane Use**	
Sometimes		Number of Cranes	Avg./Max Moves per hour
Avg. Crane Moves/hr		TEU/Crane	TEU/Available Crane Hour
CY Acres		Vessels/Crane	TEU/Working Crane Hour
Rail Acres		Crane Utilization	TEU/Man-Hour
TEU Slots		**Berth Use**	
Estimated		Number of Berths	Max Vessel DWT and TEU
Net BGY Acres		Length of Berths	TEU/Vessel TEU
Vessel TEU		Depth of Berth & Channel	Vessel TEU/Max Vessel TEU
Vessel Length		TEU/Berth	Berth Utilization - TEU
Avg. Dwell Time		Vessels/Berth	Berth Utilization - Vessels
Berth Capacity		DWT/Berth	Vessel Turn Time
Crane Capacity		**Balance & Tradeoffs**	
CY Capacity		Cranes/Berth	Net Acres/Berth
Confidential		Gross Acres/Berth	Cost/TEU
Costs		CY Acres/Berth	Man-Hours/TEU
Man-hours		CY Acres/Crane	Man-Hours/Vessel
Vessel Turn Time		**Drayage**	
Rates			
Working Crane Hours			

Data elements and metrics backed in light green are always publicly available (with rare exceptions), and can be used to develop and maintain several of the most useful metrics. There are issues of consistency and currency. Different sources can show different figures and it is not always clear which is more accurate or up to date.

Data elements and metrics backed in yellow are sometimes but not always available from public sources. Physical measures – CY acres, rail acres, TEU slots – are not particularly confidential in most cases. The fact that some ports and terminals publish those figures reinforces that conclusion. Here too there can be issues of consistency and currency.

Data on average moves per crane hour are sometimes published, but may be regarded as confidential elsewhere and of limited value. As noted in the literature, variations in moves per total hour, moves per available hour, moves per shift hour, and moves per working hour all have different implications. There are also questions about the definition of "moves" and treatment of repositioning, re-stowage, and hatch cover handling. Crane productivity measures in moves per hour is a selling point for ports with high-speed cranes or particularly productive labor, and those ports would be very sensitive to the basis of comparison. The primary audience for crane productivity data would be the steamship lines. Their ultimate concern, however, is the ability of the terminals to turn vessels on time, and crane productivity is only one factor.

Data elements in tan cells in Exhibit 74 were estimated for this study. Some information, such as vessel length and draft data, is potentially available through marine exchanges or other agencies that track vessel activity. Considerable work and expense would be required to obtain, analyze, and compile data from roughly twenty marine exchanges. Marine exchanges normally charge for their data, either as a one-time report or via subscription.

Average dwell time can be derived from proprietary marine terminal information system data, but would be confidential. Average dwell time, moreover, is of limited applicability to terminal productivity since the dwell times are a function of customer and carrier interactions. Following the 2004 peak season congestion, the Southern California terminal operators reduced the standard free time allowance in a successful effort to reduce dwell times, especially on imports. Other terminals limit the time an export load can be delivered in advance of vessel arrival to avoid long export dwell times. Empty containers, in contrast, may be stored on-terminal for months if space is available.

Capacity figures must be estimated and, as noted in the introduction, there are no industry-wide standards or formulas. Different parties will use different assumptions and methodologies to derive different capacity estimates. Ports and terminal operators that do publish capacity figures typically round them off, sometimes to the nearest million TEU.

Data relating to labor, operating costs, and negotiated rates are confidential and will remain so, as they are proprietary for most businesses.

Note that the data elements described above can be used to develop a number of additional metrics besides the core list specified above.

Many data elements are, as noted above, always available. The essential data need is for uniform availability of “sometimes” data elements via website, association, or directory. Some essential data are:

- Terminal CY Acres
- Terminal rail acres
- Terminal TEU slots

Common definitions and conventions would be essential.

Key Barriers to Data Collection

The key data barriers to uniform availability of “sometimes” data elements arise from the nature of the business and its participants.

Marine terminal operators are private, unregulated businesses that consider cost and productivity data confidential. Ports, which are public entities, do not have access to terminal cost and productivity data.

There are valid objections to comparisons via many of the possible metrics. Terminals and ports naturally want to be publicly compared only on metrics where they look good.

Both ports and marine terminal operators compete on cost, and do not want their costs accessible to either competitors or customers. Negotiated charges to ocean carriers are confidential and sensitive. Labor man-hours and costs are doubly sensitive.

Data Collection and Publication Options

There are two basic ways in which data might be collected, analyzed, and published.

- Neutral third party, government agency, or trade association collection and publishing of confidential data elements
    - Ports and/or terminals would provide data to a neutral third party or trade association.
    - A third party or association would publish compilations without revealing specific terminal data.
- Confidential benchmarking in exchange for data
    - Ports and or terminals would provide data in exchange for a benchmarking report comparing their performance with aggregates.
    - Only port-wide and aggregate data would be published.

Initial contacts with ports and terminal operators suggest that the second choice is of marginal interest at present. Because of the data barriers discussed above, and because potential users have not had experience with benchmarking data, ports and terminal operators do not at present see enough value to justify internal efforts at comparison. This attitude could change once valid, consistent comparison data become available.

For the present, the first option appears the more viable.

Candidate Organizations

A data collection and publication effort needs a home. The data collection organization needs to be perceived as objective, needs to have data collection and analysis credibility, and needs to have subject expertise. The organizations discussed below were considered to be logical candidates, although the list may not be exhaustive.

Bureau of Transportation Statistics

The Bureau of Transportation Statistics (BTS) is part of the Research and Innovative Technology Administration (RITA) in the U.S. Department of Transportation. BTS was originally established under ISTEA in 1991, and is currently authorized under SAFETEA-LU (at least through 2009). BTS's charge is to administer data collection, analysis, reporting, and publication across transportation modes. BTS is, in effect, DOT's central data warehouse. Among its many publications, BTS produces *Maritime Trade & Transportation*, *U.S. International Trade and Freight Transportation Trends*, and *America's Container Ports*.

BTS also sponsors the Maritime Data Working Group. Its members include:

- Bureau of Transportation Statistics
- Committee on the Marine Transportation System
- Federal Maritime Commission
- Maritime Administration
- St. Lawrence Seaway Development Corporation
- Transportation Security Administration
- U.S. Army Corps of Engineers
- U.S. Coast Guard
- U.S. Department of Agriculture

The Maritime Data Working Group would be a logical sponsor for initiating data collection, computation, and publication within BTS. The group's mission includes identifying data gaps, making relevant data accessible and promoting standardization and data quality.

BTS would provide the requisite data expertise, stability, objectiveness, and access/publication capabilities. BTS maintains a well-organized, regional system for users to locate and order publications or data on CD as well as downloading data from *www.BTS.gov*.

The potential downsides of BTS jurisdiction could include timeliness and industry cooperation. While BTS has annual publications, they are sometimes not updated as quickly as industry sources. Several current BTS publications, for instance, actually contain data only through 2007. Most BTS data compilations are based on information reported through regulatory processes, Customs oversight, etc., as opposed to voluntary compliance.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) is responsible for development and operations of the nation's waterway system, including seaports. The responsibility includes collecting and maintaining data. The USACE organization for data collection and publication is the Navigation Data Center (NDC) of the Institute for Water Resources, (IWR) in Alexandria, VA. The actual data collection and database maintenance are done by NDC's Waterborne Commerce Statistics Center in New Orleans (WCSC).

The strong point of the WCSC program is data on inland waterways and their operations. The major WCSC databases include:

- Waterborne Commerce of the United States
- State Tonnage Reports
- Waterborne Transportation Lines of the United States (inland and coastal vessel operators)
- Port Series Reports

The Waterborne Commerce data base is updated annually; the current data are from 2008. The Port Series Reports, however, are only updated at intervals of up to 10 years. The available data were reviewed for this study and much of the information was several years old. These reports must cover roughly 10,000 U.S. port facilities, and IWR/NDC does not have the resources to continually update the data.

IWR has recognized the need for more current data, particularly on container ports whose facilities often evolve faster, and whose trade base has grown faster than bulk ports and terminals. IWR commissioned the container port capacity analysis that parallels this productivity study, and is sharing the port and terminal facility data generated. The Port Series Reports are compiled from a series of site visits, which is why they are costly and time-consuming to update. It is conceivable that IWR/NDC could update a container port database covering about 100 terminals, rather than 10,000, on an annual basis working primarily from website data, publications, and phone contacts.

Port cooperation may be a potential problem. USACE is responsible for dredging at the ports, and is under continual pressure from those ports. Issues such as draft, vessel size, vessel utilization, etc., can be highly politicized and subject to competing interpretations affecting dredging projects. A port's productivity data collection effort could thus be hampered by its association with dredging programs.

If, however, IWR were to choose to update the port capacity database on a regular basis, the database would support many of the recommended productivity metrics.

National Ports and Waterways Institute

The National Ports and Waterways Institute (NPWI) is a research arm of the University of New Orleans. NPWI's focus is on research, strategic planning, economics, and regional development. Research and publications tend to be issue-related, as opposed to annual reports. NWPI was transferred from its original home at Louisiana State University (where it was a cooperative venture with George Washington University). It retains links to LSU and offices in the Washington, D.C. area.

NWPI researchers may thus be clients or users of port productivity metrics rather than producers.

U.S. Maritime Administration

The U.S. Maritime Administration (MARAD) is the DOT agency dealing with waterborne transportation. Its vision is to promote development and maintenance of a vital U.S. merchant marine transportation system. Container ports are part of that broader responsibility. MARAD provides expertise on port financing, infrastructure, and defense deployment readiness. MARAD's Office of Port Infrastructure Development and Congestion Mitigation (Office) coordinates port studies and surveys. The Office, however, does not have an up-to-date database of terminal information and routine data collection is not within the Office's charter. The Office is a participant in CHCP, and a major source of motivation and support for this project.

MARAD cooperates with the American Association of Port Authorities (AAPA) to produce two annual reports (*Public Port Finance Survey* and *U.S. Public Port Development Expenditure Report*) and others as needed. These two reports use industry data collected by AAPA and MARAD's analytic and publication resources, and present a useful precedent for an annual port productivity report.

American Association of Port Authorities

The American Association of Port Authorities (AAPA) is the industry association for ports throughout the Americas. About 160 port authorities are members. AAPA is the leading source for container port statistics and offers website access to its databases. Additional data are accessible through direct contact.

AAPA publishes *Seaports of the Americas*, a comprehensive directory of ports and terminal operators produced annually. Seaports of the Americas presents data on ports and terminals submitted by port authorities. The data are not consistent in content, format, definition, or timeliness as AAPA is dependent on its members' voluntary submissions.

AAPA has four strong recommendations for ongoing development and support of port productivity metrics.

- As the industry's trade association, AAPA is viewed as a port ally rather than a potential regulator. AAPA may therefore be more likely to gain port cooperation.
- AAPA has a regular annual process of consultation with port authorities to obtain information for *Seaports of the Americas*.
- AAPA data collection and publication efforts are not subject to Congressional authorization or appropriation.
- AAPA already collects information and collaborates with MARAD on the two annual reports described above.

AAPA itself has a relatively small staff and no budget or other resources to collect and compile port productivity data. The Port Finance and Infrastructure Development reports are supported by MARAD, and a similar arrangement could be developed for a productivity report.

AAPA has on-line profiles of ports in the U.S., Canada, Mexico, Central America, and South America. With MARAD support and AAPA member agreement, one publication option would be to add a standardized table or graphic to these on-line profiles.

Initial contact with AAPA suggests that the organization may be amenable to collecting and compiling container port productivity data with MARAD's financial or in-kind support.

Recommended Strategy

The most promising strategy for on-going collection, compilation, and publication of container port productivity data would involve three organizations.

- **AAPA.** The AAPA would collect a standardized set of data elements from its members and publish an annual report. The annual report could be a section of Seaports of the Americas and/or available on-line.
- **MARAD.** MARAD would provide financial or in-kind support and technical assistance, and be the U.S. DOT "customer" for productivity data.
- **USACE IWR/NDC.** The U.S. Army Corps of Engineers would share the cost with MARAD and be the federal "customer" for port capacity and infrastructure information supported by the same port data.

This approach would offer the distinct advantage of having the leading industry association and the two leading federal organizations working from the same data and definitions while sharing the cost. The resulting data compilations could be made available through AAPA, MARAD, USACE, or BTS as required.

Experience in other data collection efforts suggests that an annual update request may be more effective than asking for complete data sets every year. In this approach:

- AAPA would either collect the initial data or use the data from this study as a starting point.
- Each port authority would designate an AAPA contact.
- Each year, the AAPA would send each port a form or electronic file showing the most recent data on record and ask the Port Authority for updates and corrections. Responding to these data-update requests could be combined with existing TEU data submissions to the AAPA.

Appendix A: Literature Review

Productivity Measurement

Surveys of port characteristics, productivity, and competitiveness are useful chiefly for their insights into the basis of comparison and their methodologies. The specific port, terminal, and production data quickly become outdated. Several surveys stress the importance of comparability and uniform data comparisons.

The 2009 BTS report, *America's Container Ports* (U.S. DOT, 2009), is primarily concerned with the 2008 recession-induced decline in container traffic and its implications. The report provides a comparison of vessel calls and average vessel sizes (in deadweight tons) at U.S. container ports. On the west coast averages range from 53,562 at Tacoma to 59,287 at Seattle. East Coast ports typically see smaller vessels, with averages ranging from 41,671 at Baltimore to 53,698 at Wilmington, NC.

A parallel initiative on port productivity measures and benchmarking is currently being undertaken by Transport Canada, *Developing Utilization Indicators for Canadian Ports* (Olivier, 2009). The effort is seen as part of an overall inquiry into the reliability and competitiveness of Canadian supply chains. Transport Canada (TC) has identified eight port utilization indicators (PUIs), an example of which is shown in Exhibit 75. TC has secured the cooperation of the four major Canadian container port authorities and is working toward roll-out of the PUIs.

Exhibit 75: Port Utilization Indicators - Canadian Ports

Measure	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09
Gate Fluidity - Minutes	n/a	n/a	12.8	13.8	13.5	12.4	12.2	17
Avg. Truck Turnaround Time - Minutes	n/a	21.9	22.1	22.3	20.4	21.0	20.1	19.4
Berth Utilization - TEU/Meter	60.0	56.6	63.9	67.4	70.5	70.5	71.2	73.0
Vessel Turnaround Time - Seconds/TEU	51	46	45	42	40	41	36	34
Vessel Dwell in Port Waters - Hours/Vessel Call	n/a	31.7	33.2	30.0	30.9	33.4	31.6	31.5
Avg. Container Dwell - Days	3.2	2.7	2.3	3.0	1.8	2.5	2.8	2.0
Port Productivity - TEU/ha	1,286	1,119	1,386	1,375	1,470	1,396	1,465	1,487
Crane Productivity - TEU/STS crane	8,046	7,018	8,676	8,642	9,250	8,796	9,298	9,510
Container Throughput - TEU	179,742	158,305	194,455	195,935	210,095	200,331	213,455	218,717

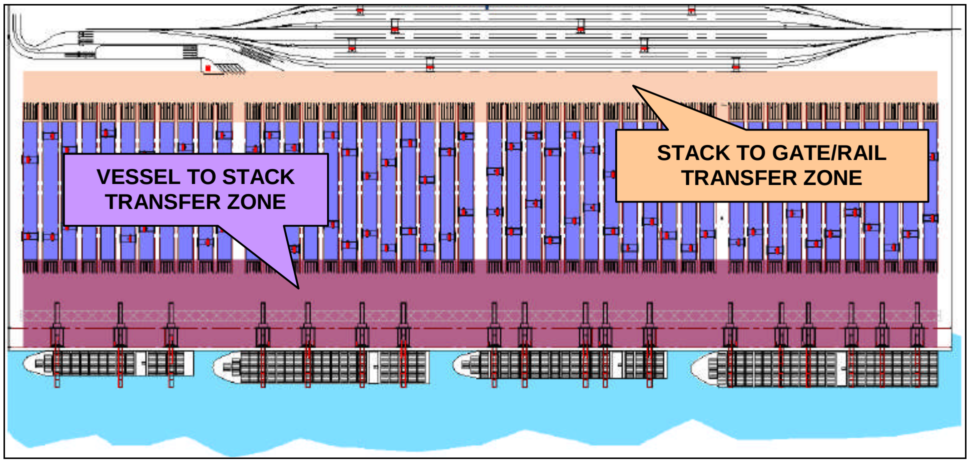
Source: Olivier (2009)

Fourgeaud, *Measuring Port Performance* (2009), notes that, in addition to technical performance, shippers and ship owners are looking for:

- reliability,
- competitive and predictable cost,
- cargo handling quality, and
- adaptability and responsiveness.

Nye, *Advanced Technology in Terminal Design* (2009), defines "efficiency" as encompassing capacity (TEU per hectare, annual TEU), productivity (containers per hour, man-hours per move), and terminal cost (land, infrastructure, equipment, systems, and labor). Nye notes that automation is not a goal in itself, but a means of striking the best balance between capacity, productivity, and cost (effectively an optimization goal). Nye cites the "end-loaded" terminal design, as implemented at APM Norfolk and proposed for Ports America at Oakland, as particularly effective at separating vessel and gate traffic and facilitating automation (Exhibit 76).

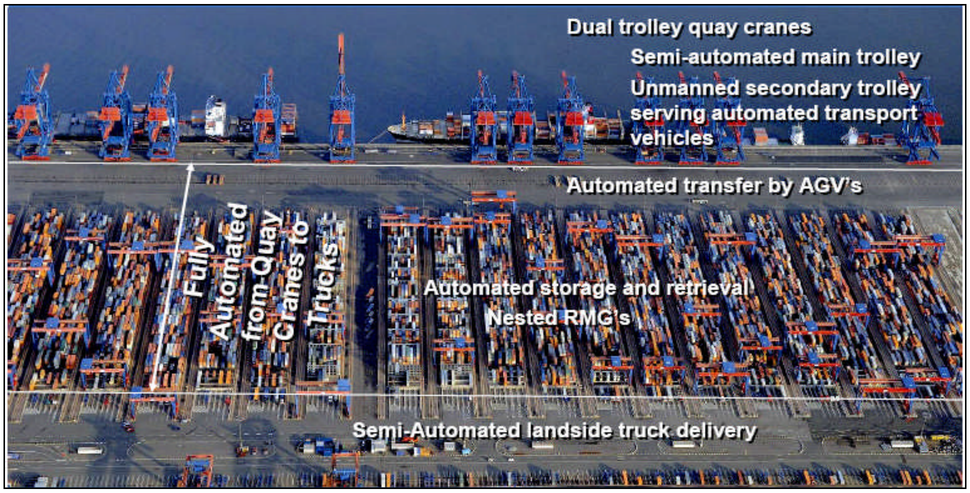
Exhibit 76: End-loaded Container Terminal Design



Source: Nye (2009)

The CT-A terminal at Hamburg is cited as a "state of the art automated terminal" (Exhibit 77).

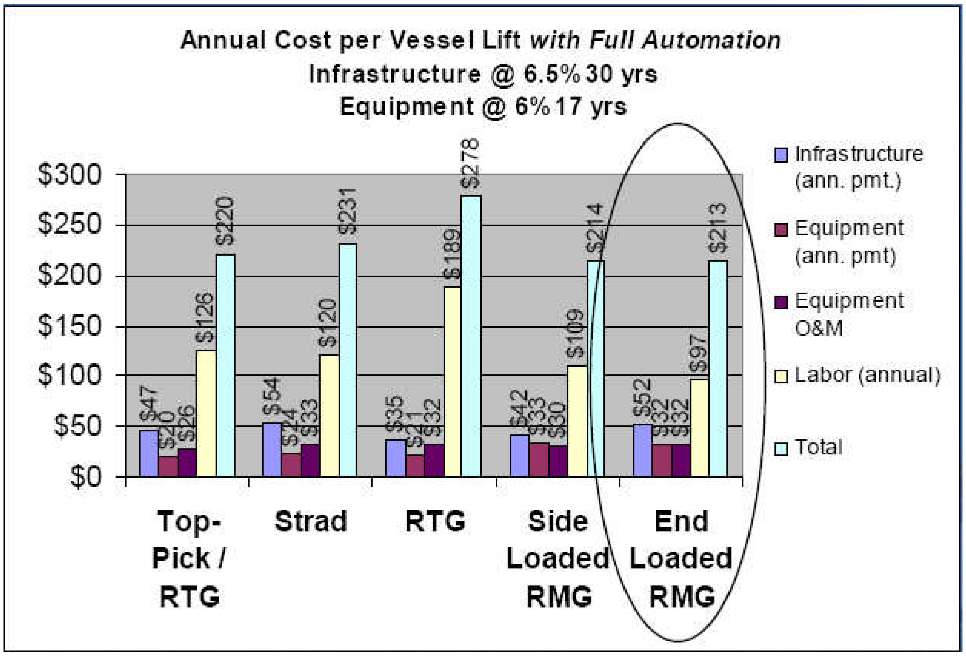
Exhibit 77: State of the Art Terminal – CT-A Hamburg



Source: Nye (2009)

Nye also provides a case study comparison of cost per vessel lift with various CY technologies (Exhibit 78).

Exhibit 78: Terminal Operating Method Comparison

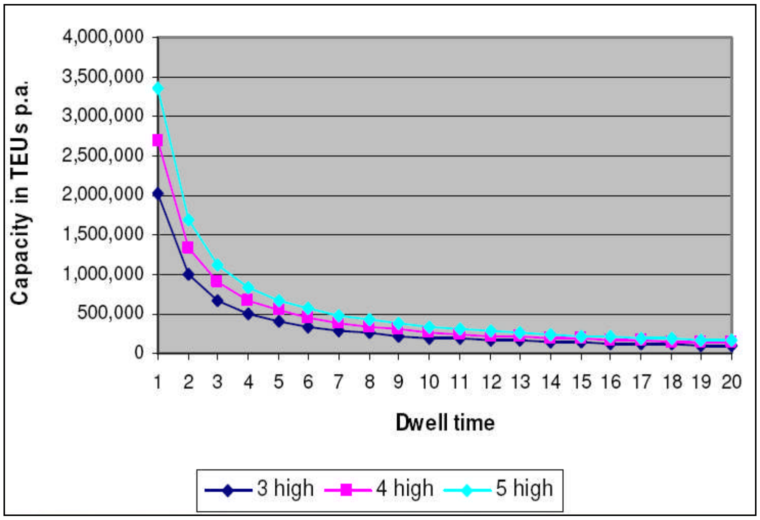


Source: Nye (2009)

Nye concluded that in the case study the top pick/RTG and straddle carrier systems did not provide sufficient capacity, and that the RTG and side-loaded RMG did not provide adequate vessel productivity due to conflicts with gate traffic. Only the fully-automated, end-loaded RMG option could meet cost, capacity, and vessel turn-time criteria. Nye's work also compared dual trolley and tandem lift crane productivity.

Rugaihuruza, *Infrastructure, Operational Efficiency and Port Productivity Management in PMAESA Region* (2007), asserts that dwell time is the most important factor influencing terminal capacity. Exhibit 79 shows the relationship for a terminal with a fixed number of storage slots, 2,990 in this example.

Exhibit 79: Terminal Capacity versus Container Dwell Time



Source: Rugaihuruza (2007)

Rugaihuruza proposes that port performance be measured in four areas:

- Service, where the key factors are vessel turn time and container dwell time
- Output, measured by container throughput in TEU
- Utilization, including berth occupancy, equipment utilization, and gate utilization
- Productivity, in terms of efficiency and cost-effectiveness, measured by (for example) cost per ton, labor cost per ton, crane moves per hour, containers per man-hour

A white paper prepared for the Maine DOT, *Container Terminal Parameters* (Cornell Group, Inc. 2007), describes marine container terminal requirements on a conceptual level, also providing a comparison of acres per berth (Exhibit 80). The comparison shows that California terminals average only 40 acres per berth *versus* higher averages on the other coasts and in the Pacific Northwest.

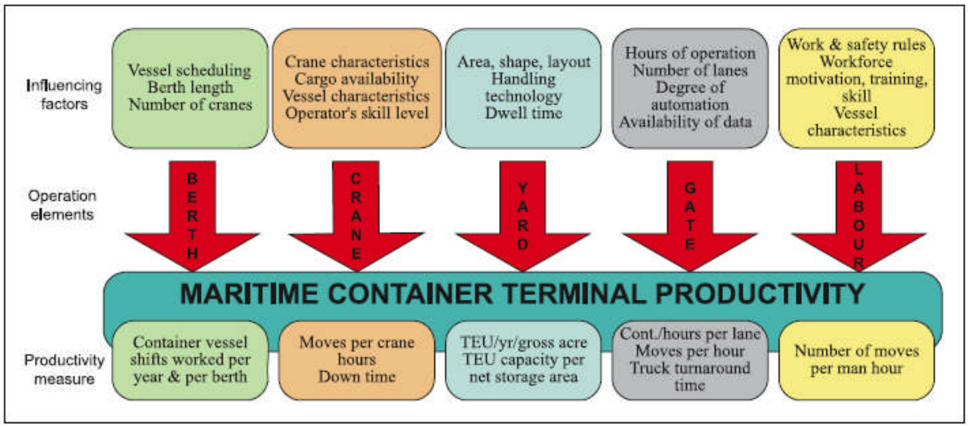
Exhibit 80: Survey of U.S. and Asian Terminals

PORT	BERTHS	ACRES	ACRES/BERTH
U.S. North Atlantic	4	178	44.50
U.S. Mid-Atlantic	3	219	73.00
U.S. South Atlantic	4	193	48.25
U.S. Gulf	7	378	54.00
U.S. West Coast	80	3200	40.00
U.S. PNW #1	2	135	67.50
U.S. PNW #2	3	220	73.33
East Asian Greenfield	9	640	71.11
Median Acres/Berth			**60.75**

Source: Cornell Group, Inc. (2007)

Beŝkovnik, *Measuring and Increasing the Productivity Model on Maritime Container Terminals* (2008), defines efficiency in terms of velocity, "a quick transshipment of containers to and from ships and the dispatch of containers by trains or truck." Beŝkovnik views the terminal as a combination of five subsystems: berth, crane, yard, gate, and labor. The diagram in Exhibit 81 shows the factors underlying efficiency in each subsystem and the associated productivity measure.

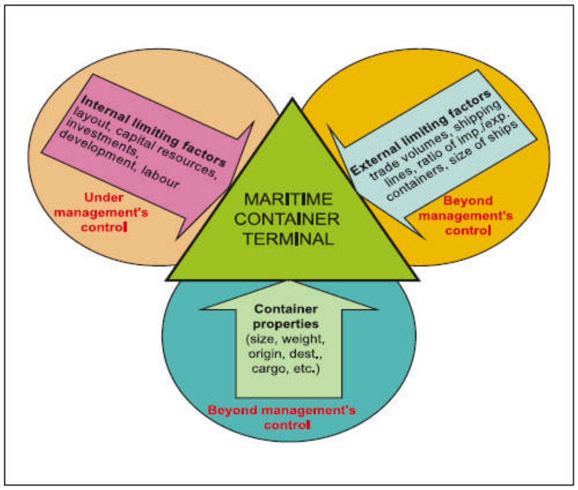
Exhibit 81: Marine Terminal Productivity Concepts



Source: Beŝkovnik (2008)

Beŝkovnik makes a useful distinction between factors under management's control and other important factors beyond management's control, as indicated in Exhibit 82.

Exhibit 82: Control Factors in Marine Terminal Productivity



Source: Beŝkovnik (2008)

Beŝkovnik also notes that ocean carriers use different measures of terminal competitiveness but most frequently compare berth productivity, vessel dwell time, and the waiting time for a free berth (expected to be zero in U.S. ports).

A review of expansion plans at Pacific Coast ports, *Container Capacity Expansion Plans at Pacific Coast Ports* (Hanam Canada Corp., 2007), provides a number of 2006 productivity comparisons (Exhibit 83), and estimates the "useful excess capacity."

Exhibit 83: Port Productivity Comparisons - 2006

Port	Annual TEU per Terminal	Annual TEU per Berth	Annual TEU per Crane	Annual TEU per Acre	Hours per Year	Lifts per Hour	Useful Excess Capacity
Deltaport	1,078,000	539,000	180,000	6,883	3,188	24	0.2
Los Angeles	1,169,000	273,000	106,000	4,858	6,096	23	0.8
Long Beach	896,000	184,000	80,000	4,858	6,096	25	1.2
Balboa	500,000	250,000	167,000	23,887	8,760		0.2
Manzanillo	450,000	225,000	113,000	15,385	8,592		0.4
Seattle	556,000	185,000	72,000	3,644	2,146	22	0.2
Vancouver	504,000	252,000	92,000	6,883	3,188	19	0.4
Lazaro	375,000	375,000	188,000	10,121	8,760		0.1
Oakland	347,000	128,000	76,000	3,644	2,322	23	1.0
Tacoma	310,000	172,000	65,000	2,834	2,045	25	1.5
Surrey	200,000	100,000	50,000	2,834	2,250		0
Portland	196,000	65,000	28,000	1,619	2,146		0
Ensenada	109,000	109,000	27,000	3,239	8,760		0
Average	**657,000**	**276,000**	**121,000**	**4,858**			

Source: Hanam Canada Corp. (2007), hectares converted to acres

The report also discusses the emphasis that shipping lines place on lifts per crane hour, noting that Deltaport and Los Angeles managed about 24 lifts per crane hour compared to 19 at Vancouver and 35 at Japanese ports. The report compares storage capacity separately (Exhibit 84).

Exhibit 84: Container Storage Capacity - 2006

Terminal	Acres	Storage Grounded TEU	Storage Total TEU	TEU/Acre
Cal United, Long Beach	15	14,400	43,200	2,808
Seaside, Oakland	9	5,898	17,694	1,900
Hutchison, Ensenada, Mexico	5		6,500	1,235
Pacific Container, Long Beach	41	15,317	45,951	1,113
SSAT, Long Beach (Matson)	11	4,000	12,000	1,059
Canterm, Vancouver	12		12,000	1,022
TSI, Delta	26		24,000	926
SSAT Long Beach	28		24,000	872
APM Terminals, Tacoma	22	4,700	14,100	645
Terminal 6, Portland	32		7,700	238

Source: Hanam Canada Corp. (2007), hectares converted to acres

This is one of very few studies to report cost information (Exhibit 85). The analysis shows the average port cost per FEU at $358 in California, $345 in Washington State, $289 at Vancouver, $246 at Deltaport, and $194 at Prince Rupert.

Exhibit 85: Container Shipping Costs, $/FEU

Item	Metric	Mexico	California	Washington	Deltaport	Vancouver	Prince Rupert
Throughput	Million TEU/y	0.8	17.8	3.3	1.2	1.0	0
Ship size basis	1000 TEU	5.5	9.4	4.4	6.0	3.5	6.0
Shipping Rate	$/FEU	1,986	1,593	1,663	1,599	1,746	1,455
Port Costs	$/FEU	113	358	345	246	289	194
Local trucking	$/FEU	189	163	200	200	150	0
Local total		**2,288**	**2,114**	**2,208**	**2,045**	**2,185**	**1,649**
Rail, storage, & trucking	$/FEU	2,110	1,945	1,907	1,770	1,935	2,181
Chicago total	**$/FEU**	**4,209**	**3,895**	**3,916**	**3,615**	**3,970**	**3,831**
Cost above base	$/FEU	594	280	301	Base	355	216
Totonto total	**$/FEU**	**4,639**	**4,230**	**4,346**	**3,575**	**3,930**	**3,791**
Cost above base	$/FEU	1,064	655	771	Base	355	216

Source: Hanam Canada Corp. (2007)

A second report for Transport Canada, *Pacific Coast Container Terminal Competitiveness Study* (Hanam, 2008), compares the competitiveness of Pacific Coast container ports. That study compares U.S. and Canadian ports based on cost, productivity, and service. The study concluded that Canadian ports have a cost advantage in wharfage costs, rail costs, and land costs. U.S. ports have lower container supply, storage, and transloading costs and faster truck turn times. Crane productivity was found to be about equal at 24 lifts per hour.

A 2006 report for the U.S. Army Corps of Engineers, *New Measures of Port Efficiency Using International Trade Data* (NETS, 2006), proposed a method for measuring overall port efficiency using trade data. That approach uses port charges, derived from trade sources, and performs a regression analysis on factors such as distance, weight, and trade balance. The result is an index of cost efficiency, but it is not directly related to terminal design or operating factors under management control. This approach could best be employed in high-level benchmarking, which would then be followed by more detailed analysis of terminal operating variables.

Le-Griffin and Murphy, *Container Terminal Productivity: Experiences at the Ports of Los Angeles and Long Beach* (2006), note the problem in comparing terminals with and without large transshipment volumes. Since transshipments generate two ship moves for a single CY transaction, terminals with large volumes of transshipments show an inflated TEU count. Despite noting this comparability problem, the authors do not attempt to correct the problem in their comparisons. As they state, TEU/acre data “are of limited value in making straight comparisons of productivity.” There is also some confusion in the survey between container moves per hour and cranes per vessel, and between annual throughput and moves per crane. Their survey makes two particularly useful observations:

- Labor union safety requirements specify a minimum distance between working cranes, limiting the number of cranes that can be used for each vessel. (Verify)
- In wheeled terminals, a 20’ container on chassis takes up the same space and time as a 40’ container on chassis, but counts as 1 TEU rather than 2 TEU.

Jeon and Park, *Status and Visions of Automated Container Terminals* (2005), focus their more specific view of automation on unmanned container transport between the container yard and quayside, also citing CT-A at Hamburg as an example.

Choi, *Analysis of Combined Productivity of Equipments in Container Terminal* (2005), proposed an approach to combined productivity optimization that focuses on mean equipment waiting times. In a case study, this approach was used to isolate a bottleneck between the transfer cranes and yard tractors.

The draft executive summary *Study on Hong Kong Port–Master Plan 2020* (HK Economic Development and Labor Bureau, 2005) cites the increasing role of customers (shippers and consignees) in choosing ports. From the customer perspective the report says that the key factors are reliability and total transport costs. From a shipping line perspective the report cites vessel turn times, box exchange (lifts), and cost (container handling charges) as key factors.

Isbell's presentation, *Satisfying the Needs of the Port's Clients* (2005), takes the customer's perspective. It lists among the keys to a successful inbound delivery process:

- "Achieving agreed to delivery times"
- "Visibility to service failures or delays."
- "Efficient and secure cargo handoffs"

These criteria emphasize reliability, and may reflect the timing of the presentation, early 2005, right after the 2004 peak season congestion in Southern California.

One of the most thorough discussions of productivity metrics is the Australian Study *International Benchmarking of Container Stevedoring* (Australia Productivity Commission, 2003). This study contains a detailed discussion of net *versus* gross crane rates (lifts per hour). The report notes that the definition of delays and non-working time (which constitute the difference between gross and net crane hours) differs from port to port. This difference may make lifts per gross crane hour more reliable, although a less precise basis of comparison than lifts per net crane hour.

The JWD white paper for the Port of Houston, *U.S. Container Terminal Throughput Density* (JWD, 2003), provides a clear illustration of terminal operator preferences. Faced with growing volumes, the APM terminal at Houston endeavored to expand its land area and limit its throughput to around 4,000 annual TEU/acre. The JWD report makes the critical observation that the cost of land (as reflected in past lease rates) increases more slowly than the cost of density (as reflected in labor and equipment costs). Terminal operators are thus rational in expanding horizontally and maintaining lower densities as long as possible.

The Australian study, in common with the JWD white paper for Houston, makes the point that the complexity of vessel deployments and the average number of containers unloaded at destination ports affects the complexity of the vessel storage task and the relative productivity of the terminal loading outbound containers.

Ward, *Practical Port Productivity Measurement* (2000), lays out some of the critical challenges in measuring productivity:

- Productivity is usually expressed as units handled per unit of time or terminal resource.

- Measurement units are not rigorously or consistently defined.
- Performance metrics do not match business needs.
- Different parties have different needs.

As an example, Ward notes that handling a given vessel could require 24 ship hours, 21 berth hours, 28 gang hours, or 19.5 crane hours. Depending on how over stowed and transshipped boxes are counted, the same vessel call can generate four different lift counts. The lift per hour metric for the same vessel call could vary from 14.3 to 23.9, depending on definitions and perspective. Ward goes on to carefully define a series of variables and inputs to productivity metrics.

Vandeveer, *Port Productivity Standards for Long-term Planning* (1998), in an oft-cited early paper, lists four basic measurement concepts:

- Throughput per terminal area
- Key equipment utilization rates
- Berth utilization
- Vessel loading/unloading rates

Vandeveer argues that throughput per terminal area provides "order of magnitude benchmarks" and is the most appropriate for land-use planning.

Ashar, *Port Productivity Revisited* (1997), makes a case for "all-in" port cost per move as a more relevant measure than moves per hour when it comes to competition between ports. Ashar suggests a "productivity-adjusted" price as a more meaningful market pricing system. The idea is that a cost per hour should be limited to moves per hour to account for the non-cash cost of vessel time.

In an earlier paper, *Productivity and Capacity of Container Terminals* (1985), Ashar observed that the new terminals being built at the time were larger versions of older terminals without innovations designed to increase productivity. This is a critical point: terminals are built *out* rather than *up* to keep costs low as long as land is readily available. Ashar proposed a terminal area survey to establish land use within the terminal and a terminal productivity profile using the following indicators:

- TEU per gross terminal acre
- TEU per CY acre
- vessel shifts per berth
- moves per crane
- moves per crane-hour

These five measures illustrate an important distinction between the productivity of resources when employed (e.g., container moves per crane hour) and the overall utilization of terminal resources (e.g., annual container moves per crane). This is essentially the task being undertaken in the present study, 25 years later.

Chung, *Port Performance Indicators* (1993), provides a discussion of port indicators applicable to other types of ports, as well as container ports. Those applicable to container ports include:

- Average vessel turn time
- TEU per crane hour
- Cargo dwell time
- Berth occupancy rate (%)

De Monie, *Measuring and Evaluating Port Performance and Productivity* (1987), argues that port productivity should be measured with respect to:

- duration of a ship's stay in port
- quality of cargo-handling
- quality of service to inland transport vehicles.

De Monie breaks down vessel time in port into several components, of which total time at berth and operational (working) time at berth are the most relevant for terminal productivity.

The National Research Council report *Improving Productivity in U.S. Marine Container Terminals* (Committee on Productivity of Marine Terminals, 1986) cites a perceived productivity shortfall at U.S. terminals when compared to foreign terminals. Several contributing factors are:

- labor-management relations
- improved information systems
- automated container identification

At the time of the report (1986) about 46% of the terminals used a grounded system and 54% used a stacking system. The report found "no clear indication" of which was the most productive but noted the superiority of the chassis system in terms of customer service and satisfaction. The report found that the choice of system was influenced by the availability of land. The chief basis of comparison between U.S. and foreign terminals was not throughput per acre but utilization–throughput as a percentage of capacity. The report concluded that the reserve capacity of U.S. terminals obviated the need for expansion in most cases. The report also found low relative utilization of crane lift capacity (e.g., 20 lifts per hour *versus* 30-35 lifts per hour in Asia or Europe). The report, most significantly, provided a profile of terminal productivity measures (Exhibit 86), and made a strong case for standardizing, collecting, and publishing such measures as a management tool and a spur to improved productivity.

Exhibit 86: Terminal Productivity Measures

Element of Terminal	Measure of Productivity	
Crane	Net crane productivity:	moves/(gross gang hours - downtime)
	Gross crane productivity:	moves/(gross gang hours)
Berth	Net berth utilization:	annual container vessel shifts/container berths
Yard	Yard throughput:	annual TEU/gross acres
	Yard storage productivity:	TEU capacity/net storage acre
Gate	Net gate throughput:	containers per hour/lanes
	Gross gate throughput:	equipment moves per hour/lanes
	Truck turnaround time:	total truck time in terminal/number of trucks
Gang	Gross labor productivity:	number of moves/man-hours

Source: Committee on Productivity of Marine Terminals (1986)

An early Australian survey of port productivity over time, *Container Terminal Productivity in Port Jackson from 1977 to 1981* (Bureau of Transport Economics, 1984), emphasized vessel time in port, noting that differences in vessel sizes and types affected terminal performance. The study compared two terminals at Port Jackson, and took the unusual step of breaking down vessel time into time waiting to berth, time at berth, time working the vessel, and time lost to delays for various reasons. Notably, vessel time at berth was longer at the terminal serving larger vessels because handling rates were about the same. Although the study itself is dated, the conceptual division of vessel time into functional components is still valuable and applicable.

Capacity and Throughput Studies

Among the most useful sources in the literature are those that analyze the underlying factors in container terminal capacity and throughput.

Parsons Brinkerhoff, Strategic Advisory Report: *Napoleon Avenue Container Terminal Development Utilizing Public-Private Partnerships* (2009), estimated the capacity of a proposed new terminal at the Port of New Orleans on three levels:

- **Ultimate Theoretical Capacity** (UTC). Considered to be the highest theoretical level of a terminal's ability to handle cargo demand. This ultimate capacity value is only constrained by the terminal infrastructure. UTC is not used for facility sizing, needs identification, or future planning.
- **Maximum Practical Capacity** (MPC). The practical upper limit of a terminal's ability to handle cargo demand is referred to as MPC. This capacity level is constrained by infrastructure, equipment, and/or operating capabilities.
- **Sustainable Practical Capacity** (SPC). The SPC is the capacity at which improvements should be considered, and generally ranges between 70% and 90% of MPC. For planning purposes, in this analysis, SPC was estimated at 80% of MPC.

The conceptual distinction is critical, not only for capacity planning, but for measures of productivity or efficiency using output as a percentage of capacity. The distinction is also important for cargo peaking, which may push the terminal close to MPC for a short period. The definition of SPC as 80% of MPC is effectively an industry rule of thumb. The Parsons Brinkerhoff study goes on to discuss the possible limiting factors on capacity: wharf/berth, storage, gates, and intermodal rail. Exhibit 87 shows an analysis of the Ceres and PAG terminals at New Orleans, in which storage was identified as the binding constraint.

Exhibit 87: Port of New Orleans Capacity Estimates

Terminal Name	Ceres	PAG	Total MPC	Total SPC
1. Berth Component	619,000		619,000	495,000
2. Storage Component	238,000	356,000	594,000	475,000
3. Gate Component	936,000		936,000	749,000
4. Intermodal Rail Component	82,000		82,000	66,000
Capacity per Gross Terminal Acre			**5,400**	**4,000**

Source: Parsons Brinkerhoff (2009)

Another major port and terminal capacity analysis was undertaken in 2006 for the Port of Long Beach by JWD Group, *Port of Long beach Terminal Capacity Analysis* (JWD 2006). This study developed long-term capacity estimates for the seven Long Beach container terminals using current and planned dimensions and capabilities. Overall capacity was defined as the lesser of berth or container yard (CY) capacity, which were independently estimated. CY capacity was estimated based on acreage, operating mode, stacking height, dwell time, etc., as shown below (Exhibit 88). (TGS is the abbreviation for twenty-foot ground slots.)

Exhibit 88: Container Yard Operating Parameters

	Dwell (days)	% Grounded	Mean Stack Height	Grounded Mode	Grounded Density (TGS/net acre)
Import local load	4.0	90%	3.5	RTG	100
Import On-dock IM load	2.0	90%	3.5	RTG	100
Import Off-dock IM load	1.5	90%	3.5	RTG	100
Export local load	6.0	95%	3.5	Top-pick	115
Export On-dock IM load	6.0	95%	3.5	Top-pick	115
Export Off-dock IM load	6.0	95%	3.5	Top-pick	115
Import empty	na		3.5		
Export empty	7.0	95%	5.5	Side-pick	115

Source: JWD (2006)

The JWD study also made the critical distinction between gross and net CY acres, and a further distinction between CY acres allocated for chassis storage and those available for container storage. As the results show, the difference between TEU/net acre and TEU/gross acre is substantial. Berth capacity was estimated as a function of berth size, expected vessel schedules, project vessel sizes, and discharge rates. A critical step was defining the minimum acceptable level of service as one that has no more than a 5% chance that one or more vessels would have to wait for a berth. This provision limited the available vessel time at berth, berth utilization, and hence berth capacity. The demand for berth space included both the length of the vessel and the minimum required spacing between vessels. The assumptions incorporated in the berth capacity analysis are shown in Exhibit 89. Note that the analysis allows three shifts per day of seven working hours each.

Exhibit 89: Assumptions in JWD Long Beach Capacity Study

- 1.20 peak-to-mean factor to evaluate peak conditions
- Vessel beam used for gap between vessels at berth
- One crane per 1,000 lifts up to seven, with fractional cranes allowed
- 33 moves per crane hour productivity
- 21 work hours per day
- 4 hours of tie-up and untie time per vessel call
- Calendar hours of vessel dwell = workdays* (24 hrs/day/21 hours worked)+4

Source: JWD (2006)

Vessel schedule reliability is a key factor in maximizing berth utilization and capacity. Exhibit 90 presents the overall study conclusions.

Exhibit 90: Port of Long Beach Terminal Capacities

Terminal	CY Capacity (TEU/yr)	Vessels	Berth Throughput (TEU/yr)	% Queue	Overall Throughput (TEU/yr)	Comments
Pier A Small	3,240,000	6	3,180,000	3%	3,180,000	Berth Capacity = 3.2 M TEU/yr
Pier A Big	3,560,000	6	3,190,000	3%	3,190,000	Berth Capacity = 3.2M TEU/yr
Pier C	930,000	4	580,000	3.50%	580,000	Berth cap. = 58M TEU/yr; 5-vsl sched excess queuing
Pier G	3,240,000	7	3,230,000	3%	3,230,000	Limited by CY
Pier J	4,240,000	2+7	4,250,000	3.5% & 5%	4,240,000	Berths and CY are balanced
Pier S	1,340,000	5	1,420,000	None	1,340,000	Reduce vsl sched. to balance Berth & CY
Pier T	4,530,000	10	4,420,000	4%	4,420,000	Berth Capacity = 4.4M TEU/yr
Pier E 342 Acre	3,330,000	7	3,320,000	2%	3,180,000	Limited by CY
Pier E 312 Acre	2,900,000	3+4	2,870,	<1%	2,870,000	Limited by CY
Pier E No Fe. Action	3,101,000	3+5	2,910,000	5% & 3%	2,910,000	Limited by CY

Source: JWD (2006)

The most comprehensive analysis of container port capacity, as opposed to terminal capacity, is the Maritime Development Alternatives Study (MDAS), *Maritime Development Alternatives Study* (JWD, 2004), prepared for the Port of Oakland by a consultant team including JWD, Parsons, and TY Lin. This study addresses the factors in terminal capacity (berths, cranes, space, yard equipment), but goes on to analyze the overall throughput limits imposed by rail intermodal terminals, rail linehaul capacity, and the road and highway system. The study found that the Port of Oakland's container terminals had a long-term capacity of roughly 6 million annual TEU, but that the achievable throughput was currently limited to between 2.5 million and 3.5 million TEU by road and rail limits. Depending on the rate of cargo growth, those limits could be reached in 7-10 years. With appropriate road and rail improvements, Oakland should have sufficient capacity to handle expected demand until at least 2030. The study went on to describe the road and rail improvements necessary to achieve the full throughput capabilities of the terminals themselves.

SF Bay Containerized Cargo Outlook (Tioga, 2009) draws on the MDAS report and compares its capacity estimates with a long-term container trade forecast to assess the capability of San Francisco Bay ports to accommodate expected growth.

A white paper prepared by JWD Group for the Port of Houston Authority, *U.S. Container Terminal Throughput Density* (JWD, 2003), likewise discusses the factors behind terminal capacity and productivity. This study is one of the few that recognizes the operational limits on CY storage capacity. Specifically, the study notes that typical RTGs capable of passing one container over a stack of four (“1 over 4”). Space is still necessary in the stack to sort containers or re-handle them to reach the lower tiers. JWD estimates that terminals typically maximize stacking at 2.5 to 3.0 containers high, achieving a practical storage capacity of 200-300 TEU/acre. They go on to explain that ports such as Houston or Oakland with higher export volumes typically need to re-handle containers more often to match vessel storage plans, and, therefore, usually have lower stacking and storage densities. Finally, the report notes (although does not quantify) the cost and competitive service advantages of lower density operations.

In *Modern Marine Terminal Operations and Management* (Atkins, 1983), a book prepared under the sponsorship of the Port of Oakland, Atkins provides detailed comparisons of the terminal operating methods used at the time. With few exceptions, the same systems are used at present. The book covers Ro-Ro and general cargo operations outside the scope of this study, top-pick/side loader operations, straddle carrier operations, wheeled operations, and rubber-tired gantry (RTG) operations. Although the speed and lifting capacity of these equipment types has increased since 1984, their relative advantages and disadvantages have not. The text therefore remains valuable and instructive.

There have also been a number of theoretical studies aimed at optimizing operations and resource allocation within the yard. Chen, Hsu, and Huang (2003) surveyed the work done on simulating and optimizing container yard operations (as opposed to overall terminal productivity). They make the critical observation that the key task of terminal managers is to allocate available resources among terminal functions. They found that most of the approaches to date used either analytic or simulation models applied to specific sub-problems within the terminal. Moreover, many of those modeling efforts required strong and perhaps unrealistic assumptions. Leong and Lau (2007) proposed an algorithm-based method of creating job schedules for container cranes, focusing on just that one aspect of terminal productivity. In *Simulating Operations Policies in a Container Terminal* (2001?), Itmi, *et al* developed an object-oriented simulation model of a container terminal to investigate alternative operating practices.

Henesey, *et al*, *Market-Driven Control in Container Terminal Management* (2003) and *Container Terminal Performance* (2004), suggest an intriguing agent-based approach to resource allocation in automated terminals. In effect, resources, such as crane time, would be allocated through market like interactions between electronic “agents” representing major terminal functions. These agents would bid for resources in real time based on the volume, priority, and opportunity cost associated with their work load. For example, a yard gantry might be assigned either to stack containers being unloaded from the vessel or to deliver stacked containers to waiting truckers. The crane's time would be divided between the agent representing vessel operations and the agent representing truck loading according to the costs associated with either advancing or delaying each function. This approach envisions a degree of automation well in advance of present practice, especially in the U.S., but may have a long-term application.

Best Practices

There is wide literature on best practices in terminal operations, mostly focused on technology. For this effort, Tioga reviewed documents with a broader scope than just a single technological innovation.

Schmidmeir, *Leveraging Technology to Boost Port Productivity* PowerPoint (2006), regards technology as an *enabler* of best practices. He argues that legacy terminal operating systems suffer from "over-customization" and "under-integration." Best practices are presented in categories--container handling equipment dispatch, yard stacking, crane scheduling, and storage planning.

- Pooling of straddle carriers or yard tractors across multiple quay cranes is claimed to offer up to 60% better yard equipment utilization than assigning each yard machine to a single crane.
- Automated yard stacking control is claimed to increase yard capacity and substantially reduce re-handles compared to manual stack planning.
- Automated stowage planning is claimed to improve efficiency over manual vessel planning.
- Optimized crane scheduling is claimed to improve crane and labor productivity and reduce vessel turn time over manual planning and communications

Tarkenton, *Trends in Marine Terminal Operations Management* (2005), emphasizes "cargo velocity" as the key to productivity, service, and revenue. Cargo velocity is "the ability to handle maximum volume with maximum efficiency." Tarkenton lists the following measures as "enhancements" to cargo velocity:

- Limits to on-terminal empty storage
- Off-dock empty container yards
- On-terminal empty storage lots with live lift operations
- A port-wide chassis pool
- Various IT initiatives
- A virtual container yard
- Improved equipment reliability
- Improved relationship with truckers

- Improved Longshore labor relations

Taro, *Trends in North America Terminal Operations* (2006), notes the use of off-dock empty depots and chassis lots to increase CY capacity, and increases in export demurrage and reductions in free time to reduce export dwell time. Taro also lists the following productivity initiatives:

- Technology advancements to automate yards
- Twin pick and quad lift spreader bars
- RTGs with GPS navigation
- OCR and RFID systems to improve traffic flow

In discussing the conceptual role of automation, Ranstrom, *Increasing Throughput Using Automation* (2005), notes the actual and potential application of automated stacking cranes, automated guided vehicles, vessel storage, and locating opportunities for twin lifts and twin carries. The example used is the ECT terminal at Rotterdam. McCarthy, *Current and Future Role of Technology in Marine Terminals* (2006), notes the role of automation in achieving higher CY storage and throughput densities, particularly for the efficient use of rail-mounted gantries.

A 2001 study of landside access for the Port Authority of New York and New Jersey, *Intermodal Productivity and Goods Movement, Phase II* (Port Authority of New York and New Jersey, 2001), focused on gate operations and made several recommendations to improve throughput and productivity. They are:

- Expanding gate hours, notably keeping the gate open during lunch and offering two shifts rather than one
- Adding gate lanes
- Offering an appointment system
- Encouraging truckers to have complete documentation
- Using Optical Character Recognition (OCR) and Computer Character Recognition (CCR) technology

A study from the University of Southern California, *Port Operations: A Review of Practices* (Higgins, *et al*, 1999), looked at container port capacity from the perspective of military deployment. The authors draw on the work of Vandeveer (1998), and provide regression analyses of throughput per unit area for Western and Asian ports. The throughput for Asian terminal was found to be about three times higher. The authors speculated on the causes for the difference but did not investigate. Most usefully, the authors list the following best practices:

- improved labor-management relationship
- improved relationships with truckers and railroads
- increased use of “steady men,” longshoremen who work regularly at the same terminal
- improved communication within the terminal and with outside parties

- improved information flow
- automated gates
- increased use of on-dock rail, although drawbacks were noted

Ward, Practical Port Productivity Measurement (1998), focuses on wharf and crane productivity, specifically the ability to handle ever-larger container ships. Ward lists multi-hoist, and multi-pick cranes as potential solutions, and these technologies have since been implemented at a number of ports. The use of cranes on both sides, the so-called ship-in-a-slip (SIAS) system, is also considered but that option is still theoretical.

Modeling and Theoretical Approaches

The importance and complexity of marine container terminal operations have led a number of researchers to explore various mathematical and statistical modeling approaches. These approaches are primarily focused on the allocation of resources within the terminal itself. The assignment of container cranes, yard gantries, and labor has received the most attention. Gonzalez and Trujillo, *Efficiency Measurement in the Port Industry* (2008), provide an extensive review of the port efficiency modeling literature. They documented a wide range of approaches and results and a general lack of comparability due to differences in port types, production definitions, and input variables. They also see a need for improved data collection.

Monteiro, *Productivity and Efficiency Measurement in Ports* (2009), provides a conceptual framework for modeling port productivity. Raw operational data (such as TEU handled or crane hours) are combined to form key performance indicators (KPIs). KPIs are typically ratios and include most of the performance metrics used or suggested by other authors, such as crane moves per hour. KPIs do not, however, specify a functional relationship, and Monteiro notes that different parties with different perspectives choose different KPIs. The next step is to develop functional relationships, for which Monteiro considers three approaches: Price-based Index Formulas, Stochastic Frontier Analysis (SFA), or Data Envelope Analysis (DEA).

Talley's works on an overall economic model of a port, *An Economic Theory of the Port* (Talley, 2006) and *Port Performance: An Economics Perspective* (Talley, 2007), extend the theoretical treatment beyond the terminal level. These treatments transcend the functional engineering relationships of berths, cranes, etc., to examine the mission of the port itself in maximizing throughput and profit. As such, Talley examines demand as well as cost and production.

There have been several applications of Data Envelope Analysis to overall terminal productivity. Data Envelope Analysis (DEA) uses output data (in most cases, annual TEU) and a selection of dependent variables to generate a "DEA Score" for each production unit, in this case a port or terminal. The best scores define a data envelope akin to an economic production frontier. Less favorable scores indicate relatively inefficient resource use, unrealized economies of scale, or other shortfalls.

There may also be some confusion due to the researcher's lack of experience with the container terminal industry. Kaiser, *et al*, *Efficiency Measurement of US Ports Using Data Envelopment Analysis* (2006), analyzed ro-ro terminals on the same basis as dedicated container crane terminals, and apparently used incorrect data for acreage at the Port of Long Beach. Turner, *et al*, *North American Containerport Productivity 1984-1997* (2004), found it surprising that larger vessels led to higher productivity, and that the presence of on-dock rail reduced overall throughput per acre, both points that are obvious to industry participants.

Turner, *et al*, (2004) uses DEA with time-series data from 1984 to 1997. They conclude that container ports exhibit economies of scale, and identify rail access and service as a “critical determinant of container port infrastructure productivity.” Unfortunately, they do not delve into the common metrics for terminal operation. The link they found between rail access and port throughput may be attributable instead to the size of the market being served, which in turn explains the presence of multiple railroads. Wang, Cullinane, and Song, *Container Port Production Efficiency: A Comparative Study of DEA and FDH Approaches* (2003), compared approaches to port production efficiency using DEA and a Free Disposal Hull (FDH) Model. They found that different modeling techniques led to different conclusions, and that the use of time-series or panel data would be more productive than using cross-section data. These authors also examine previous efforts to apply DEA or other techniques to the port productivity issue.

Poitras, *et al*, *Measuring Port Efficiency: An Application of Data Envelopment Analysis* (1996), use DEA to develop an efficiency ranking of 23 international ports. They found that the efficiency rankings varied with methodology but that DEA was a promising approach. Another application of DEA to container terminals, *An Application of DEA Windows Analysis to Container Port Production Efficiency* (Cullinane, *et al*, 2004) took the time factor into account on the grounds that port efficiency should change (and presumably improve) over time. The authors used several years of data from Asian ports, Long Beach, NY/NJ, and European ports. The study used quay length, terminal area, number of container cranes, number of yard gantries, and number of straddle carriers as land and equipment input proxies, and a pre-determined relationship between labor and terminal facilities. Unfortunately, this approach leaves the analysis vulnerable to differences in terminal technology (e.g., wheeled terminals at Long Beach *versus* stacked terminals elsewhere) and significant variations in manning practices. In contrast to other studies, Cullinane, *et al*, found no economies of scale. The paper states that “the ports measured as being highly efficient appear to be those that do not actively invest over time.” The authors thus seem to have confirmed that terminals that do not expand must make greater use of the land and equipment they have. The authors conclude that “existing programming methods for estimating efficiency are inadequate in capturing the long-term increased efficiency and competitiveness that accrue for significant investments.”

Notteboom, *et al*, *Measuring and Explaining the Relative Efficiency of Container Terminals by Means of Bayesian Stochastic Frontier Models* (2000), applied Stochastic Frontier modeling techniques to a sample of 36 European and 4 Asian container ports. The study reported a higher degree of efficiency in hub ports than in feeder ports. Liu, *et al*, *Container Port Productivity and Port Policy Evaluation* (2009), expect to use Stochastic Frontier Analysis (SFA) and Markov Chain Monte Carlo methods. The authors create a Port Operator Efficiency Index, but individual ports are not identified.

The apparent limitation on the consistent use of DEA or other analytic techniques is the variability and relevance of inputs. Authors have used inputs ranging from cargo uniformity and depreciation charges to berth length and the number of tugs, few of which are under the control of terminal developers or managers. Of the two widely used DEA models, the “CCR” (Charnes, Cooper, and Rhodes) version assumes consistent returns to scale, which does not correspond to the realities of container port development or operation. As terminals increase in scale, the binding constraint on their capacity and productivity will shift from resource to resource, and they will change production functions as they progress from low-cost, low-density operations to high-cost, high-density operations. As an example, Liu *et al* found that the DEA-CCR, DEA-BCC models indicated that Los Angeles and Long Beach (terminal unspecified) were more efficient than Rotterdam, Hamburg, or some of the Hong Kong terminals. The FDH model found that most of the ports and terminals examined had equally high efficiency and would therefore be of limited utility as an analytic tool. The DEA “BCC” variation returns to scale and may be more suitable.

While DEA may be a promising theoretical approach, studies reviewed to date provide only limited practical insight. The studies confirm the existence of economies of scale in container terminal operations, but the existence of scale economies was never in doubt. The DEA studies may have been limited by their use of port-wide output data and characteristics, rather than terminal-specific information. The choice of dependent variables may also limit the practical application of studies. The researchers used port leasing policy, berth occupancy, the availability of double-stack clearances, and other factors as dependent variables only to find them insignificant in the analysis. Sharma and Song, *Performance Based Stratification and Clustering for Benchmarking of Container Terminals* (2009), suggest combining DEA with data mining techniques to create a better diagnostic tool.

The efforts to model container terminal production frontiers using DEA or related techniques face some basic obstacles. At any given time, terminals almost certainly have a suboptimal combination of production resources. Terminals do not have effective short-run control over the land area available, and cannot adjust their acreage to match demand. Berth length and channel depth are likewise fixed in the short run, and often for the long run as well. Adding a new container crane is a multi-year, multi-million dollar proposition. Even yard lift equipment, such as RTGs or straddle carriers, requires a substantial investment and lead time. In the short run, labor is almost the only variable input.

The multiple efforts at modeling container port performance illustrate a classic dilemma: the data available to modelers often lack explanatory power, and data more directly related to efficiency are inaccessible or confidential. The modelers are thus in the difficult position of trying to identify a production frontier using variables that are secondary or tertiary at best. The literature confirms this problem in a round-about way by concluding that many of the variables used have no explanatory power, that better data are needed, and that the modeling effort overall is in an early stage of development.

End Notes

In addition to the sources reviewed above there are a number of other potentially useful articles and presentations on port productivity and related subjects. Literature reviews are included in most of the publications cited above, notably Wang, *et al*, *Container Port Production Efficiency: A Comparative Study of DEA and FDH Approaches* (2003). An extensive review of the literature on port economics is contained in Pallis, *et al*, *Port Economics, Policy and*

Management – Review of an Emerging Research Field (2009), a work reviewed in draft and published in Transport Reviews, 2009.

The great majority of the sources above are obtainable in full text versions and are being made available on Tioga's FTP site for use in this project. A few, however, were only obtainable in abstract or executive summary form and are so indicated in the references listing.

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Appendix B: Insights from Rail Intermodal Terminals

Objective

The objective of this Appendix is to document the historical and current patterns of rail intermodal terminal development, identify those patterns that are most applicable to the marine port industry, and to draw conclusions useful for the marine terminal productivity study.

Rail terminal efficiency is measured by *cost per lift*, with a lift being the transfer between rail and highway modes. Measures of physical productivity are subordinate and managed with the goal of influencing the cost per lift.

An emerging theme of this Port Productivity Study is that the treatment of land costs is a key to understanding the development patterns, planning decisions, and subsequent productivity at marine terminals. The relatively low cost of land in the U.S. leads to efficient facility designs and operational practices that use much more land than terminals in major Asian or European cities.

The development pattern of United States rail intermodal terminals shares some of the same characteristics with marine terminals; therefore, as part of the larger examination of marine terminal productivity and productivity measurement, Tioga analyzed the development patterns of rail intermodal facilities and identified their implications for the marine terminals that are the primary subject of this study.

To illustrate the financial implications of current rail development options and show how land costs strongly influence that development, Tioga modeled the cost of six hypothetical scenarios. These scenarios illustrate how terminal cost per lift increases as the cost of land increases; and how that increase can be mitigated through the use of stacking, coupled with capital equipment, and technologies that drive scale economies.

Background

In 2006 North American railroads moved 14,234,074[3] intermodal loads in containers and trailers through approximately 225 intermodal terminals.[4] The function of the intermodal terminals is to transfer the container or trailer between modes. Each transfer is called a lift. In 2006, there were more than 30 million lifts performed in North American rail terminals.[5]

Rail intermodal terminals and marine terminals are functionally very similar. The main difference is that the "berth" in a rail intermodal terminal is a set of railroad tracks which can be

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[3] http://www.intermodal.org/statistics_files/stats1.shtml

[4] 225 is the approximate number in the IANA data set. There are a few identifiable duplicates in IANA's data, and the data set does not include some smaller terminals or on-dock rail intermodal terminals.

[5] There is at least one lift at each end of a loaded movement. In addition, there are movements of empty equipment, and some loads are lifted more than twice.

served by a side loader or gantry crane. Rail terminals lift both trailers and containers. Trailers were previously rolled on and off rail cars, but this practice has largely been replaced. On the railroad a switch engine moves the loaded train to/from the loading tracks. In a marine operation this function is performed by a maritime tug. Beyond these apparent differences, the clerical, gate, and container yard functions are very similar. The lift equipment and yard tractors are nearly identical.

Overview of Rail Terminal Services

Lifts. Activity at intermodal terminals is most commonly measured in lifts. A lift is the transfer of a trailer or container from a rail car to the ground/chassis, or from the ground/chassis to rail car. Often there is a service component. Typically, outbound trailers and containers arriving prior to an agreed cut-off time must be lifted to a train prior to a scheduled release time. Inbound trailers and containers must be lifted off the train (grounded) and made available for drayage within a specific time window, often 2 hours.

Contract terminal operators are typically paid based on the number of primary lifts they perform. In most terminals, lifts are counted by shift. Some terminal operators distinguish between primary and secondary lifts. A primary lift is a lift to/from a rail car. A secondary lift is between a chassis and a stack.

Gate transactions. While lifts is the measure of activity for the rail side of the intermodal terminal, gate transactions is the measure of activity for the highway mode. Trucks enter and leave the terminal to deliver and pick up loaded and empty trailers and containers. The truck flow through the terminal can be used as a demand/work measure for gate and clerical personnel. It can also be used to identify the impact on traffic through a determination of a gate activity/lift ratio (typically 1.5 gate transactions for every 1 lift).

The daily cycle. Terminals typically strive to match shipper practices. For many facilities, this means handling inbound trains in the morning and outbound trains in the afternoon or evening. This cycle is less pronounced at the largest terminals and those in the middle of a network.

The weekly cycle. Most customers ship five or six days per week. Most rail intermodal terminals work six or seven days per week because trains move seven days per week. Intermodal terminals, therefore, handle most outbound traffic Monday through Friday. A small minority are handled on Saturdays, and an even smaller portion of the outbound are handled on Sundays. Inbound traffic flows into the terminal all weekend. Generally, it is unloaded throughout the weekend in order to make it available to customers, most of whom want the traffic Monday morning. The weekly cycle strongly influences the rail car and trailer storage requirements.

Annual cycle. Generally, intermodal terminals have relatively small seasonal peaks in March and October, and have a significant low period in late December and early January.

Intermediate "hub" terminals. Intermodal movement from shipper to receiver often involves handling at intermediate terminals. For example, in Los Angeles, international intermodal shipments move between marine terminals and intermodal terminals over the highways.

Domestic transcontinental shipments that must change railroads are often handled the same way in gateway cities, such as Chicago. Terminals that provide these services have cycles and peaking characteristics influenced/driven by the unique demands of the interchange traffic.

End-point terminals. End-point terminals, with little impacted from intermediate movements, experience shipper driven cycles and peaks. End-point terminals require larger parking lots to buffer weekend-driven demand peaks.

Supplying Rail Terminal Services

Most rail intermodal terminals are owned by railroads.[6] As with marine transportation, the cost of rail intermodal terminal operations is bundled into the point-to-point transportation rate. Rail customers typically do not see a separate accounting for terminal costs.

Sub-contracting practices vary widely in the rail industry. In Canada and in some U.S. facilities, 100% of the work is performed by rail employees. It is more common, however, for a U.S. intermodal terminal to operate with a combination of rail and contractor employees.

Regardless of the status of their employers, in a railroad terminal, there are typically three functional categories of labor: yard workers, clerks, and mechanics. Yard workers drive the yard tractors and lift equipment. They also serve as ground men working the hitches and interbox connectors. Mechanics are further subdivided into those who work on powered equipment and those who work on trailers, containers, and chassis. In a heavily unionized environment, each category may be represented by a different union. In smaller and nonunion environments, the distinctions between supervisors and labor are blurred as are the distinctions between functional labor categories. In very small terminals, a yard worker may unload a trailer and then drive the drayage truck that delivers it to the customer.

In the United States, there are several intermodal terminal operating companies that provide intermodal terminal services, up to and sometimes including operating switch engines. Many of these services are sold on the basis of a price per lift because it is accepted as a fair measure of terminal activity. When railroads offer to subcontract terminal services, they prepare a Request for Proposal that outlines the menu of services that are to be contracted. There is absolutely no “standard package” of services; each and every procurement is unique.

The menu may include:

- Labor to make the transfer, store, and retrieve the unit in the yard. In most, but not all locations, the tie down labor is included.
- Labor to check units in and out of the gate and perform clerical functions. It is relatively more common for the railroad to provide its own clerical services.
- Labor to maintain the equipment.

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[6] On dock rail intermodal facilities are the most common exception. These are typically owned by the port, leased to the marine terminal operator, and staffed with less flexible Longshore labor.

- Allocated capital costs of mobile equipment (lift equipment, yard tractors, and ancillary vehicles). Almost always the terminal operator provides yard tractors and ancillary vehicles; more often than not, the railroad provides the lift equipment.
- Fuel, utility, and other supply costs.
- Information systems and communications costs.
- Liability for accidents, regardless of responsibility.

Rarely, railroads will select a "turn-key" operation for their intermodal facilities. In this case, the contractor provides all of the equipment, sometimes including the switch engine. The only personnel on the terminal, including security, may be contractor employees.

Tioga is not aware of any example of a design/build/operate arrangement using railroad-owned land, though there has been some discussion of this approach. In this case, an outside party would perform not only a turnkey operational service, but also finance and build the facility.

Finally, there is a significant minority of private and on-dock terminals, which are not owned by railroads. These are typically operated by rail intermodal terminal operators and marine stevedoring firms. In these cases, the entire terminal function can be said to be subcontracted.

Rail versus Marine Container Moves

Almost all U.S. rail intermodal terminals are wheeled, with containers parked on chassis rather than stacked or grounded. Each container transaction, inbound or outbound, ordinarily consists of a single lift between chassis and rail car. Secondary lifts or "flips" are rare and are often discouraged with high assessorial charges.

Almost all major U.S. marine terminals are hybrids, with many or most loaded containers stacked. A container transaction involving stacked containers requires at least *three* lifts. For an import box, for example, there will be at least three:

- one from the vessel to a yard chassis;
- one from the yard chassis to a stack; and
- one from the stack to a road chassis.

In marine terminal straddle carrier operations there would also be at least three:

- one from vessel to ground at the apron;
- one from the apron to the CY; and
- one from the CY to the road chassis.

In any stacked operation, there is also the possibility of additional lifts to sort the stack or to get to the desired box. Where import loads are wheeled, there should be only a single lift from the vessel to the road chassis. As a result, marine terminals (or grounded rail intermodal terminals) spend more capital on lift equipment.

Rail Terminal Productivity Measures

Railroad terminal operators tend to look and measure terminal productivity in a number of different ways based on the time horizon in question. The daily issue at an intermodal terminal is how many people and machines are needed for the next shift. There is generally much more labor flexibility in rail intermodal terminals than in port operations. The terminal operator can most often decide which of his employees will operate lift equipment and which will perform other job responsibilities, such as yard driver or tiedown person.

The question is answered based on an estimate of workload for the shift, coupled with knowledge of the equipment and the skill level of individual workers. At the level of the shift supervisor, the "who" is the most important question. The workload is estimated based on the certain knowledge of the volume and schedule status of inbound trains and an estimate of outbound business volume that will arrive at the terminal prior to "cut off." Some railroads issue reservations; others talk to customers ("UPS has 55 coming tonight") to improve the quality of these estimates. At this level, productivity measures, such as lifts per man hour and productivity rates for individual operators, are used to size the crews.

Planners with a longer time horizon are typically more interested in longer-term productivity issues involving investments in land, equipment, and facilities. Often these individuals are involved in capital investment decisions. To measure performance and support this kind of analysis, railroads and their contractors rely on a number of standard performance measures.

Rail Terminal Performance Measures

Facility Measures. These measures typically compare the annual lift count to the portions of the facility. Lifts per track space (or foot of track), lifts per parking space, and lifts per acre are commonly used measures.

Equipment Measures. Equipment productivity is measured in terms of lifts per time period (shift, day, month, and year). More important, though, is schedule compliance. Regardless of long-term efficiency, a terminal needs enough operational equipment to meet the peak demands imposed by the train schedule and associated customer commitments.

Labor Measures. Labor productivity varies widely. The most common labor specializations in an intermodal terminal are drivers (heavy equipment and yard tractors), mechanics, and clerks. In some places each trade is represented by a different union. In other locations workers are not unionized and are cross-trained between specializations. In some locations the distinction between labor and management may not be obvious. In addition, terminals are often staffed by a mix of contractor, railroad, and railroad subsidiary employees. The most common measures compare lifts or gate transactions with payroll. Lifts per man-hour and staff minutes per gate transaction are also common measures.

Rail Intermodal Terminal Development

While the origins of the rail intermodal freight industry can be traced back to the loading of circus wagons on rail flat cars more than a century ago, modern Trailer on Flat Car (TOFC) service is a post-World War II phenomenon. Railroads advanced the business in order to stem market share losses to motor carriers, which were accelerated by the construction of the Interstate Highways.

In the early years, most terminals made the mode transfer by driving the trailers onto ordinary flat cars. This was called “circus” loading, after the way in which circus wagons were loaded onto railroad flatcars in the 1800s. Terminals were cheap to build and could achieve near optimal efficiency with relatively low volumes. As a result, intermodal terminals proliferated and almost every medium-sized (and larger) community in the US had a simple intermodal terminal, usually called a “piggy back” ramp. These facilities were usually built on the edges of existing freight or passenger facilities. The low profit margins on early rail TOFC/COFC business would rarely have justified the purchase of land.

To address the problem of low profit margins, railroads found that they could improve intermodal service by operating dedicated intermodal trains between major city pairs. Stopping at every medium-sized city en-route slowed the trains to a point that service became uncompetitive and rates became unprofitable. Intermodal service to these communities actually improved when local piggyback ramps were closed, as traffic was drayed to a “hub” location in a major city that could load the freight on a dedicated intermodal “through” train.

Furthermore, beginning in the 1960s, it became possible to operate a terminal at a much lower cost by lifting the trailers or containers on and off the rail cars. The capital cost of the heavy lifting equipment and the paved surface to support it was high, requiring a relatively large volume of traffic to gain this efficiency. It was also subsequently determined that a large amount of tare weight could be taken out of flat cars if they did not need to be strong enough for heavy trucks to drive on. These economic factors made intermodal service viable only in the largest cities, and resulted in the abandonment of many small- and medium-sized facilities.

In the late 1960s and early 1970s, there were a number of “side-by-side” rail mergers. The associated facility rationalization led to an additional decline in the number of terminals. For example, on Conrail, which was formed in 1976 from the bankrupt northeastern railroads, the combination of these factors caused the number of terminals to decline from 40 to 24 between 1979 and 1984.

Since 1975, rail intermodal volume has grown dramatically. To adequately manage this relatively rapid, long-term growth, most railroads have focused their available capital and management attention on easily served, long-haul, high-density corridors. This emphasis has limited intermodal traffic, to traffic lanes between large cities in which all of the major railroads involved have a long haul (500 miles or more). Even given this restrictive strategy, railroads have been adding roughly 500 acres of new intermodal terminal capacity each year to keep pace with growth.

As a rule, intermodal terminals accommodated this growth by expanding within the available railroad-owned land. The expansion of intermodal business paralleled reductions in the need for massive freight classification yards, LCL terminals, and locomotive maintenance facilities. Rail intermodal terminals were therefore able to expand with established railroad property boundaries. Exhibit 91 and Exhibit 92 show an excellent example from San Bernardino, where a former locomotive shop complex was replaced with intermodal terminal parking.

Exhibit 91: San Bernardino, June 1994

Exhibit 92: San Bernardino, June 2009

During the mid-1980s, double-stack rail technology was widely implemented for landside distribution of very large volumes of steamship lines' container traffic. These double-stack operations were much more profitable for railroads than conventional Trailer-on-Flatcar (TOFC) and Container-on-Flatcar (COFC) services. Terminal development to support this traffic again occurred mainly in very large port and inland cities, and only on double-stack-capable rail routes.

"On-dock" or "near-dock" rail access became much more important to competing marine facilities, and many new terminals were developed, sometimes by the ports themselves.

In addition, each of the seven major North American railroad systems was party to at least one merger in the 1990s. These mergers tended to spur terminal development as railroads sought to exploit new market opportunities. Consider, for example, the sale of Conrail to CSX and NS. CSX developed new terminal capacity in Chicago, Philadelphia, and Cleveland. NS developed terminal capacity in more than a dozen eastern locations. Much of this development occurred as railroad sites were reconfigured to handle the new business opportunities.

Exhibit 93 and Exhibit 94 illustrate this process for Hobart Yard at Los Angeles.

Exhibit 93: Hobart Yard, May 1994

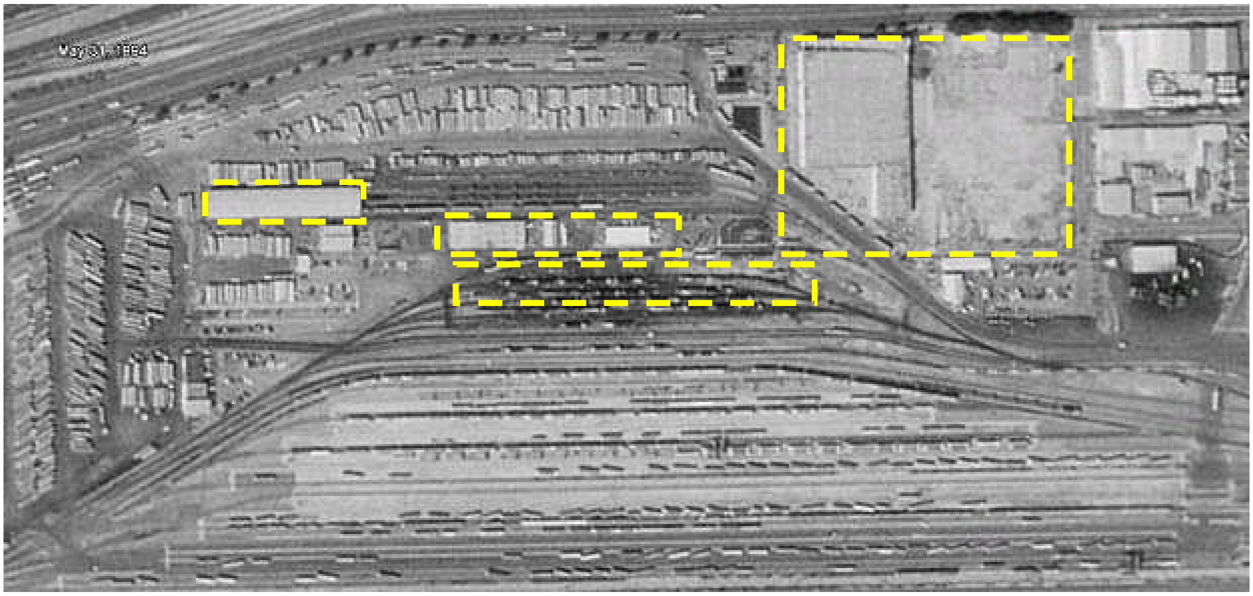


Exhibit 94: Hobart Yard, July 2007

As the industry has grown, the land available at rail-owned legacy terminals has been insufficient and has been supplemented by extensive new terminal development. These new terminals can be categorized as on-dock facilities, facilities developed at former military bases, and new “greenfield” facilities. New CSX and NS terminals in suburban Atlanta are examples of greenfield developments during this period.

By the year 2000, the rail intermodal business was well established and growing. The markets that successfully supported intermodal terminal services were (and continue to be) those that involve mass movements of trailers or containers. These typically include:

- **Large container ports.** Ports concentrate long distance container flow in a manner that is conducive to intermodal rail services. Most large ports have on-dock and near-dock intermodal terminals. One port, Virginia, operates a remote inland port in support of its waterside facilities.

- **Large metropolitan areas.** Almost every metropolitan area with a population over 1 million has intermodal rail service. As a minimum, they represent large concentrations of demand for consumer goods moving in containers. Most have large legacy terminals, which have been in operation since the 1950s. Markets have grown in some cities, like Atlanta, to the degree that they now also have new suburban green field terminal developments.

- **Production/distribution hubs.** These can be completely unrelated to the other two factors. The extreme examples are auto production facilities that have intermodal service and are located in smaller communities or rural areas. The terminal operating in Marysville, Ohio, in support of Honda is a prime example.

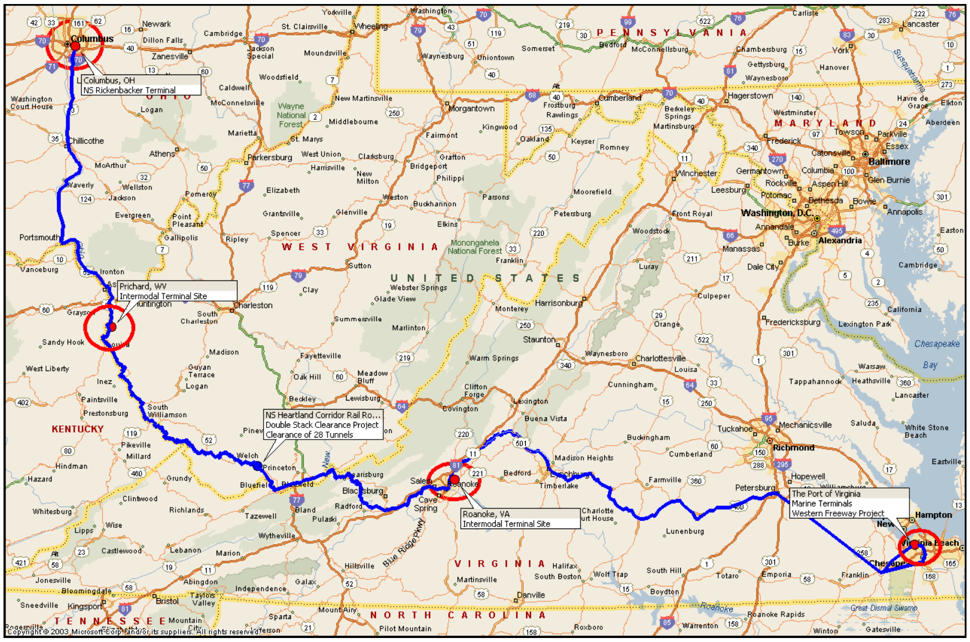
Current Development Patterns

Since 2000, a number of additional development trends have emerged, most of which impact or have parallels with marine terminals.

Corridors

NS has led the effort to create Public-Private Partnerships (PPPs) for the development of new intermodal rail corridors. New terminal development is typically part of these corridor programs, both in traditional intermodal markets and in smaller cities in strategic intermediate locations. The “Heartland Corridor,” the first example, is a series of intermodal projects designed to improve freight mobility and rail intermodal capacity along the Norfolk Southern (NS) rail line between the Port of Virginia and Columbus, Ohio (Exhibit 95). This line serves the marine terminals at Norfolk and Portsmouth, and runs through southern Virginia and southern West Virginia to Columbus, Ohio. NS routes continue beyond Columbus to serve other Midwest markets including Chicago and connections with western rail carriers. The projects will enable double-stack train operations on the route, improve rail access to developing marine terminals in Portsmouth, and increase intermodal terminal capacity along the route with new terminals in Columbus, Ohio; Roanoke, Virginia; and Prichard, West Virginia.

Exhibit 95 Heartland Corridor



Two of the largest inland rail intermodal markets for the Port of Virginia are Chicago and Columbus. NS currently operates its double-stack trains to Chicago via a circuitous route through Harrisburg, PA. However, the Heartland corridor route does not currently have the 20’3” vertical clearance necessary to operate double-stack container trains. There are 28 tunnels between Roanoke and Columbus which require modification to enable double-stack train operations on this route. The project to clear these tunnels is the most significant project of the Heartland Corridor with an estimated cost of $130 million. Once the clearance project has been completed, NS will be able to operate its Norfolk-Chicago double-stack trains on the Heartland Corridor route. This will save 233 miles relative to the route over Harrisburg, and improve transit time to Chicago by about one day. Since Columbus will be on the route of the Chicago trains, double-stack service to Columbus will be significantly improved as well.

Succinctly, the project establishes a new and better rail intermodal route between The Port of Virginia and the Midwest, and new intermodal terminals are being developed concurrently to take advantage of the prospective new service. Additional new rail corridors are planned by NS (Crescent Corridor for domestic traffic between New Orleans and New York) and CSX (National Gateway Corridor to improve access to Mid-Atlantic Ports).

Logistics Parks

A “logistics park” is a logistics-based industrial park that includes both a traditional business park and a rail freight intermodal terminal. Most current greenfield developments have this feature. The rail facility adds value to the business park by providing proximity to desirable freight transportation services. The business park adds value to the rail facility by providing an opportunity for rail shippers to locate near the rail terminal. The development pattern allows railroads to establish new facilities to meet changing customer demands and to influence the pattern of that demand in a way that favors their businesses.

The first of these was established by BNSF in Alliance, TX. The largest is BNSF’s Logistics Park Chicago (LPC), which is located in Joliet, IL, near the Chicago metropolitan region’s rapidly developing southern boundary (Exhibit 112). Several logistics parks have been developed or are planned throughout the United States. The land for the rail terminals is often provided at below-market prices to induce the railroad to locate there and act as an “anchor” tenant.

Exhibit 96 Logistics Park Chicago

Legacy Terminals

Almost all of the above-mentioned developments are located where land is relatively cheap. As a result the terminals have typically been developed as “wheeled” operations. The exceptions to this are in Seattle and Los Angeles where BNSF is leading a trend toward increasing throughput on land-locked legacy terminals in high-demand areas. Increased throughput is accomplished by stacking chassis, grounding boxes, and using gantry cranes, some of very wide span.

Hobart Yard in Los Angeles is the largest intermodal terminal in the United States, handling approximately 1.24 million lifts in 2008. In order to accomplish this on a constrained footprint, the facility makes extensive use of remote parking facilities, stacking by rubber tired gantry cranes, and chassis stacking (Exhibit 97 and Exhibit 98).

Exhibit 97: Yard Crane and Container Stacking Area at Hobart

Exhibit 98: Chassis Stacking

Seattle Intermodal Gateway. The only major U.S. rail intermodal terminal that does not operate wheeled is BNSF's Seattle Intermodal Gateway (SIG), which serves the Port of Seattle. SIG (Exhibit 99) is on an extremely constrained 70-acre site, adjacent to the Port and surrounded by commercial development. SIG operations ordinarily transfer containers between rail cars and road chassis brought by draymen. On-site container and chassis storage is minimal. SIG is also the first U.S. rail terminal to use new wide-span gantry cranes (Exhibit 100) in an effort to further boost throughput by increasing rail track capacity in this constrained location.

Exhibit 99: BNSF SIG, August 2004

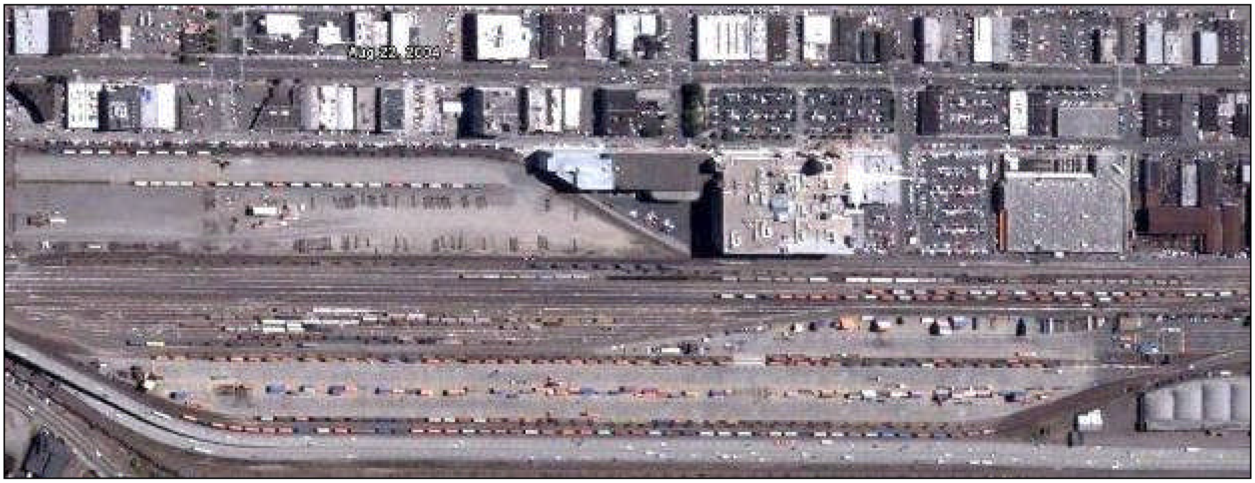
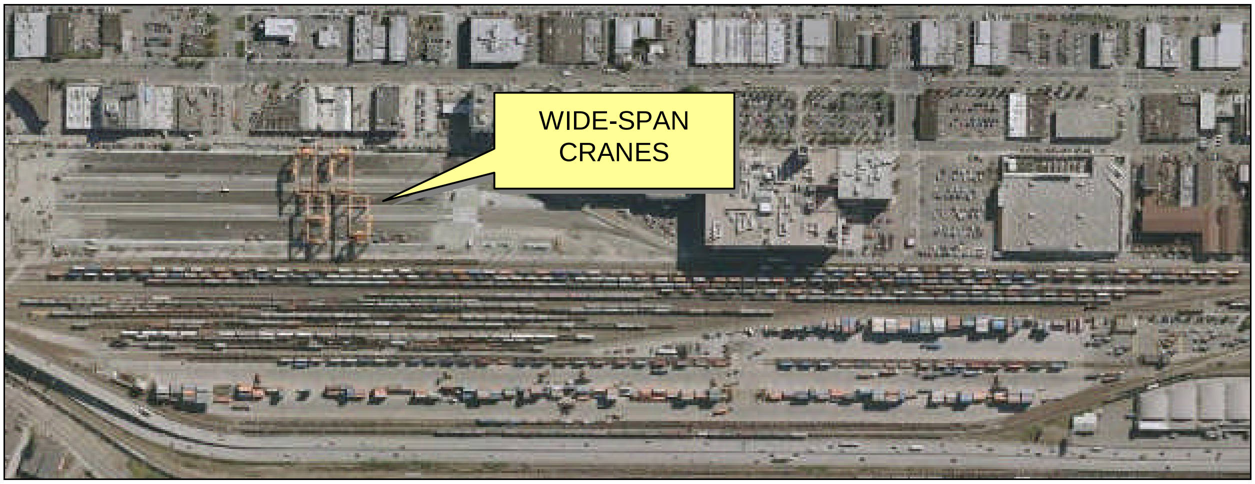


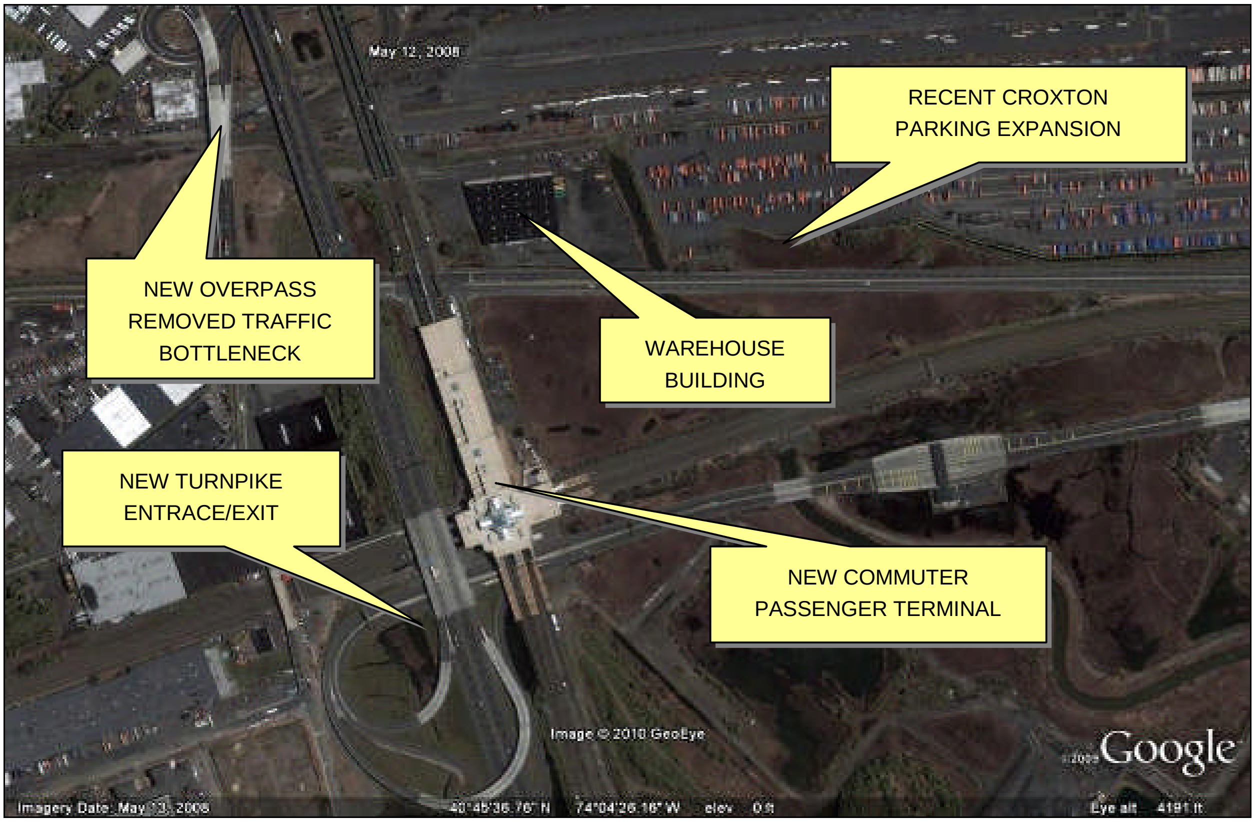
Exhibit 100: BNSF SIG, December 2007



Croxton Yard. Norfolk Southern has utilized a different strategy in Northern New Jersey at their legacy Croxton facility, which serves the New York Metropolitan Area. In order to preserve wheeled "truck like" intermodal service for domestic customers, and in anticipation of Crescent Corridor volumes, NS has sought to use its condemnation powers to obtain nearby land. In the first rail condemnation case in more than 50 years, NS is seeking to acquire the warehouse building identified in Exhibit 101.

The photo also shows contiguous development of a new station on the New Jersey Transit passenger rail system, a new Exit from I-95 (New Jersey Turnpike), and a new overpass over the west end of the yard, typical of issues experienced by many legacy terminals. All of this development increased land values, which resulted in the railroad's dispute over value with the warehouse owner.

Exhibit 101: West End of Croxton Yard



Remote Lots and Satellite Operations

In recent years both marine and rail intermodal terminals have established remote lots and satellite operations to free up acreage at the main facility and add capacity on readily-available land.

Exhibit 102 shows satellite parking and loading areas added to Hobart Yard in Los Angeles. The lots on the other side of the tracks were used for parking only, while the “Commerce” facility to the east was used for loading and unloading trains. (It has since been idled by the recession.)

Exhibit 102: BNSF Hobart and Satellite Yards

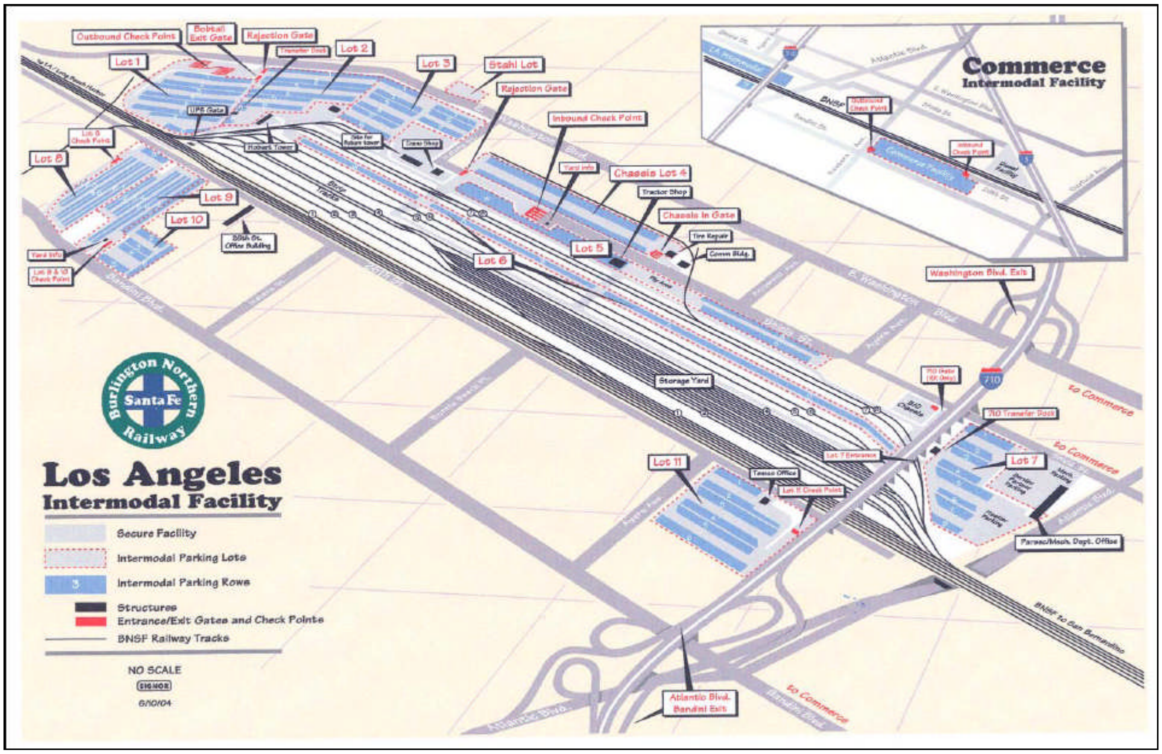
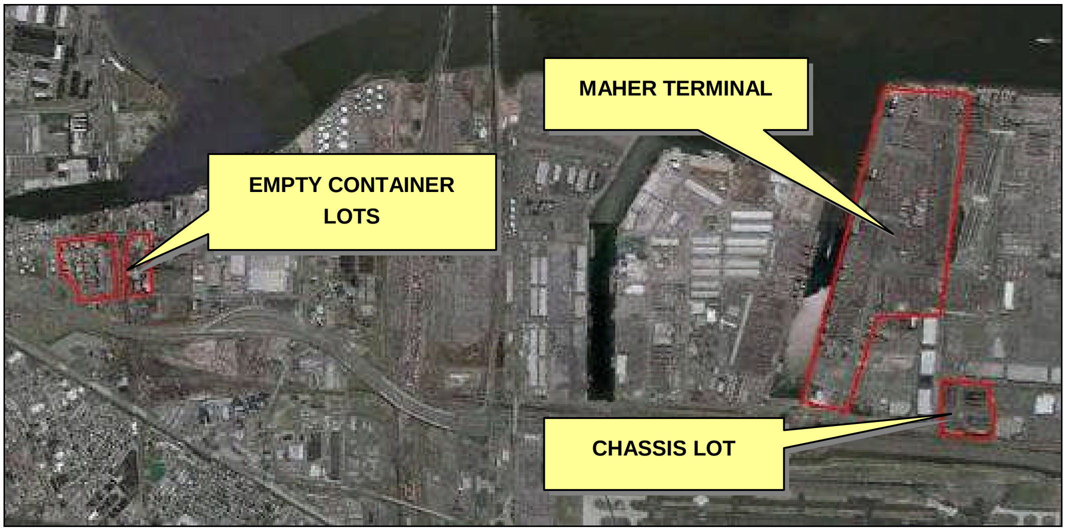


Exhibit 103 shows off-site chassis and empty container lots established by Maher Terminals at the Port of New York and New Jersey. These permit use of the main terminal space for the highest priority units, loaded containers. Off-site chassis or container yards have also been established at Houston and Los Angeles, but their use decreased with the addition of new marine terminals and with the recession-induced decline in trade.

Exhibit 103: Maher Marine Terminal and Remote Lots, Port Elizabeth



It is also common for privately operated ancillary depots and storage facilities to cluster around both rail and marine terminals. These so-called "drop lots" are used by trucking companies to stage and store equipment, or to store containers or trailers in excess supply (due to seasonal or other down turns) for leasing companies and others.

Railroads have far more flexibility than ports in siting and configuring new intermodal terminals. A rail site must be of sufficient size and shape; accessible to the relevant main lines and highways; close to the relevant market; free from conflicting uses; and have suitable topography and physical characteristics. Those criteria still usually leave railroads with multiple sites to compare. In stark contrast, marine container terminals must be built on deep waterways accessible to large containerships; on sites that are flat or fillable, with rail, highway, and market access; and which can pass all the regulatory and environmental tests. Such sites are comparatively rare and costly.

Rail-Marine Comparisons

Commitment to Wheeled Operations

While containers are sometimes stacked for longer term storage, and many rail terminals also stack or rack bare chassis to conserve space, railroads are much more strongly committed to wheeled operations than are marine terminals.

The primary reason is customer service. Many rail terminals still handle significant numbers of trailers for premium customers such as United Parcel Service. While trailer volume is declining as a share of the business, it still represents 15%.

An additional 28% of the business is being carried in domestic containers and must be handled with truck-competitive service levels. One way in which railroads accomplish this is to make terminal turn times for draymen as short as possible, a goal that is more easily achieved in a wheeled environment.

In addition, railroads implicitly value land based on the assumption that the property will eventually be needed to support the continuation of the rail enterprise and needs to be preserved for that purpose.[7] Rail managers are highly reticent to sell property, except as an element of an industrial development effort designed to garner traffic. As a result, the land is often treated as a “sunk cost” and therefore applied to the best available short-term rail use. The absolute commercial value of the land seldom becomes an issue in an investment decision when expanding a legacy terminal and is never reflected in operating cost measures. Once the decision has been made to use land for an intermodal terminal (or any other use), the terminal is not “charged” for the use of that land.

With the underlying cost of land either very low or not in the equation, rail intermodal terminals use land liberally to maintain wheeled operations. The explicit cost of horizontal expansion, then, is usually limited to grading, paving, etc. Wheeled operations conserve both labor and

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[7] Even when railroads sell property, governments sometimes step in to preserve rail right of ways and access. A positive example of this kind of activity is New York City’s purchase and 17-year preservation of the Arthur Kill Lift Bridge and the Staten Island Railway. Changing market demand created the need to reactivate the railroad in 2007 in part to provide a rail facility to support the New York Container Terminal.

capital, which are critical aspects of the railroads' calculations. Rail intermodal terminals thus use land as a low-cost resource. The underlying value of the land is usually considered only when the railroad is faced with a choice between using a large parcel for continuing intermodal operations or selling it on the open market. Such measures are fairly uncommon, and are usually taken only when the buyer provides a practical alternative that permits the continuation of the business.

Chassis Supply

A railroad's intermodal business can be categorized by its equipment type, e.g., trailers, international containers, or domestic containers. Chassis are required for the latter two categories. For the international business, railroads require the lines to provide a chassis to the terminal at the time of unloading. Some railroads may require the lines to remove them immediately after the train has been loaded.

Steamship lines often transfer this responsibility to a pool operator who is typically provided with on-site space to store chassis. There are three providers of pool chassis: Ocean Carriers Equipment Management Association (OCEMA), Seacastle (Trac), and Flexivan. Each of these organizations is now developing large regional pools with multiple termination points on both rail and marine terminals. OCEMA pools are cooperative organizations to which lines contribute chassis they own, and which OCEMA manages through its Consolidated Chassis Management subsidiary. These pools are growing both in numbers of chassis and geographical scope.

Flexibility

Rail terminal operators have far more flexibility than marine terminal operators in adjusting both near-term and long-term capacity.

Rail terminal operators can vary the size of the workforce in much finer movements. The rail workforce, regardless of union representation, does not have a minimum gang size or supervisory requirements comparable to Longshore unions. Rail terminal managers also have more flexibility in assigning workers to different tasks and in scheduling shifts and breaks. Rail terminal contractors who have worked with different unions have commented that the differences in work rules are much more important than the differences in wage rates.

Rail terminal operators also have more flexibility in the types and numbers of lift machines and other equipment used. Marine container cranes are multi-million dollar investments with long lead times. They are rarely moved between terminals until retired or replaced. In contrast, the equipment used at rail terminals is basically the same as that used in the container yards of marine terminals: rubber-tired gantries, side loaders, reach stackers, empty handlers, and yard tractors. These units can be shifted between terminals as demand changes (although the cost of dismantling and moving a gantry crane is significant).

At a marine terminal, the ultimate constraints on capacity are the length and depth of the berth and the area available for the container yard. Within these overall constraints, the throughput capacity and efficiency of the terminal are matters of capital investment, technology, and management. The corresponding features of a rail intermodal terminal are the number and length of loading and storage tracks and the area available for parking. A critical distinction is that it is usually far easier and less costly to expand rail trackage than to dredge or extend container ship berths. Changes to rail trackage are ordinarily contained within rail property and can be accomplished with the company's own funds and on the company's own schedule. Dredging or extending marine container berths is a multi-year process involving numerous permitting agencies and multi-million dollar budgets. Exhibit 104 shows trackage changes in progress at BNSF's Hobart Yard.

Exhibit 104: On-Site Trackage Changes, Hobart Yard, June 2009

Peaking and Work Flow

The flow of work and demand peaking at a rail terminal is dramatically different from that at a marine terminal, even though each handles many of the same containers for the same customers.

Vessel arrivals on most international routes are weekly, on a fixed day. A large vessel may discharge and load 2,000 or more containers at each call. Marine terminals typically handle multiple vessel services, with a series of peak demand periods during the week.

In contrast, major rail intermodal terminals have multiple daily train arrivals and departures, with each train accounting for up to 300 units. Rail terminals work daily, around the clock. It is common for trains to arrive in the early morning hours to be unloaded for morning availability, and for outbound units to arrive in the afternoon to be loaded on outbound trains that night. As a result, the daily and weekly workload at rail terminals does not peak as dramatically as at marine terminals.

Daily train service also leads to much shorter unit dwell times at rail terminals, especially for outbound moves. Inbound units arriving on trains may wait a day or two for customers, but outbound units will generally be put on a train in less than 24 hours. By comparison, at marine terminals, import dwell times average about 2-4 days and export dwell times are typically 5-7 days. The shorter dwell times at rail terminals allow more frequent turnover of parking spaces and correspondingly higher annual throughput capacity for the same acreage.

Rail terminals also have far more flexibility in handling trains than marine terminals have in handling ships. Large rail terminals have multiple loading tracks and can shift trains or parts of trains between loading tracks and nearby storage tracks as required. Moreover, a car or set of cars that arrived from one destination rarely needs to go back where it came from, so the terminal manager can load the cars that came from Chicago with containers for Houston and send them out on the Houston train. In contrast, outbound marine containers are booked for specific voyages of specific vessels. Marine terminals do not shift vessels between berths or handle them out of order.

Arrival variability is also a pertinent difference. In major corridors intermodal train performance is relatively predictable. Train arrivals are likely to vary by only a few hours at most. Vessel arrivals, however, may vary by a full shift or a day or more, greatly complicating terminal planning and operations.

Cost Modeling

Tioga developed its Terminal Cost Model to estimate the short- and long-term unit operating costs of an intermodal rail terminal. The model was originally developed to assist terminal operating companies, and has also been used by ports and terminal owners. Inputs to the model provide for realistic operating and activity scenarios. Outputs from the model include the unit operating costs, the productivity of the various labor classifications, and capital assets (Exhibit 105). The model provides for annualized land and capital costs and other expenses that are borne by all the stakeholders.

Exhibit 105: Tioga Terminal Model Sample Output

Cost Category	Case 1	Case 2	Case 3	Comments and Cost Factors
Volume	26,000	52,000	135,200	
Mangement	1	2	4	
Lift Labor	4	6	10	$ 20/Hour
Clerical Labor	3	5	8	$ 15/Hour
Mechanical Labor	1	2	4	$ 25/Hour
Lift Machines	1	2	4	Side loaders, Mixed new/used
Yard Tractors	2	4	9	Mixed new/used
Switch Engine	1	1	1	Owner function (could be contractor)
Crews	1	2	2	Shifts per day
Acres	70	70	70	Purchase total acrage at start
Land	$ 17,500,000	$ 17,500,000	$ 17,500,000	$250,000 per acre
Construction	$ 6,500,000	$ 13,000,000	$ 33,800,000	$500K per acre and 2000 lifts per acre
Estimates				
Contractor's Lift Rate	$ 23.77	$ 22.70	$ 19.71	
Gate Cost per Lift	$ 9.24	$ 6.16	$ 7.37	
Owner Operating Cost	$ 15.47	$ 14.35	$ 5.98	Mainly the switch engine
Annual Facility Cost	$ 26.37	$ 26.37	$ 26.37	Construction
Annual Land Cost	$ 67.31	$ 33.65	$ 12.94	Return on land
Total Annual Cost per Lift	$ 142.16	$ 103.23	$ 72.37	
Average Operating Cost per Lift	**$ 48.49**	**$ 43.21**	**$ 33.06**	

Volume and Schedule Information. The model produces a unit price based on average volume and productivity information, and a projected weekly operating schedule.

Labor Costs. The model calculates the average hourly cost of labor including fringes based on the specific provisions of the labor contract and the seniority profile of the work force.

Productivity. The model accepts detailed industrial engineering data regarding the terminal's specific equipment, configuration, and operating schedule. For projected terminals lacking detailed data, Tioga applies standard data for typical equipment and design features.

Equipment and Fuel Costs. This model accepts specific new and used equipment costs based on the age and condition of individual lift machines, yard tractors, and other equipment operated by the terminal contractor. Maintenance costs are calculated based on typical preventive maintenance practices and labor costs as described above. Fuel costs are calculated based on local fuel cost and specific equipment usage rates.

Other Operating Costs. Other operating costs such as utilities, security, ordinary terminal maintenance, terminal operator's profit, etc., are included based on typical industry operating practices.

Capital Costs. Tioga's model expresses land, facility, and other large capital costs as unit costs based on expected life volumes and interest rates.

Outputs from the model include the cost per unit of the terminal operation, the productivity of the various labor crafts, and capital assets. Unit costs can be displayed for any required cost element. As an in-kind contribution, Tioga offered to use the intermodal terminal productivity and cost model to analyze potential productivity measures and their applicability to marine container terminals.

Scenarios

Tioga developed six hypothetical scenarios based on a notional 50-acre rail intermodal terminal with differing operating assumptions, each of which is applicable to rail and marine terminal development. The scenarios are designed to illustrate the impact of the value of land on a railroad's terminal development strategy.

Scenario 1. This scenario represents the situation faced by a new terminal developer in the Midwest during the current recession. Land is plentiful and free. A developer will provide the land to a prospective intermodal terminal for free in the expectation that landing this "anchor tenant" will enhance the value of nearby properties. The basic assumption is that land is free and the terminal will operate at 2,000 lifts per acre, 100,000 lifts annually. This is a common, medium-sized intermodal facility. Yard labor productivity is estimated at 4.29 lifts per man-hour, which is relatively high, and the capital cost allocation for terminal equipment ownership is estimated at $3.28 per lift.

The Tioga model estimated the expected full price per lift for this terminal at approximately $60 per lift. This includes all the operating costs, equipment cost, and facility costs. Capital costs are annualized assuming standard finance lives and salvage values. Operating costs include rail switch crews, facility costs, terminal operator costs, and terminal owner costs. A breakdown by cost category is included in Table 1 below.

Scenario 2. This scenario is identical to Scenario 1 except that land costs are more typical, $100,000 per acre. This adds $4 per lift to the previous scenario.

Scenario 3. This scenario is the same as Scenario 1 and 2 except that land is assumed to be much more expensive at $1,000,000 per acre. This makes the full cost of the terminal $100 per lift. This scenario is unrealistic in that management actions would be taken to preclude this kind of operation. Most likely the land would be sold at a profit, and, if warranted, a new, less costly location for the intermodal terminal would be sought.

Scenario 4. This scenario assumes a high land cost and a throughput of 5,000 lifts per acre, for a total of 250,000 lifts on the same acreage. This is the kind of mixed wheeled/grounded operation found in large cities, most often in legacy terminals. The railroad has taken frequent commercial action to minimize equipment dwell. Empty containers and bare chassis are stacked, and, in some cases, loads are also stacked.

In this scenario, labor and equipment costs are increased to produce the gain in throughput. Yard labor is assumed to be 2.45 lifts per man hour and terminal equipment costs have risen to $6.63 per lift. The full cost stands at approximately $70 per lift, more than the simple terminals in Scenario 1 or 2, but clearly better than Scenario 3.

Scenario 5. This scenario represents a major commitment to developing a system that will produce a very large number of lifts in one place, very economically. Wide-span Kone cranes have recently been installed by BNSF in Memphis and in their near dock terminal in Seattle. Similar Keunz cranes are currently being installed in North Baltimore, OH, by CSX. The cranes span 300'+ and cost about $5 million per unit. The cranes do not require yard tractors; yard labor productivity is assumed to increase to nearly 7 lifts per man hour, a rate nearly unheard of in a conventionally operated facility. The equipment cost per lift is assumed to increase to over $ 8 per lift.

Tioga used its model to estimate the costs at $45 per lift assuming the volume at 10,000 lifts per acre. This analysis is theoretical, as the technology is very new and actual cost data are not available.

Scenario 6. This scenario represents a calculation of the risks associated with a commitment to the new technology. Should the anticipated throughput not materialize, lift costs could get very high. At 5,000 lifts per acre, the costs are estimated at $75 per lift.

The table in Exhibit 106 summarizes these results.

Exhibit 106: Cost Comparisons

Case	Type	Land Cost per Acre	Lifts per Acre	Yard Cost per Lift	Admin Cost per Lift	Switching Cost per Lift	Ownership Cost per Lift	Facility Cost per Lift	Land Cost per Lift	Total Cost per Lift
1	Wheeled	$ -	2,000	$19.89	$9.69	$8.54	$3.29	$17.73	$ -	$59.14
2	Wheeled	$100,000	2,000	$19.89	$9.69	$8.54	$3.29	$17.73	$4.16	$63.29
3	Wheeled	$1,000,000	2,000	$19.89	$9.69	$8.54	$3.29	$17.73	$41.57	$100.70
4	Mixed	$1,000,000	5,000	$31.55	$8.03	$5.87	$1.91	$7.09	$16.63	$71.08
5	Grounded	$1,000,000	10,000	$16.35	$5.88	$2.93	$1.96	$7.09	$8.31	$42.53
6	Grounded	$1,000,000	5,000	$27.89	$8.03	$5.87	$1.91	$14.18	$16.63	$74.51

Location is Notional--All costs are general estimates

Yard Cost Per Lift--Yard Equipment and Labor
Admin Cost Per Lift--Terminal Gate and Administrative Functions
Switch Cost Per Lift--Switch Engine and Crew
Owner Cost Per Lift--Utilities, Security, Owner's Supervision
Facility Cost Per Lift--Facility Construction
Land--Land Cost

As the case study shows, land costs represent about $4 or less per lift at a typical wheeled intermodal terminal, less than 10% of the fully allocated cost per lift. When land costs increase, this cost grows proportionally until costly land saving strategies are instituted. These strategies result in an increase in the cost per lift as throughput per acre grows, but the cost increase is less than the cost of expansion property.

Scenario 5 shows that CSX and BNSF’s new wide crane technology holds some promise for low cost terminal handling, but only if a very high volume is maintained and most likely only in a fully stacked environment.