# ASSESSING CONTAINER TERMINAL PRODUCTIVITY

***Experiences of the Ports of Los Angeles and Long Beach***

## AR 05-06

P.I. : Hanh Dam Le-Griffin, Ph.D.
Department of Civil and Environmental Engineering
University of Southern California

METRANS APPLIED RESEARCH PROJECT

February, 2008

# DISCLAIMER

The content of this report reflects the views of the author, who is solely responsible for the accuracy of the information presented herein. The study was based on several field surveys and managerial and expert interviews conducted by the author with a number of industrial representatives. These participants, however, assume no liability for the contents or views presented in this report.

# ACKNOWLEDMENT

As the principal investigator of this project, I would like to acknowledge the financial and intellectual support of METRANS and my colleagues at both the University of Southern California (USC) and California State University Long Beach (CSULB). METRANS is a U.S. Department of Transportation (DOT) designated University Transportation Center devoted to solving the transportation problems confronting major metropolitan areas through an integrated approach that blends the disciplines of engineering, policy, planning, public administration, and business administration. With its multi-modal orientation, and emphasis on goods movement, freight infrastructure capacity, and transit and highway infrastructure renewal, METRANS was an ideal sponsor and host organization for the research conducted for this project.

In addition, I would like to specially thank various terminal operators, whose names shall remain confidential as per their request, at the Port of NY/NJ, ports of Seattle and Tacoma, Port of Oakland, Port of Vancouver, Port of Manzanillo, and the ports of Long Beach and Los Angeles, for their valuable support in contributing time and expert opinions throughout the series of meetings and interviews conducted for this study. Their contributions of data and unique insights into the operating environment and concerns of commercial entities were generously provided and greatly appreciated.

Sincere thanks are due as well to the dedicated and resourceful staff at CSULB and CITT for their considerate and consistent support in the production of this research. The research assistant for this project, Melissa Murphy, deserves particular thanks and credit for her diligent and thoughtful efforts in the production of this work, enthusiasm for the subject and professional approach, all of which made it a pleasure to work with her on this project.

Principal Investigator
Hanh Dam Le-Griffin, Ph.D.
Department of Civil and Environmental Engineering
University of Southern California

# ABSTRACT

The past two decades have witnessed the emergence of a global trading and shipping system, and within this system ports have become key nodal points serving an ever increasing volume of container traffic. The continued growth in trade volume and dynamic aspects of the world's shipping industry, such as the use of distribution channels to permit distant production and in-transit inventory management (Just-in-Time, JIT) strategies, demand that ports improve their operational productivity and managerial efficiencies to enhance overall cargo handling capacity and the efficiency of their cargo handling systems.

Pure physical expansion is constrained by a limited supply of available land and escalating environmental concerns, especially for urban center ports such as the port of Los Angeles and Long Beach (POLA-POLB). For local and regional authorities, the expansion of port capacity in developed urban settings, or through the creation of newly reclaimed space, represents a costly and procedurally difficult choice. For the larger community, expanding port cargo handling capacity by improving the productivity of existing terminal facilities appears to be the course of action they would prefer to see the ports take. Existing political realities require that improvements in cargo handling capacity be accomplished with a sufficient mitigation of adverse environmental and social impacts. Meeting these environmental and social expectations while improving productivity sufficiently to accommodate both existing and anticipated demand in container volume, however, presents a daunting challenge for terminal operators and port authorities, particularly within the port operating regimen as currently found in the U.S.

Given these challenging circumstances, a key objective of this study is to assess the current operating performance and the future level of productivity required for container terminals operating at POLA/POLB. This sets the stage for an evaluation of the extent to which POLA/POLB capacity can be expanded through productivity improvements. Considering the existing operating environment at POLA/POLB, the answers to these questions assist in highlighting significant challenges that hinder a desirable level of terminal productivity, and help to identify appropriate improvement strategies.

# TABLE OF CONTENTS

# LIST OF TABLES AND FIGURES

# 1. INTRODUCTION

Throughout most of maritime history, the competitiveness of a commercial port has been collectively determined by its geographic location, its physical characteristics, and its relationship to landside transportation systems and urban centers. And while these factors remain important, today's ports must also integrate and balance a number of dynamic market-place processes—including globalization, containerization, and modern logistics—as they work to define their particular competitive position. The past two decades have witnessed the emergence of a global trading and shipping system, and within this system ports have become key nodal points serving an ever increasing volume of container traffic. The continued growth in trade volume and dynamic aspects of the world's shipping industry, such as the use of distribution channels to permit distant production and in-transit inventory management (Just-in-Time, JIT) strategies, demand that ports improve their operational productivity and managerial efficiencies to enhance overall cargo handling capacity and the efficiency of their cargo handling systems, whereas earlier challenges could often be met with physical expansion and engineering solutions.

Pure physical expansion is constrained by a limited supply of available land and escalating environmental concerns, especially for urban center ports such as the port of Los Angeles and Long Beach (POLA-POLB). For local and regional authorities, the expansion of port capacity in developed urban settings, or through the creation of newly reclaimed space, represents a costly and procedurally difficult choice. For the larger community, expanding port cargo handling capacity by improving the productivity of existing terminal facilities appears to be the course of action they would prefer to see the ports take. Existing political realities require that improvements in cargo handling capacity be accomplished with a sufficient mitigation of adverse environmental and social impacts. In this context, expanding port capacity by improving the productivity of terminal operations appears to be the most immediately viable solution for terminal operators. Meeting these environmental and social expectations while improving productivity sufficiently to accommodate both existing and anticipated demand in container volume, however, presents a daunting challenge for terminal operators and port authorities, particularly within the port operating regimen as currently found in the U.S.

Given these challenging circumstances, a key objective of this study is to assess the current operating performance and the future level of productivity required for container terminals operating at the ports of Los Angeles and Long Beach (POLA/POLB). In this report we first present a brief survey of POLA/POLB facilities and cargo handling characteristics, along with basic definitions and concepts of performance measures commonly used by the industry to define port productivity. This information provides the background for discussions on container terminal productivity and why productivity, as measured by these indicators, varies so significantly between different ports. With this, current performances of POLA/POLB are assessed by conducting an overall analysis on where POLA/POLB stand among U.S. and selected international container ports in terms of operational productivity. Following this overall assessment an analysis of the relationship between productivity and future capacities necessary to accommodate projected container volumes at POLA/POLB will be provided. The economic benefits associated with improved port productivity, as perceived by various stakeholders with an interest in enhanced productivity, leads to a discussion on the challenges of improving terminal productivity, particularly from the terminal operators' perspective. This analysis also takes into consideration whether maximizing the value of these productivity indicators is the most appropriate goal for terminal operators, given the unique operating environment of their particular port. This sets the stage for an evaluation of the extent to which POLA/POLB capacity can be expanded through productivity improvements. Considering the existing operating environment at POLA/POLB, the answers to these questions assist in highlighting significant challenges that hinder a desirable level of terminal productivity, and help to identify appropriate improvement strategies.

## 2. TERMINAL OPERATIONAL GOALS AND PRODUCTIVITY MEASURES

The basic function of a container terminal is the *transfer* and *storage* of containers. Terminal operators are accordingly attentive in maximizing operational velocity as containers are transferred from ship to shore, to the container yards (CYs), and through the terminal gates; as well as with efficiently utilizing available terminal space as containers are frequently stored at terminal CYs for a period of time (days) before being received by customers.

Performance indices commonly used by the parties interested in port terminal productivity can be classified into two groups: Group 1 includes indices that measure terminal facility utilization; and Group 2 measures terminal operational performances. Most common indices used to measure annual average facility utilization include *berth utilization*—TEUs per meter (or foot) of container quays; *crane utilization*—TEUs per quayside container gantry crane, and terminal *land utilization*—TEUs per acre of terminal space. These measures serve as an aggregate measure of productivity and provide an indication of how well capital investments in container handling facilities at each port terminal are being utilized, as well as of the cargo handling capacity in-place to accommodate projected growth in demand. These measures tend to vary among ports depending on a terminal's performance level and the differing capabilities inherent in alternative trade patterns, cargo profiles and vessel sizes.

On the other hand, indices that measure container handling performance are directly related to the transfer functions of a container terminal, including the movement rate of ship-to-shore operations or *berth productivity*, the movement rate of gate transactions or *gate productivity* and *turn-time for truck*. Berth productivity is often measured by the number of **moves per hour** for the total gross time a vessel is being serviced at berth. Generally, berth productivity is determined by crane productivity—the movement rate of a quay crane (QC) [**moves per crane-hour**], the number of QCs used per serviced vessel, the productivity of workers employed at quay side [i.e. **moves per man-hour**], and also the technology or type of yard equipment used (because congestion occurring in the container yard can often create backup traffic in the quay area). Ocean carriers, with their current deployment of large capacity vessels of 8,000-plus TEUs, are more and more demanding a faster container handling speed to minimize the time spent at dock (i.e. reduce **turn times of a vessel**). As quayside is the most important interface between the terminal and its premium customers—ocean carriers—improving berth productivity is strategically important to terminal operators. Gate productivity, on the other hand, measures the movement rate of gate operations [i.e. **moves per hour** of gate operation] which is often determined by the number of gate lanes/booths; by an efficient arrangement of gate operations; by the type of gate transaction; and most importantly, by the technology or type of the data processing system used in processing gate transactions. The rapid growth of container volume in recent years has stimulated large investments in advanced information and processing technologies for gate operations at many POLA/POLB terminals. This has significantly reduced transaction time at gate and consequently the wait times of trucks at the terminal gate. "Truck turn time" refers to the time it takes to drop off and/or pick up a container at a specific terminal; counting from the time when a truck arrives at the in-gate to the time it leaves the out-gate. Regardless of whether the nature of a transaction is single (i.e. only to pick up or drop off a container) or double (i.e. drop off a container and pick up another container), truck turn time includes the time it takes to drop-off and/or pickup a container at a terminal CY, and the time it takes for a truck to process through both the in- and out-gate. With conventional technology as currently employed in CY operations at many US ports (i.e. manually operated Rubber Tired Gantry crane, RTG), the time it takes to drop-off and receive a container at a CY is significantly different between terminals with high storage density (i.e. high-stack container storage configuration) and a terminal using an "on-wheels" storage configuration. In the absence of advanced technology, increased storage density achieved by stacking containers in several tiers will often reduce the operational accessibility to a specific container, and as a result increase the time it takes to retrieve or receive an import container by truck; that is, space utilization and truck-turn times are inversely related in this circumstance. Similar to improved berth productivity, which is important to the continuing relationship between a terminal operator and its waterside customers—the ocean carriers, faster truck turn times is an attractive level of service measure for the terminal's landside customers—the cargo owners; shippers and consignees.

To this point, it is important to keep in mind that there is an inverse correlation between improved land utilization—the efficient use of available terminal acreage, and performance in terms of faster truck-turn times—a service quality often demanded by shippers and consignees. The degree of this inverse relationship will narrow according to the level of advanced technology being used, particularly for CY and gate operations. Again, in the absence of advance technology, the challenge for terminal operators is to define the configuration of container storage density in relation to a specific range of truck-turn times as required to guarantee a level of service to their customers in accordance with terminal customer contract agreements.

**Table 1:___Common Productivity Measures of Container Terminals**

| Element of Terminal | Measure of Productivity | Measure |
|---|---|---|
| **Crane** | Crane Utilization<br>Crane Productivity | TEUs/year per Crane<br>Moves per Crane-Hour |
| **Berth** | Berth Utilization<br>Service Time | Vessels/year per Berth<br>Vessel Service Time (hrs.) |
| **Yard** | Land Utilization<br>Storage Productivity | TEUs/year per Gross Acre<br>TEUs/Storage Acre |
| **Gate** | Gate Througput<br>Truck Turnaround Time | Containers/hour/lane<br>Truck Time in Terminal |
| **Gang** | Labor Productivity | Number of Moves/man-hour |

Overall, productivity of a container terminal is influenced by a range of factors, only some of which can be controlled by terminal operators (DOWD at el, 1990). Factors internal to the terminal and under the control of the operator include terminal land use arrangements, capital resources invested, and, to a certain extent, labor productivity. External factors beyond the control of operators include trade volumes, shipping patterns, and the ratio of import to export containers (which influences the number of empty containers handled at a terminal and the availability of container chassis). The size and type of ships calling at a terminal, as well as the landside capacities and performance of intermodal rail and highway systems, are additional external factors affecting the productivity of terminal operations.

All of the indicators of terminal productivity presented in Table 1 are used in one fashion or another in conducting productivity analyses. However, obtaining reliable and consistent data for many of these indicators presents a continuing challenge. A uniform system for evaluating the productivity of container terminals would require the disclosure of a substantial amount of terminal-level data, data which terminal operators generally consider to be proprietary in nature. Moreover, as confirmed over the course of this investigation, no public source or single point exists for information on port/terminal performance measures, including official port websites and those of other port-related organizations, such as the Pacific Maritime Association (PMA). This lack of performance data can be attributed to the situation where, until now, there has been no need to establish a public mechanism to monitor or report on terminal performance: this information has been of interest primarily to terminal operators and, to a lesser extent, port authorities.

In addition to the issue of data availability, care should be taken when these indicators are used for cross-port/terminal comparison purposes. How to interpret the productivity figure is very important, it is not always the more is the better. Every port, or terminal at the same port, has its own physical characteristics and operational practices stemming from physical and institutional conditions and business agreements (i.e. customer contract agreements) that dictate its potential level of productivity. In other words, every port/terminal has its specific set of performance indicators and the value of these indicators is often calculated based on specific physical and institutional variables and operational goals. An optimal solution relative to a specific indicator will depend on how the specific variables for that port/terminal constrain its performance. Thus, using these performance statistics for the purpose of relative productivity comparisons among terminals or ports can often lead to misplaced efforts to improve the productivity of particular operational elements while disregarding the economic efficiency of the entire containerization system. Taking the land productivity indicator—the number of TEUs handled per acre at the terminal, as a typical example, a lower figure is often interpreted as being less productive in a cross comparison chart. The real interpretation of this figure, however, actually depends on the economics of the container port/terminal operation in different regions. For example, one would expect “lower” land productivity in the region when land is cheap and labor is expensive. Perhaps the best use of the TEUs/acre indicator is as an initial indicator of the potential additional capacity any particular terminal should be able to accommodate. The TEUs/acre indicator of a port, taken in reference to the acceptable industry average of 6,500 TEUs/acre, suggests how much capacity is available, given the operational economic characteristics of that port. A port with an indicator of 4,000 TEUs/acre, for example, is performing more than 50% below the industry practical level, suggesting that capacity improvements are possible, and that the evaluation of productivity options should look at relative land and labor costs as components of the operational environment.

Because of this, comparisons of productivity between major container ports and terminals are usually made at a high level of aggregation based mostly on publicly available data, such as facility characteristics and physical resources (e.g. number of berths, total length of container handling quayage and total terminal acreage) and annual throughput demand (e.g. volume handled in TEUs). Counts of total throughput and average utilization levels of port/terminal facilities such as TEUs handled per year, TEUs per linear foot of container quays, and TEUs per acre of terminal area, for example, are commonly used to gauge the relative productivity of a port/terminal. Though these measures are clearly instructive in certain respects, when they are used for the purpose of comparisons among ports they should be used advisedly owing to the varying capabilities inherent with different patterns of trade, cargo profiles and vessel sizes that are externally characterized and particular for a specific port.

Measures that are less aggregated and more directly related to a specific performance characteristic, such as “moves per crane-hour” or “average service time” of a vessel, are not publicly available and often lack uniformity. Some terminals measure “service time” as the total time a vessel is berthed at the terminal. Other terminals only count the time a ship is actually worked, excluding waiting/standby time and shift breaks. And shift break rules can vary between terminals, all of which causes “service time” to be an inconsistent measure of relative terminal productivity. Due to the lack of a publicly available resource, most of performance data used in this study and analysis was obtained through surveys and interviews conducted directly with terminal operators at a number of U.S. and international ports, or from industry documents. The ultimate goal of this study is not to criticize the performance of POLA/POLB container terminals, but rather, though a better understanding of the value, nature, impact and influence of their performance measures, to identify the possible cargo handling capacities relative to future growth that can be achieved with various investment and operational options.

# 3. POLA/POLB TERMINAL PRODUCTIVITY

## 3.1 Overview of Port Facilities and Operating Characteristics

In 2006, the ports of Los Angeles and Long Beach, as a complex, were the busiest container port in the United States, and the 5th busiest in the world. Although these ports also handle non-containerized cargo, they are primarily container ports, with containers representing 76% of all cargo handled (PMA Statistics, 2006). In 2006 POLA/POLB handled about 15.8 million TEUs of exports, imports and empty boxes. About 78 percent of the ports' loaded containerized cargo was inbound (Port Statistics 2006).

In contrast with the major transshipment centers of Hong Kong, Singapore, Rotterdam, or terminals at the Panama Canal where a large share of containerized cargo is transshipment, most containerized cargo currently handled at POLA/POLB is destined for the U.S. market, with a small percentage destined for Canada and Mexico. This being the case, POLA/POLB is characterized as an origin-destination type port, as opposed to the transshipment-center type. For origin-destination type ports, cargo handling capability and the capacity of landside operations and facilities are the most important elements of terminal productivity. In particular, the capacity and efficiency of marshalling yards (CYs) and terminal gates determine the necessary handling capacity of a terminal. Conversely, for load-center ports, the waterside operation of berths and quayside container cranes are the more important determinants of productivity.

Physical characteristics of POLA/POLB container terminal facilities are summarized in Table 2 in terms of the number of container berths, total terminal acreages, total quay length, and number of quay cranes as of 2006. For data on POLA, two West Basin Container Terminals are combined and counted as one terminal. Also, Port of Los Angeles Container Terminal (Berths 206-209) is currently not active terminal and thus is not included in this table.

**Table 2:___Physical Characteristics of POLA/POLB Terminals**

| | Container Terminal | No. Container Berths | Total Terminal Acrage | Quay Length (ft) | No. Quay Cranes |
|---|---|---|---|---|---|
| **POLB** | Terminal 1 | 3 | 170 | 3600 | 10 |
| | Terminal 2 | 2 | 57 | 1800 | 3 |
| | Terminal 3 | 2 | 125 | 2100 | 5 |
| | Terminal 4 | 3 | 105 | 2750 | 7 |
| | Terminal 5 | 5 | 246 | 6379 | 19 |
| | Terminal 6 | 5 | 256 | 5500 | 13 |
| | Terminal 7 | 4 | 380 | 5000 | 14 |
| | | **24** | **1339** | **27129** | **71** |
| **POLA** | Terminal 8 | 5 | 257 | 5000 | 11 |
| | Terminal 9 | 5 | 173 | 3050 | 11 |
| | Termnal 10 | 5 | 185 | 5800 | 10 |
| | Terminal 11 | 3 | 195 | 4700 | 8 |
| | Terminal 12 | 4 | 292 | 4000 | 12 |
| | Terminal 13 | 6 | 484 | 6500 | 14 |
| | | **28** | **1586** | **29050** | **66** |

The existing container handling facilities and associated infrastructure, in terms of container terminal acreage, container quay length, and number of quay cranes, is compared with container throughput (TEUs) handled by POLA/POLB and other major US, Asian and European ports in 2006 to examine the utilization level of these facilities for POLA/POLB in comparison with other ports. The results of indicators on land utilization (TEUs/acre per year), quay productivity (TEUs/foot of berth per year) and quayside container crane productivity (TEUs/crane per year) are summarized in Table 3.

**Table 3:___Facility Utilization of Major US and International Container Ports**

| Port | 2006 Volume ('000 TEUs) | Gross TEUs/Acre | TEUs/berth ft | TEUs/Crane |
|---|---|---|---|---|
| **POLB** | 7,290 | 5,444 | 269 | 102,676 |
| **POLA** | 8,470 | 5,340 | 292 | 128,333 |
| **Vancouver** | 2,208 | 5,686 | 236 | 116,211 |
| **Seattle** | 1,987 | 3,950 | 176 | 79,480 |
| **Tacoma** | 2,067 | 4,210 | 229 | 89,870 |
| **Oakland** | 2,391 | 3,150 | 109 | 62,921 |
| **NYNJ** | 5,128 | 4,773 | 209 | 111,487 |
| **H.Road** | 2,046 | 2,092 | 185 | 81,840 |
| **Savannah** | 2,042 | 1,450 | 125 | 113,444 |
| **Charleston** | 1,987 | 5,030 | 203 | 94,619 |
| **Singapore** | 24,792 | 25,798 | 643 | 210,102 |
| **Shanghai** | 21,719 | 26,487 | 1052 | 212,931 |
| **TPT** | 4,700 | 15,825 | 398 | 174,074 |
| **Hamburg** | 8,862 | 6,623 | 292 | 121,397 |
| **Rotterdam** | 9,690 | 8,022 | 293 | 142,500 |
| **Mexico*** | 659 | 10,138 | 254 | 164,750 |
| **Panama*** | 2,366 | 9,389 | 247 | 102,870 |

Source: Based on the Lloy's List Ports of the World 2007 and Ports' documents.
Notes: TPT: Port of Tanjung Pelapas, Malaysia
* Based on data of a representative terminal only

As the results show, POLA/POLB quay productivity is clearly higher than that of other major American ports, and was not too far behind major European ports on this measure as these ports compare to the premium ports in Asia. In terms of the average utilization of quayside container cranes, however, POLA/POLB position is not that straightforward. As POLA/POLB remain higher than other U.S. West Coast (USWC) ports, their position is lower to some U.S. East Coast (USEC) ports as well as other major ports in Asia, Europe and the Americas. Larger and faster cranes, serving increasingly larger vessels, are the primary basis for rising quay and gantry crane utilization rates. The drive to larger cranes has been created by the increasing size of containerships, with operators pressing for these larger vessels to be turned around in the same time as preceding generations of smaller vessels. The highest rates of productivity on these measures are achievable at deep-sea ports, where average vessel and consignment sizes are highest. Also, higher productivity is also possible at ports with large percentage of transshipment volumes, as discussed earlier.

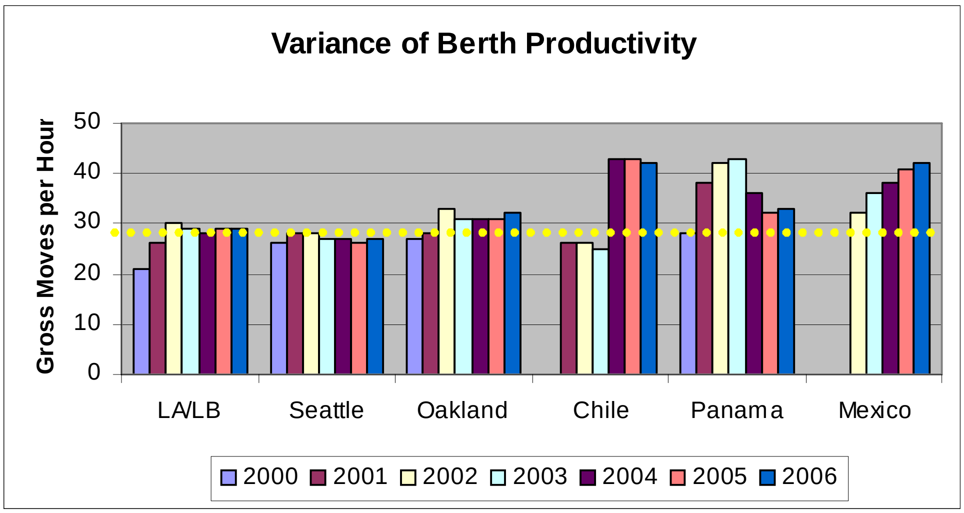
## 3.2 POLA/POLB Terminals Productivity: A Comparative Analysis

The rapid growth of container volume handled by POLA/POLB has called for major improvements in container handing capacity and overall operational productivity. Transferring and storing containers are the basic functions of a modern container terminal including POLA/POLB. As mentioned earlier, terminal operators are accordingly attentive in maximizing operational velocity as containers are transferred from ship to shore, to the container yards (CYs), and through the terminal gates; as well as with efficiently utilizing available terminal space as containers are frequently stored at terminal CYs for a period of time (days) before being received by customers. In this section, an analysis is conducted regarding the productivity of container handling for POLA/POLB terminals, in terms of *Berth Productivity* and *Land Utilization*. Productivity at POLA/POLB, as gauged by these measures, is compared with that of other North American and international ports whenever possible. Again, due to the possible distortions in data and the varying capabilities inherent with the differing patterns of trade, cargo profiles and vessel sizes found at any particular port, these comparisons between ports should be used advisedly, though they are clearly instructive in certain respects.

### 3.2.1 Berth Productivity (Moves per hour)

Container handling productivity is directly related to the transfer functions of a container terminal, including *berth productivity*. Figure 1 demonstrates the relative level of berth productivity, measured by *average gross moves per hour* for the representative container terminals at several leading U.S. and international ports. Even though POLA/POLB are operating at the rate that is normally acceptable by the industry in the North American port context (gross 28 moves/hr, as indicated by the yellow dotted line in Figure 1), and more or less at the same level of berth productivity as other U.S. ports, by this measure the ports are performing well below the level achieved at international ports. Also, as demonstrated in Figure 1, berth productivity at POLA/POLB has remained generally at the same level through the period of 2000-2006, despite a large increase in container volume during this time. Furthermore, among the terminals in Chile, Panama and Mexico, Panama is the only transshipment terminal, whereas the others are origin-destination (O-D) terminals that mostly handle local cargo, similar to POLA/POLB terminals.

**Figure 1: Berth Productivity (Moves/hour)**




From an operational point of view, terminals handling a high percentage of transshipment cargo can achieve a higher level of productivity. This is because in these operations each container is handled (and counted) twice—and transshipment operations often involve larger vessels capable of using large-block container stowage configurations that allow for continuous loading/unloading operations at one location without frequently repositioning the crane. Also, Transferring operations generally involve mainly the quay and apron areas adjacent to the dock (that allows shortening the movement distance of transfer equipment)—resulting in more moves per hour overall for transshipment operations relative to traditional OD terminal operations. And yet, the performance statistics presented for terminals in Chile and Mexico, which are managed by the same operators as several terminals at POLB, suggest that the high berth productivity levels experienced at these ports are not due solely to the high percentage of transshipment cargo: rather it appears that the inherent operating environment found at various gateway regions may explain a substantial portion of the variance in berth productivity seen among the terminals at POLA/POLB and the others in Figure 1.

In this regard, some of the significant operational differences occurring at these leading international ports would include a 24/7 operating regime and a greater number of quay cranes being used simultaneously to work a vessel. As demonstrated by operations at POLA/POLB, 3 to 4 cranes per vessel are typical, whereas at these international ports 6 to 8 cranes per vessel are a common practice for vessels with carrying capacity of over 6,000 TEUs. According to terminal operators interviewed for this study, these differences in operating practices are partially a result of the current labor/safety and manning rules associated with vessel servicing operations. Local safety rules require a minimum distance between traffic lanes serving a quay crane, and therefore limit the number of working truck lanes to 5 or 6 at most. Furthermore, adding more cranes allows for higher handling rates, but also increases the number of stevedoring and work gangs. Consequently, terminals tend to avoid the option of increasing the number of working cranes to achieve a higher productivity rate if the greater productivity achieved does not generate sufficient revenues to offset the increase in labor costs.

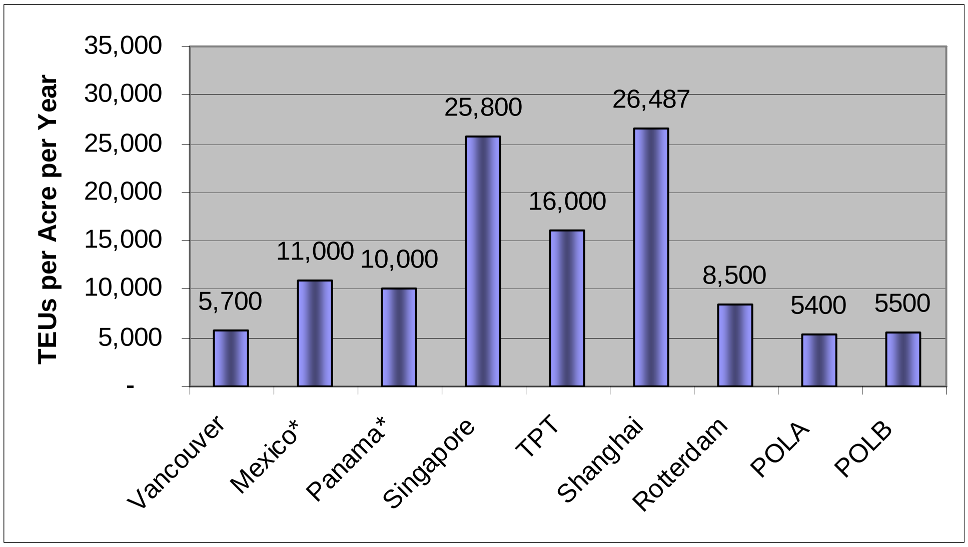
### 3.2.2 Land Utilization (TEUs per acre per year)

The efficient use of available terminal space or *land utilization* relates to the number of containers stored in an area of the terminal (**TEUs/acre per year**). Improving the utilization of container terminal space typically involves higher storage density (i.e. stacking density) and/or shorter storage time (i.e. dwell time) of containers at terminal.

Land utilization rate (Gross TEUs/acre per year) for leading international and U.S. ports was calculated using 2006 throughput data (Million TEUs). As demonstrated in Figure 2, U.S. container port terminals have for years lagged far behind their counterparts in Asia, where ports typically operate 24 hours a day and 7 days a week, and the average utilization rate was over 15,000 TEUs per gross terminal acre in 2006; and also less than northern European premium ports, which achieved 8,600 TEUs in 2006

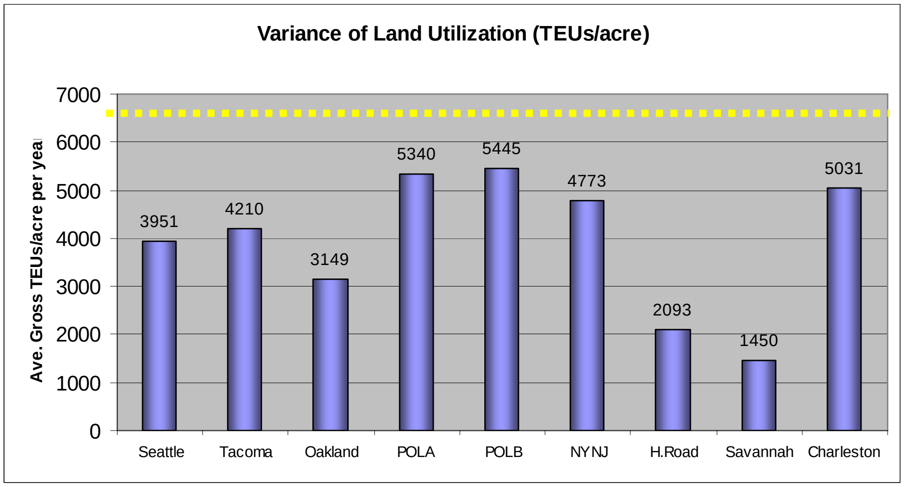
**Figure 2: Land Utilization (TEUs per Acre)**

**—International Comparison—**




The fact that POLA/POLB fall behind terminals in Latin America in term of this land utilization measure, as shown in Figure 2, is somewhat surprising. Like POLA/POLB, a terminal in Manzanillo, Mexico, for example, has experienced fast growth in container volume in recent years. This terminal is operating with a limited terminal space of about 62 acres—one fourth the average terminal acreage of POLA/POLB—and yet this terminal is able to increase stacking density to almost 20,000 TEUs/acre by employing a large block storage of 12 to 15 boxes wide and 7- to 8-high for empty containers, and 6- to 8-wide and 6-high for loaded containers, as a common practice whenever necessary to accommodate increased volumes. Also, the operating environment in this terminal was found to be relatively flexible in terms of terminal land use, labor is trained and allowed to dispatch for different types of work according to a daily demand, and flexible hours of operations.

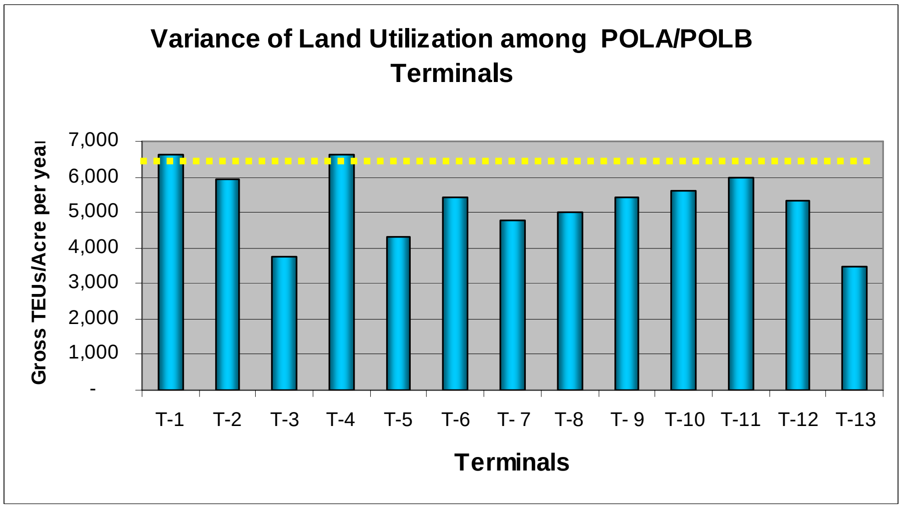
**Figure 3: Land Utilization among US Ports**




Further more, as demonstrated in Figure 3, average gross density (TEUs/acre) of POLA/POLB terminals in 2006 was higher than other U.S. ports, although it was still far behind the industry practical level of 6,500 TEUs/acre (as indicated by the yellow dotted line in Figure 3). Care should be taken, however, as these performance measures are based on gross terminal acreage. The fact that land utilization at POLA/POLB terminals is well under the industry practical level reflects the possible capacity for future growth without requiring significant expansion, based on the level of density as practically accepted by the industry for NA ports context.

Moreover, as showed in Figure 4, land utilization among POLA/POLB terminals varies extensively, with some POLB terminals operating at over 6,600 TEUs per acre per year, and others as low as 3,500 TEUs per acre per year in 2006.

**Figure 4: Land Utilization among POLA/POLB Terminals**[1]




With conventional technology (i.e. typical Rubber Tyred Gantry crane, RTG), increased storage densities (i.e. high-stack container storage configuration) often reduce the operational accessibility to containers, and as a result increase the time it takes to receive an import container by truck. The variance of land utilization levels among POLA/POLB terminals, as shown in Figure 4, reflects the trade-off decision made by terminal management based on the incremental cost of handling operations and the actual availability of space at each terminal.

## 4. PRODUCTIVYT AND POLA/POLB CAPACITY UTILIZATION

Long term investment in POLA/POLB and innovative measures to increase port productivity should be carried out in a coordinated fashion to ensure continued growth and the international gateway status of these ports on the Pacific coast. *Capacity utilization* is a concept that refers to the extent to which a port terminal actually uses its installed cargo handling capacity. Thus, it refers to the relationship between actual container volume handled and the potential container volume that could be practically accommodated with the installed facilities and equipment. As an accepted practice, when capacity utilization rises above somewhere between 75% and 85%,

[1] Per request for confidential consideration, terminal names are omitted. Numbers are used in stead.

terminal operations start showing signs of congestion and thus operating costs will increase. When capacity utilization rises beyond 85% and approaches 100% on a regular basis, operations slowdown and may eventually become halted. On the other hand, excess capacity means that insufficient demand exists to warrant terminal capacity expansion. With this concept, an analysis of container handling capacity utilization for POLA/POLB terminals was conducted in comparison with other ports when possible. Results of this analysis are summarized in Table 4. In this table, capacity utilization for 2005 is based on the actual data and the practical capacity of these terminals in 2006 is calculated based on the current terminal acreages of the North American West Coast (NAWC) ports and the assumption on operating density of 6,000 TEUs/acre per year. This is manageable though slightly higher than the actual average density level of POLA/POLB in 2006, which were 5,445 TEUs/acre and 5,340 TEUs/acre for POLB and POLA, respectively.

**Table 4: Estimated Capacity and Utilization Levels of POLA/POLB**

| | 2005 | | | 2006 (Est. 6000 TEUs/acre p.a.) | | |
|---|---|---|---|---|---|---|
| | Througput ('000 teu) | Capacity ('000 teu p.a.) | Utilization (%) | Througput ('000 teu) | Capacity ('000 teu p.a.) | Utilization (%) |
| POLA | 7,485 | 9,025.0 | 83% | 8470 | 9516 | 89% |
| POLB | 6,710 | 7,834.0 | 86% | 7290 | 8034 | 91% |
| Oakland | 2,273 | 3,810.0 | 60% | 2390 | 4550 | 53% |
| Seattle | 2,088 | 2,766.5 | 75% | 1987 | 3018 | 66% |
| Tacoma | 2,070 | 2,840.5 | 73% | 2067 | 2946 | 70% |
| Vancouver | 1,767 | 2,135.6 | 83% | 2208 | 2330 | 95% |

As these results show, average capacity utilization levels at POLA/POLB are relatively higher than other major NAWC ports in 2005, except for Vancouver. Also, utilization percentages increased noticeably for both ports in 2006 as container volume continued to increase at double-digit rates while capacity development was undertaken during this time at a much slower rate.

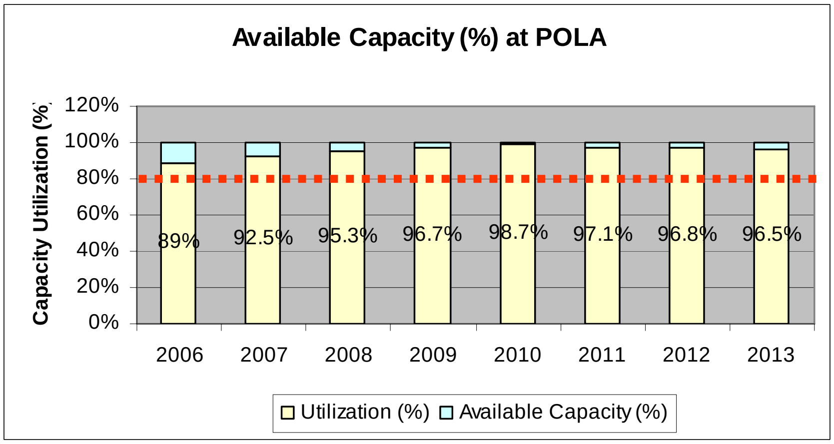
To avoid congestion and to handle projected cargo growth, the ports of POLA/POLB have planned and executed a number of development projects that include the reconfiguration of existing terminals, new terminal developments, and a major landfill project in the West Basin to provide additional acreage for terminal development. At POLA/POLB, major committed and planned container port developments for the period of 2007-2015 include:

- Expansion of China Shipping Terminal in 2007 which provide additional 0.4 million TEUs per year in 2007 and 0.3 million TEUs per year in 2008 to POLA
- New investment in quay site crane at TraPac which provide 0.2 million TEUs per year in 2008 to the port of POLA
- Expansion of Pier T (Pacific) which will provide 0.2 million TEUs per year in 2007 for POLB
- Expansion of Pier T (Hanjin) which will provide additional 0.3 million TEUs per year in 2008 for POLB
- Pier S development in POLB scheduled for 2010 which will provide additional 1.5 million TEUs per year

Although the timing of these development will depend on the pace of demand growth, to assess the capacity utilization for POLA/POLB as presented in Figures 5 and 6, we assume these projects will be carried out as planed and have included the additional capacity provided by these projects in the capacity forecast for POLA/POLB for the period from 2007-2013. Further capacity could be generated if the ports allow other expansion plans to go ahead or by the terminals initiating more vertical operations, that is, by stacking containers instead of storing them on chassis.

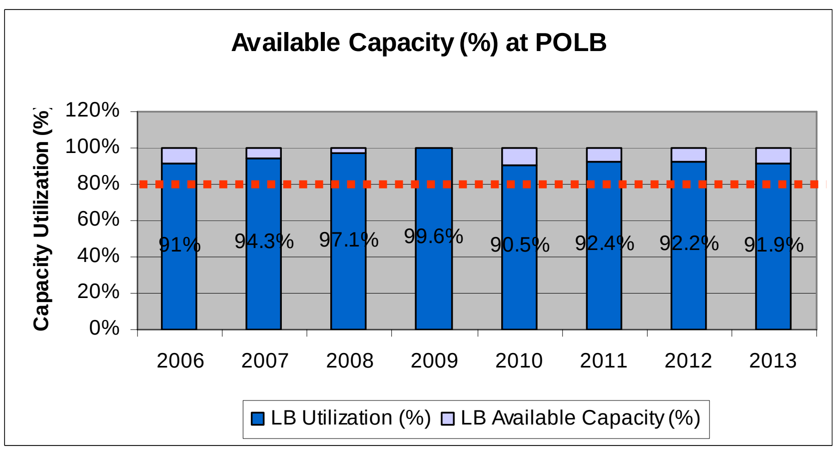
For the forecast of port demand for the period spanning 2007-2013, we assume a compound annual growth rate of 6.5%, with a specific annual growth rate of 8% in 2007, 7% for 2008, with the rate lowering to 3.5% for 2012 and 2013. At these rates of increase, the combined TEU volume for POLA/POLB will nearly double by 2020. Due to the uncertainty of future development plans beyond 2013, in this exercise capacity utilization for POLA/POLB is forecast up to 2013 only.

**Figure 5: Forecast Capacity Utilization of POLA (2007-2013)**




As the capacity utilization forecast in Figure 5 shows for POLA, virtually full utilization rates of 96.7% and 98.7% are reached in 2009 and 2010, leaving little if any opportunities for future capacity growth.

**Figure 6: Forecast Capacity Utilization of POLB (2007-2013)**




Similarly, as demonstrated in Figure 6 for POLB, the port will face the most critical capacity constraints in 2009. As Pier S is scheduled to open in 2010, capacity constraints become somewhat relieved, though operations remain at a relatively high level of capacity utilization (92%), significantly above the industry practical level of 80% to 85%. As POLA/POLB consistently operate at a high level of capacity utilization, the ports will face the prospect of a declining market share due to capacity constraints.

## 5. CAPACITY ENHANCEMENT THROUGH GREATER PRODUCTIVITY

As identified in interviews with terminal operators, a number of strategies to achieve greater cargo handling capacity for POLA/LB have been implemented or are under consideration, including:

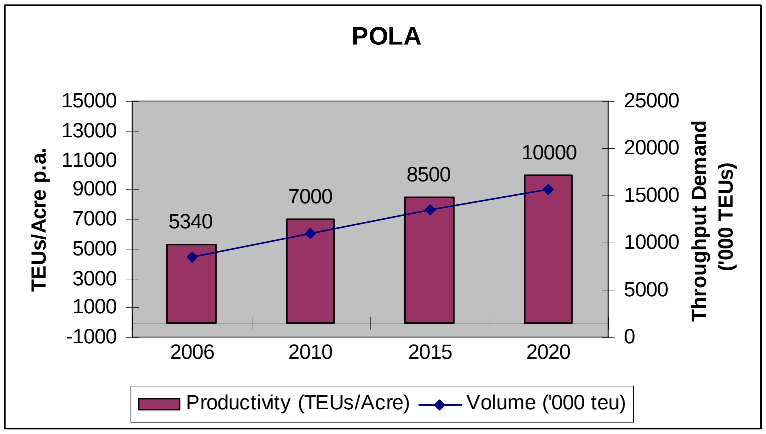
- Expanding hours of operation (i.e. PierPass Program)
- Decreasing dwell times
- Better utilization of terminal land by increasing stacking density
- Increasing utilization of on-dock rail
- Improving velocity—"fluid" movement of containers by dray-away or short-haul rail operations and shuttle trains to off-dock facilities
- Inland container yards—collaborative CYs
- Improving operational efficiency though technology to control labor expenses.

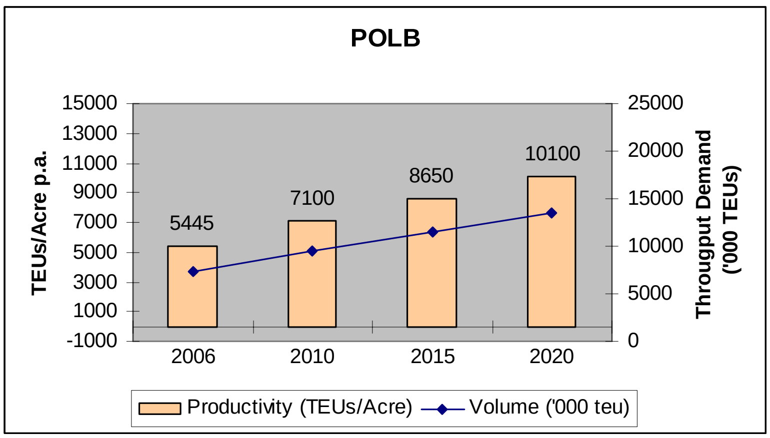
An overall assessment of potential cargo handling capacities for most of the terminals at POLA/POLB consistently shows that future growth will be primarily constrained by limited container yard space. Given this determination, the analyses and discussions in this section focus on those strategies aimed at a better utilization of terminal space.

### 5.1. Increase Land Utilization (TEUs/acre per year)

Even with completion of the expansion projects noted above, which would add only nominal acreage to the ports, POLA/POLB will have to work with almost the same terminal acreage that currently exists, despite the continuing growth in container volume. In this section we will demonstrate how throughput per acre could be improved in accordance with projected demand while maintaining operations at the desired levels of capacity utilization.

**Figure 7: Forecast Productivity per Acre Required at POLA/POLB**



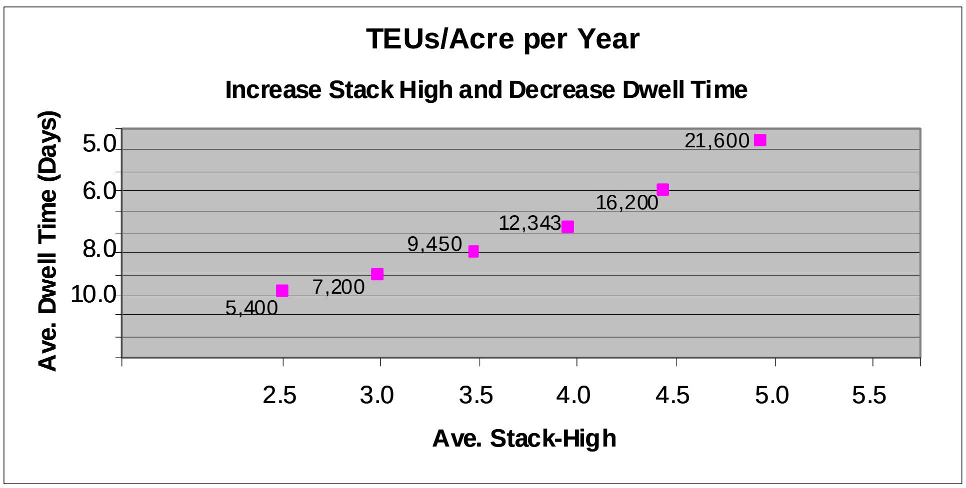




The productivity per acre required to accommodate future growth in demand at POLA and POLB is shown in Figure 7. As these graphics demonstrate, both POLA and POLB will have to double their current productivity (TEUs/acre) to handle forecast growth in throughput. As the current condition of POLB is relatively more constrained in terms of terminal acreage, the productivity level per acre required here is slightly higher than that at the POLA. However, with the development of Pier S comprising an additional 160 acres of terminal space in 2010, the requisite TEUs/acre for POLB will decrease slightly to 7,600 TEUs in 2015, before needing to rise again to 8,900 TEUs/acre level in 2020.

### 5.2. What Will It Take For POLA/POLB to Double Productivity (TEUs/acre/year)?

As currently planned, POLA/POLB terminals will need to at least double their productivity standard in terms of the efficient use of available terminal space to meet the capacity required for projected throughput demand. Improving the utilization of terminal acreage typically involves higher *storage density* and/or shorter storage time (i.e. *dwell time*) of containers at terminal. This means improved horizontal capacity through enhancing vertical and time-space capacity.

**Figure 8: TEUs/Acre per Year as Function of Dwell Time and Stack Height**




Increasing average stack height, from an average of 2.5- to 5-high, for example, will increase terminal static capacity per acre (TEUs/acre), which means that more TEUs can be accommodated per acre at a time. However, when it comes to the measure of storage capacity per-acre/per-year, dwell time (days) is the key factor. With a decrease in the average dwell time of a container in the terminal, say from 10 to 3 days, the dynamic capacity per acre will be increased. Stack height and dwell time are important tools to use, either solely or in combination, to adjust terminal capacity when necessary. These factors, however, also play a role in how a terminal's customers perceive the level of service received. Figure 8 demonstrates the relationship between different productivity levels (TEUs/acre per year) as a function of dwell time and stack height. The resulting TEUs/acre per year shown in this chart (dotted points) are the product of two productive actions: a decrease in dwell time from 10 to 5 days, and an increase stack height from 2.5- to as many as 5-high, accordingly.

As this figure suggests, the current average gross density of 5,400 TEUs/acre per year at POLA/POLB is the result of a combined practice of an average 10-days dwell time and a 2.5 stack height. Current severe trade imbalances result in more empty boxes occupying terminal space (dwell time) for a longer period of time, and the continued practice of storing a high percentage of containers on-chassis (in single tier configurations) may well explain this performance result. To reach the productivity level of around 10,000 TEUs per-acre per-year, as suggested in this case, POLA/POLB should be operating at an average stack height of 4-high and above, and should reduce average dwell time to less than 7 days. It is important to note that the resulting productivity levels and associated factors shown in Figure 8 are based on average gross density level. Net productivity levels could be higher, and vary among POLA/POLB terminals depending on terminal configurations and land uses that affect the ratio of container yard acreage (where containers are actually stored) to total terminal space, including but not limited to wharf, office building, gate and on-dock rail areas.

Furthermore, although in recent years more and more terminals have moved toward stacking operations, storing containers on-chassis (OC) remains the dominant storage method at many POLA/POLB terminals. Many terminals continue to use this method for 100% of their import containers.

**Table 5: TEUs/acre by Different Combination of CY Operations**

| CY Operation | Ave. Dwell Time (days) | Ave. Stack-high | TEUs/acre per Year |
|---|---|---|---|
| Mix of 70% On-Chassis & 30% Stack [Ave.60 TEUs/acre] | 10 | 2.5 | 5,400 |
| | 9 | 3 | 7,200 |
| | 8 | 3.5 | 9,450 |
| | 7 | 4 | 12,343 |
| | 6 | 4.5 | 16,200 |
| | 5 | 5 | 21,600 |
| Mix of 50% On-Chassis & 50% Stack [Ave. 80 TEUs/acre] | 10 | 2.5 | 7,200 |
| | 9 | 3 | 9,600 |
| | 8 | 3.5 | 12,600 |
| | 7 | 4 | 16,457 |
| | 6 | 4.5 | 21,600 |
| | 5 | 5 | 28,800 |

Up to this point, so far as capacity improvement is concerned, switching from on-chassis (OC) storage to a greater use of stacking represents an initial effort for POLA/POLB terminal for dealing with limited terminal space. An example of how a changing percentage of OC operations would change the respective productivity level of a terminal is demonstrated in Table 5. Here two scenarios are considered: 50%-50% and 70%-30%, for OC to Stacking systems respectively. Based on practical experience for the NA port context, a mix of 50%-50% OC to Stack would produce an average of 80 TEU ground slots per acre, while the 70%-30% scenario would result in only an average of 60 TEU ground slots per acre. From this, productivity levels for TEUs/acre per year were calculated at different levels of dwell time and stack height, and the results are summarized in Table 6. As these results suggest, by switching from 70% to 50% on-chassis storage, terminals could achieve higher TEUs/acre per year without imposing changes on dwell time and current stack height. Roughly speaking, for a 100-acre terminal, switching 20% on-chassis operation to a stack system would allow the terminal to accommodate an increase in volume of over 200,000 TEUs plus per year, in accordance with different combinations of dwell time and density levels as applied by a particular terminal.

## 6. CHALLENGES TO BETTER LAND UTILIZATION: A TERMINAL OPERATOR'S PERSPECTIVE

As mentioned earlier, the larger local community and government agencies would prefer that the ports achieve needed increases in capacity by improving the productivity of existing terminal facilities. In practice, implementing this preferred approach to sufficiently improve capacity for future growth presents a particular challenge to terminal operators and port authorities. For terminal operators, a sizable gap exists between this "preferable action" and truly executable and practical options.

The terminal operators interviewed for this study confirm that productivity (TEUs/acre per year) needs to increase to at least a level acceptable relative to other leading world ports to realize enhanced terminal capacity. As independent commercial entities, however, terminal operators must predicate their decisions on productivity in order to achieve three goals at the same time; namely, how to handle additional volumes while maintaining competitive levels of customer service and not unduly increasing operating expenses. In other words, meeting the service level required by major customers under a long-term contract, in terms of the speed and efficiency with which containers are handled, represents an obligation and thus a key factor for many terminals in determining how container storages and facilities/equipment needs are arranged.

As previously noted, with the absence of advanced technology (i.e. quasi or fully automated RMG) increased container densities often increase the time it takes to receive an import container by truck; so, as noted previously, the productivity of TEUs/acre and level of service are inversely related. Based on the experience of POLA/PBOB terminals, it would take 15 to 20 minutes for a truck to receive an import container on-chassis, where as it usually takes 45 minutes to over an hour for a stacked container. Most of this difference is the time it takes to retrieve containers from a stack using current handling technologies employed at the ports. In order to provide a level of service of 15 to 20 minutes as often demanded by customers, terminals ought to use on-wheel storage configurations whenever necessary. The other option would be to add more yard equipment (i.e. more RTGs) to work the container stacks. This means each RTG is assigned to a smaller container stacking block in order to shorten the distance and the time it takes to deliver a container from a respective stack.

For this sole purpose, more equipment employed for almost the same amount of throughput means an increased unit cost ($/TEUs) of container handling operations. Increased unit costs are a result of additional equipment costs (about $2 million per RTG), and a large increase in labor costs. Labor cost calculations are based on the basic wage of $35/hr for straight time plus benefits and the additional man-hours required by the labor rules and manning agreements established in the labor contract. Several terminals find it practical to avoid additional labor costs by deploying other type of yard equipment, such as side/top loaders or reach stackers, which have fewer manning requirements but only work well in less dense yard layouts, as opposed to using conventional RTGs to operate in yard configurations with higher stacking densities. As manning rules in the current labor agreement require 4 labors to operate a RTG, while only one is required to handle a top or side loader, one terminal found their productivity to be 7 to 9 boxes per hour using a RTG, as opposed to 14 to 16 boxes per hour using two top loaders. This single case may not be representative of the productivity experienced in general; however it does clearly demonstrate the relative economic efficiency that low density operations enjoy in the current operating environment at POLA/POLB.

Lagging behind other leading international ports in terms of advanced terminal handling technologies is another concern for terminal operators when considering higher density yard configurations. High-density terminal operations using RTGs and Rail Mounted Gantry (RMGs) cranes are a common feature in Asia and Europe. In these operations, innovative and intelligent technologies are employed along with the use of RTGs or RMGs. In these operating environments, the use of a Terminal Operating System (TOS) or Automated Stacking Cranes (ASCs), as an example, allows terminals to automate and optimize their cargo handling processes. The benefits of the TOS as a planning and management tool are that it will allow terminal operators to obtain accurate real-time information on every operation and therefore undertake interventions if necessary at the appropriate time. The ports of Shanghai, China, Tanjung Pelepas, Malaysia and the port in Rotterdam, which are experiencing record growth in recent years, are among the growing number of ports deploying these innovative operating technologies. By incorporating the auto-positioning system with the use of RTG and RMG, each container's movement and location will be automatically updated. Therefore, the inverse relationship between stacking densities and truck turn times can be significantly reduced or even eliminated. The lesson offered by these examples is that implementation of the TOS is a necessary step toward high density stacking operations. Innovative technologies supported by equipment availability, adequate storage layout, and a re-commitment from worker to increased productivity will allow terminals to handle more containers without having to sacrifice their quality of service, such as turn times for vessels and trucks or higher incremental costs.

At this point, it appears that the ability for POLA/POLB to meet projected growth in container volume by improving productivity of terminal space would be limited under the current operating environment. Constricted on one side by regulatory structures that make physical expansion costly and time consuming, and on the other side by labor agreements that delay the introduction of advanced technologies, the ports are left with a rather narrow range of options to increase cargo handling capacities in order to satisfy persistent customer demands for faster and more reliable service.

## 7. CONCLUSION

Productivity at POLA/POLB is of interest to numerous governmental agencies and communities throughout the Southern California Region, the state, and the nation as a whole. Relative to other port operations in North America, POLA/POLB demonstrate a higher level of productivity; however, when compared to the productivity levels of other leading ports around the world, POLA/POLB generally perform at a significantly lower level of productivity.

Expanding terminal acreage to achieve greater handling capacity does not represent a practical option, due to the high cost of acquiring the necessary land and extensive environmental regulatory requirements. This moves the opportunity to expand cargo handling capacity to an increase in the productivity of existing terminal acreage. When considered in terms of TEUs/acre, if the current rate of port development remains at the same pace as demonstrated in the past decade, POLA/POLB would have to at least double their current levels of productivity in order to accommodate the volume of demand forecast for 2020. Meeting the challenge to perform at this level, however, will be difficult for these ports to achieve. In the port operating environment as it exists in Southern California, long standing labor agreements and operating practices effectively limit the potential for introducing innovative cargo handling technologies. Moreover, manning rules induce higher operating costs as the per acre densities increase, in this case because the full potential of advanced technologies have not, as of yet, been introduced.

In these circumstances, POLA/POLB will be effectively capped at a productivity level of around 10,000 TEUs/acre per year. Achieving productivities greater than this level would require the introduction of advanced technologies, or an expansion of terminal acreage. With the pressures of ever increasing demand continuing to grow, POLA/POLB terminals are being forced into a corner—either labor rules will have to change to allow for the use of advanced technologies that improve productivity without sacrificing service levels and incurring higher incremental costs, or regulatory structures need to be loosened to permit the needed physical expansion to occur.

## 8. REFERENCES

ALDERTON, Patrick (2003), Book *"Port Management and Operation"* Lloyd's Publication.

BAKER, Greg (1998) *"Understanding Container Handling Statistics."* Available at http://www.aph.gov.au/library/pubs.

CcDOTT (2000), "*Marine Terminal Productivity Measures,*" Project Report.

Container International Year Books 2000 and 2006.

DOWD, T.J. and Leschine, T.M. (1990), "Container Terminal Productivity a Perspective," *Maritime & Policy Management*, Vol. 17, No.2, pp.107-12

Hong Kong Development Council Website at http://www.pdc.gov.hk

JWD Group Study (2003), "*US Container terminal Throughput Density,*" Available at http://www.JWD.com

Le, Hanh D. and Murphy, Melisa (2006), *"Container Terminal Productivity: Experience at the Port of Los Angeles and Long Beach,"* National Urban Freight Conference, Feb, 2006, Conference Proceeding.

Loyd's List Port of the World 2007 Edition

Maritime and Port Authority of Singapore website http://www.singaporepsa.com

MARAD, 1998, "*Improving Productivity in US Marine Container Terminal,*" Available at http://www.marad.dot.gov.

Pacific Maritime Association website at http://www.pmanet.org.

Port of Tanjung Pelepas, Malaysia Website at (http://www.ptp.com.my/)

Port of Manzanillo, Mexico Website at (http://www.portofmanzanillo.com)

Port of Klang, Malaysia Website at (http://www.pka.gov.my/Intro.htm),

Port of Los Angeles Website at http://www.portoflosangeles.org

Port of Long Beach Website at http://www.polb.com. .

Productivity Commission, (2002), *"International Benchmarking of Containers Stevedoring,"* Report to Australian Government, available at http://www.pc.gov.au.

Stonebridge Associates Report to California Trucking Association (2006), "*Survey of Port Driver Attitude on PierPass Off Peak Program,"* Available at http://www.pierpass.org.

United Kingdom Department for Transport Report (1999). "*Recent Developments and Prospects at UK Container Ports."* Available at http://www.dft.gov.uk.

Other Various Port Websites.