

**White Paper on the Terminal Capacity of Pier 300 with the  
Automation of the 41-acre Backland at Proposed Berth 306**

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## Berths 302 – 306 [APL] Container Terminal Improvement Project

### White Paper on the Terminal Capacity of Pier 300 with the Automation of the 41-acre Backland at Proposed Berth 306

#### Background

Currently Eagle Marine Services, LTD (EMS) operates the existing 291 acre APL Terminal at Berths 302 to 305, within the Port of Los Angeles (POLA). The APL Terminal includes 261 acres covered by an existing lease (Los Angeles Harbor Department [LAHD] Permit No. 733) and an additional approximately 30 acres of adjacent backlands authorized for use under a month-to-month space assignment (Non-Exclusive Berth Assignment No. 01-31). The proposed Berths 302 to 306 [APL] Container Terminal Improvement Project (the proposed Project) would add a new berth at B306 and make available an additional 56 acres, which would be operated by EMS under an amendment to the existing LAHD Permit No. 733. In addition, EMS would continue to utilize the 30 acres currently authorized for use under the month to month Non-Exclusive Berth Assignment No. 01-31. The term of the amended permit would remain unchanged (1998 to 2027), but the permit would be amended to include the additional 56 acres.

APL has developed plans to improve approximately 41 acres of already constructed but unimproved fill as container terminal backland and operate this area as an automated terminal within the larger overall terminal. Areas outside this expansion would continue to operate manually, as they do today, for some time. While these existing terminal areas may eventually be converted to automated operations, discussion of this is beyond the scope of this paper.

APL is not 100% certain that they will develop the expansion area as an automated terminal. Their other option is to simply expand their conventional operation into the new area. This generates two fundamental questions with regard to terminal capacity which are addressed by this paper:

- 1) What is the future capacity of the overall terminal including the expansion area?
- 2) Is the capacity different if the new portion is operated as a manual vs. automated terminal?

AECOM's typical technique for analyzing the capacity of a container terminal is to analyze the berth capacity and the container yard (CY) capacity independently. The smaller of these two values establishes the overall terminal capacity because the overall capacity is constrained by the most restricted component.

The future terminal, including the expansion project will consist of 5,250 feet of wharf and 347 total acres of terminal area.

#### Berth Capacity

The primary inputs to the P300 berth capacity analysis are:

- Vessel length and number of effective "berths" in 5,250 feet of wharf
- Work hours per day
- Vessel call size and number of dock cranes assigned
- Dock crane productivity
- Seasonal peaking factors
- Maximum practical berth utilization

Of these inputs only the work hours per day and dock crane productivity might be different for the automated vs. manual sections of the terminal. 21 hours per day is the current ILWU maximum. It may be possible to do some work on a 24/7 basis in an automated terminal, but because the dock cranes will still feature human drivers, conemen, and lashers, the daily operating hours are unlikely to change with automation.

The relative dock crane productivity of manual vs. automated terminals is the topic of a considerable amount of discussion. In order to understand this issue, a bit of background on the basics of dock crane operation is helpful. Typical specifications of a modern dock crane are shown in Table 1. The specifications in Table 1 are also used as the assumptions for the delay incurred to pick and set containers, and to remove or install inter-box connectors (IBCs). Speeds in Table 1 are shown in feet per minute (fpm).

Hoist w container	300 fpm
Hoist w/o container	600 fpm
Trolley	750 fpm
Pick or set container	20 sec
Align spreader into below-deck cell guides	15 sec
Install/remove IBCs	30 sec

Table 1  
Typical Dock Crane

AECOM has analyzed dual hoist cranes of this nature as part of other planning and analysis projects and believe that they are capable of approximately 40 moves per hour when they are working on one hatch of a vessel and are perfectly fed, i.e. they never have to wait for an automated guided vehicle (AGV).

In practice, it is not possible to always have an AGV under a dock crane when it is needed. The dynamic nature of real-world container terminal operations poses many challenges to decisions about AGV routing, which depend on accurate predictions of the future. Some of the many issues include:

- Complexity of choosing from amongst a large fleet of AGVs for each task. Note that APL is proposing to use 66 AGVs (perhaps 90% of these may be operating under peak conditions), and any of these machines is eligible to do any required task on the terminal. The terminal's operating system therefore has to choose the "best" AGV of perhaps 60 options, and it needs to do this hundreds of times per hour in order to support efficient operations.
- Lag in timing between instructions from the terminal operating system (TOS) and AGVs
- Delay due to navigation conflict between AGVs at intersections
- Variable timing for the human dock crane driver from one move to the next
- The need to move hatch covers on and off the vessel
- The need for dock cranes to gantry between locations on the vessel
- The need to load reefer containers with doors facing the opposite direction as the rest of the containers on the ship
- The need to occasionally handle cargo that is "out of gage" and may not fit in a standard ASC block
- The need to intermittently refuel (or recharge) AGVs
- The need to occasionally remove AGVs from service for preventative or corrective maintenance
- Time lost due to late labor arrival/early departure

For these reasons, real world productivity at existing automated terminals CTA in Hamburg and Euromax in Rotterdam have been closer to 25 moves per dock crane per hour at terminal startup. Moderate improvements over time at these facilities have pushed productivity to approximately 30 moves per hour in a mature operation with an experienced staff.

Given the unique nature of APL's design, especially the requirement for AGVs to circulate through the ASC stacks instead of simply parking perpendicular to the stack at the waterside end, AECOM would expect productivity at APL's terminal to start below that of other ASC/AGV terminals. APL has predicted a gross dock crane productivity of 27 moves per hour for their automated system. This is similar to what APL is able to achieve today in a conventional terminal.

Although automated terminals in Hamburg and Rotterdam have been able to achieve productivity levels somewhat higher than this, AECOM believes that 27 moves per gross hour is reasonable at Pier 300 due to the following differences between P300 and other automated terminals in Northern Europe:

- 1) The labor unions in Europe allow flexible shift start times whereas the ILWU adheres to strict shift starts. This means that terminals in LA only get an effective seven hours of work from an eight hour paid shift. In other words, the first move at P300 does not happen at 8:00 or 8:01 but more typically 8:15. Similar time is lost around the lunch hour and shift end.

This means that a net productivity of 30 moves per hour as measured from first to last move equates to a gross productivity for the entire paid shift of 26 or 27 moves per hour

- 2) The concept that APL is proposing is unique and more complicated than existing automated terminals. See Appendix A for more detailed discussion.

A technical paper "Design, Simulation, and Evaluation of Automated Container Terminals" from Liu, Jula, and Ioannou, published in 2002, cites an expected productivity of over 40 moves per dock crane per hour for an automated terminal roughly similar to the concept proposed by APL for Pier 300. The paper assumed that a dock crane is capable of a theoretical maximum of 42 moves per hour. In other words, the paper predicted that ASC+AGV terminal systems will be able to achieve in excess of 95% of the theoretical maximum productivity of a dock crane!

The dock cranes at ECT, it should be noted, were then and are today operating at perhaps 60% of their theoretical capacity (i.e. the low-mid 20s of moves per hour per crane) so it is surprising that no reference is made to actual productivity from the only real world ASC+AGV terminal operating at the time the paper was written. AECOM believes the paper has little relevance to current discussions of automated terminals due to its age and omission of many key aspects of real world operating conditions.

In the long run, container ships that visit POLA are expected to occupy approximately 1,300 feet each. This means that a 5,250 foot wharf is effectively four berths for the purposes of capacity analysis. Inputs for vessel size, crane assignment, seasonal peaking, and maximum practical berth utilization are the collective opinion of APL and POLA. Table 2 shows the expected berth capacity for a 5,250 foot berth at P300 is equal to 3.2 million TEU per year.

a	Number of berths	4.00
b	Work hrs per day	21.0
c	Work days per week	7.0
d	Max overall berth occupancy	60%
e	Effective hours per berth [b*c*d]	88.2
f	Mean moves per call - peak week	4,500
g	Dock crane moves/hr	27.0
h	Mean cranes per ship	4.5
i	Mean work time per ship [f/(g*h)]	37.0
j	Ship tie-up & untie time (hr)	4.0
k	Mean vessel call time (hr) [i+j]	41.0
l	Potential ship calls per peak week [a*e/k]	8.6
m	Peak week capacity (moves) [f*l]	38,687
n	Peak/mean season	110%
o	Annual berth capacity (moves) [m*52/n]	1,830,000
p	TEU per container	1.75
q	Annual berth capacity (TEU) [o*p]	3,200,000

Table 2  
Berth Capacity at P300

#### CY Capacity

While the overall terminal size is listed at 347 acres, the net area available for container storage is estimated by POLA at 262 acres, for a net/gross ratio of just over 75%. The quarter of the terminal not used for container storage is taken up by the wharf, buildings, parking, gate, and other support areas. Each net acre of container storage typically allows about 100 twenty-foot ground slots (TGS) of storage, which means the overall terminal should have approximately 26,000 TGS of container storage available.

Based on our past capacity studies at POLA, AECOM expects that the mean dwell time at P300 is approximately 4.6 days. The stacking height of containers on the terminal is expected to increase over time. Both manual or automated terminals are likely to be based on equipment that can stack 1-over-5 high. The highest mean overall height in this case is approximately 3.5 containers per stack. AECOM examined a range of stack height from 3.0 to 3.6. The resulting CY capacity figures are shown in Table 3.

a	Total TGS available	26,000	26,000	26,000	26,000
b	Mean stacking height	3.0	3.2	3.4	3.6
c	Total TEU capacity [a*b]	78,000	83,200	88,400	93,600
d	Mean dwell time (days)	4.6	4.6	4.6	4.6
e	Turnovers per year w/o peaking [365/d]	78.7	78.7	78.7	78.7
f	Peak/mean week throughput	110%	110%	110%	110%
g	Peak/mean inventory per week	140%	140%	140%	140%
h	Turnovers w/ peaking [e/f/g]	51.1	51.1	51.1	51.1
i	Annual overall CY capacity (TEU) [c*h]	3,980,000	4,250,000	4,520,000	4,780,000

Table 3  
Container Yard Capacity

### Overall Terminal Capacity and Conclusions

Even the relatively low stacking height of 3.0 containers, the CY capacity of the terminal will exceed the berth capacity by a considerable margin. Figure 1 shows the comparison of berth capacity and CY capacity at a variety of mean stacking heights.

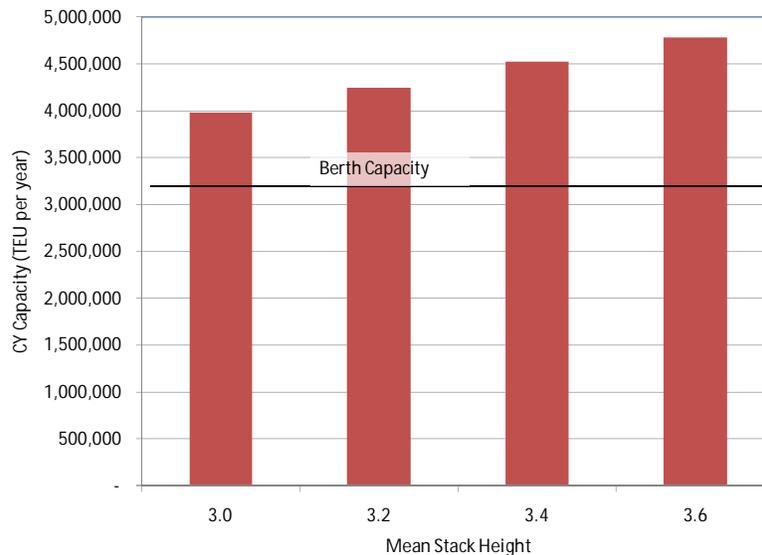


Figure 1  
Berth vs. CY Capacity

This evaluation above answers the two fundamental questions with regard to terminal capacity which can be summarized as follows:

- 1) What is the future capacity of the overall terminal including the expansion area?

The terminal's overall capacity is equal to the berth capacity of 3.2 million TEU per year. APL's proposed automated CY area may feature a stacking height that is taller than considered by AECOM in this analysis, however, this will only increase CY capacity and not overall capacity due to the berth capacity limitation. The business rationale for automating a portion of the terminal would be to reduce costs rather than to increase capacity as other improvements would be necessary to increase capacity as discussed.

2) Is the capacity different if the new portion is operated as a manual vs. automated terminal?

There is no significant difference in the terminal capacity whether or not APL operates the expansion area as an automated terminal or a manual terminal because none of the factors that influence berth capacity are expected to be significantly different between these two options.

# Appendix A: APL's Concept vs Other Automated Terminals

Figure A.1 shows a plan view of APL's proposed layout on the expansion area.

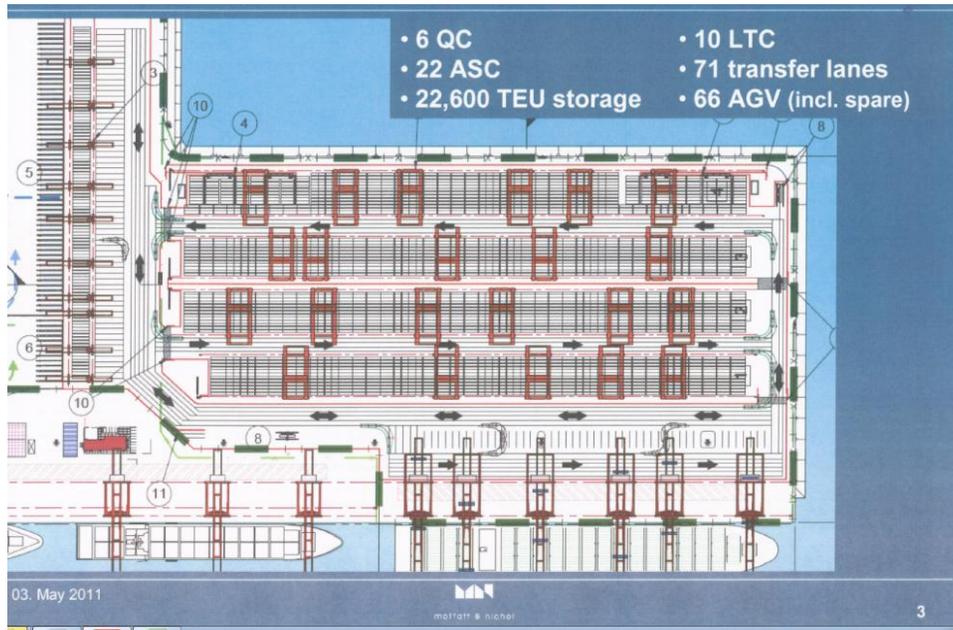


Figure A.1  
APL's proposed Automated Operation at P300

APL proposes to use dual hoist dock cranes to transport containers between the ship and the backreach of the dock crane. APL will use robotic automated guided vehicles (AGVs) to transport containers horizontally through the automated portion of the terminal. Figure A.2 shows an AGV.



Figure A.2  
AGV

APL proposes to use unmanned rail mounted gantry cranes (RMGs) also known as automated stacking cranes (ASCs) to stack the containers. AECOM is aware of three other AGV+ASC type automated terminals in the world:

1. *ECT Rotterdam* – what many consider to be the world’s first automated terminal which opened in 1993. Due to the limitations of the computer systems at the time, this terminal featured only one ASC over each block of containers.
2. *CTA Hamburg* – the first “modern” automated terminal with two ASCs per block and direct street truck access to the ASC blocks. This terminal opened in 2002. It features dual hoist dock cranes working to the backreach similar to what APL is proposing for P300. This terminal also has the unique feature of the two ASCs within each storage block operating on different rail gauges so that they can pass each other while working. This feature has yet to be copied outside of Hamburg.
3. *Euromax Rotterdam*. This terminal opened in 2008 and is very similar to CTA Hamburg except for the fact that both ASCs serving each container storage block run on the same set of rails and do not pass each other.

What these three terminals, and effectively every ASC based terminal worldwide, have in common is that the ASC blocks are aligned perpendicular to the wharf.

Figure A.3 shows an aerial view of CTA Hamburg. Note the AGVs operating in the space between the wharf and the waterside end of the ASC blocks.

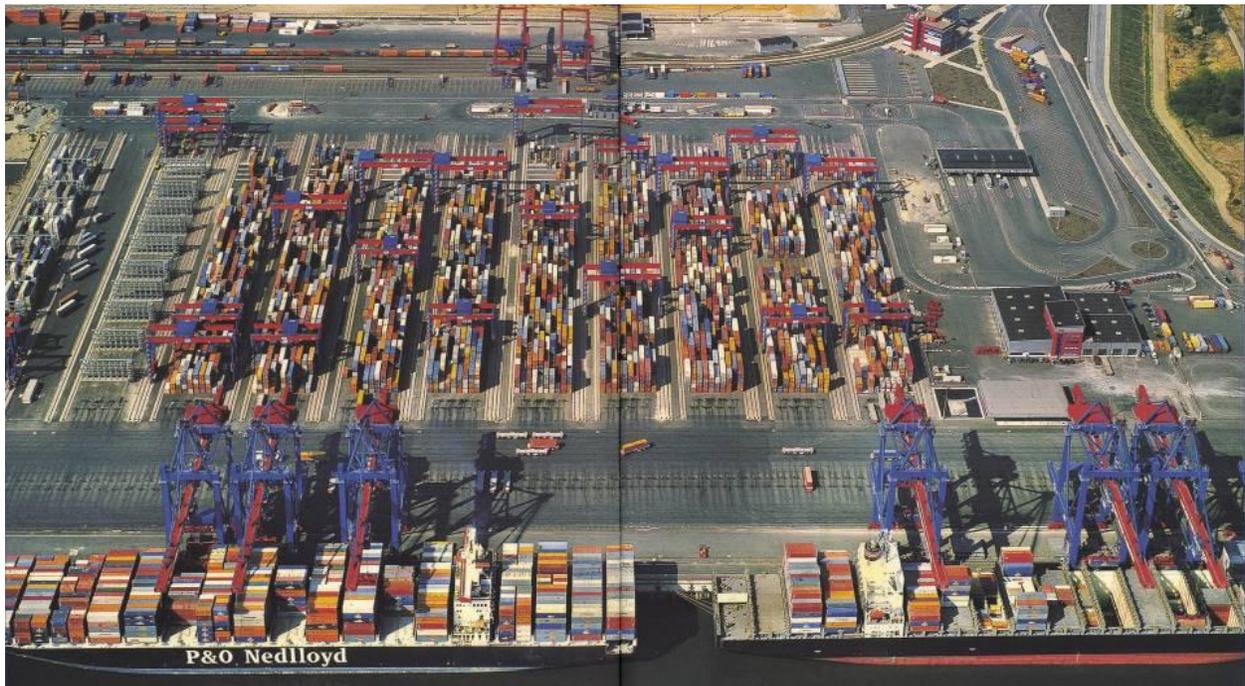


Figure A.3  
CTA Hamburg's ASC+AGV operation

The other feature common to every ASC terminal in the world except for the very first one at ECT, is that street trucks back up to the landside end of the ASC blocks to receive and deliver containers directly from and to the ASC. Figure A.4 shows an example of the truck interface at CTA Hamburg.



Figure A.4  
CTA Hamburg's Truck Interface

APL's proposed system has many features that are found in no other terminal in the world including:

- ASC rows parallel to the wharf
- AGVs that drive parallel to the ASCs and access containers from the side of the ASC stacks
- AGVs are used to extract gate containers and move them to a special RMG/street truck transfer area as opposed to allowing street trucks direct access to the ASCs. The RMGs in this transfer area are called landside transfer cranes (LTC).

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