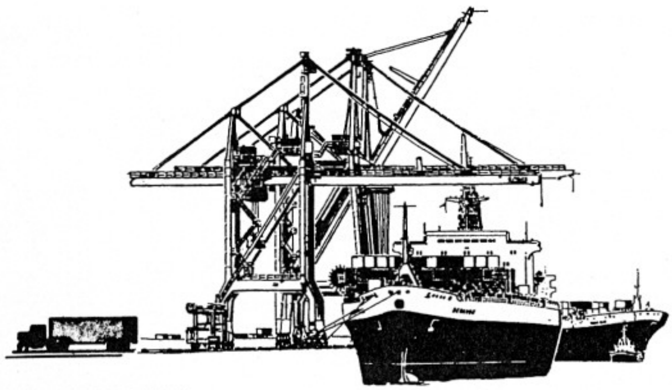
PRODUCTIVITY

And Capacity Of Container Terminals Part II



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Many U.S. ports face the same problems of coping with the development of new facilities while the existing ones are not fully utilized. Since the subject is broad, Mr. Ashar has divided the paper into two, separate articles. The first article appeared in the October/November 1985 edition of WWS/World Wide Shipping.

This article elaborates on the issues of port capacity and port expansion. These issues are closely related to the productivity issues which were discussed in the previous article—the more productive you are, the more capacity can be generated in your terminals, and the less you need to expand them.

The previous article suggested that U.S. public ports have failed in enhancing productive usage of container terminals. Instead of promoting novel technologies and efficient working practices to increase capacity, U.S. ports concentrated on development of new terminals, consuming large, expensive and scarce waterfront lands. In order to cope with this situation, this author suggested that ports should establish a *Terminal Management System.* The management system should be designed to collect operational data from container terminals, and analyze and monitor it through a scheme of productivity indicators. The Container Terminal Capacity Model presented in this article is based on data produced by the Terminal Management System.

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The Container Terminal Capacity Model

The Container Terminal Capacity Model (CTCM) presented here is different from common methods for capacity calculation discussed in professional literature. It is substantially more detailed than the simplistic, all-inclusive, capacity formula recommended by MARAD, UNCTAD (and many others; it is much simpler,) however, than the complicated and difficult to apply Monte Carlo simulations. The model discussed here was developed for the Port of Seattle (for the recent Harbor Development Strategy project), but can be easily adapted to any port. The model does not necessarily require the use of a computer though it was found that application of common micro-computer software can greatly facilitate computation.

The CTCM revolves around a simple manual simulation: the port planner considers available terminals and assigns ("loads") each of them with a selection of shipping lines—until terminals reach their "full-load" capacity. There is on one hand a pool of terminals, each with its own characteristics, and on the other hand a pool of lines, each of different size and working pattern. The process of loading lines to terminals is controlled by a set of rules. It is completed when all terminals are "full", i.e., when a limitation in one of the terminal's elements (berthage or yard, as will be explained later) is reached.

Following is a short description of the model's three components: terminals, shipping lines and loading rules.

Container Terminals

Container terminals are usually composed of four basic elements:

1). Vessel Berthage - the water-side entrance/exit to/from the terminal where ships exchange boxes with the container yard.
2). Container yard - the open area adjacent to the berthage from/to which the containers flow to/from ships.
3). Gate(s) - the land-side entrance/exit to/from the terminal, where containers are being exchanged with outside parties.
4). Ancillary facilities - support facilities such as CFS, offices, maintenance & repair shops, employee parkings and the like.

The berthage and container yard are the major elements of the container terminal; they constitute the bulk of the investment and occupy most of the waterfront land-base. Gates and ancillary facilities can either be easily expanded on-terminal, or can be provided off-terminal. It is also assumed, though indirectly, that there is no limitation on availability of berth and yard equipment. Consequently, *the CTCM concentrates on the capacity of the two major terminal elements, the berthage and the container yard; they are the determinants of terminal capacity.*

Terminal berthage is determined by the number of vessels which can work there simultaneously. Accordingly, berthage output is defined by the number of ship-shifts per year that can be generated there.

Container yard is measured by the number of containers that can be stored there. Accordingly, its output is defined by the number of TEUs per year (of vessel movements) that can be exchanged there.

Shipping Lines

Each shipping line has specific operational characteristics. For the purpose of terminal capacity calculation the most important characteristics are those relating to berthage and container yard utilization, i.e. moves and TEUs per call, frequency, ship working schedule, container yard system and container dwell times.

Instead of dealing with each line separately (there are more than 30 of them in Seattle), the CTCM groups the lines into three categories:

Table 1.
Shipping Lines Characteristics

Line Type	Moves per Ship-Call	Frequency (days)	TEU Move	TEU per Year
Large	1,500	7	1.9	148,607
Medium	600	7	1.7	53,186
Small	200	14	1.5	7,821

Table 2.
Berth Capacity Calculation

Type	Moves per Call	Moves per Crane-Shift	Average Crane-Shift per Call	RHL Crane-Shift per Call	RHL/Avg	Net Ship-Shifts per Call	Safety Margin	Gross Ship-Shift per Call	Gross Ship-Shift per Year	Berth Requirement Coefficient
Large	1,500	170	8.82	12	1.36	7	6	13	678	0.64
Medium	600	150	4.00	6	1.50	4	6	10	521	0.49
Small	200	120	1.67	3	1.80	2	6	8	146	0.14

Comments:
1. RHL = Reasonably High Level
2. Ship-shift calculation is based on

Type	Day 1 I II III	Day 2 I II III	Day 3 I II III
Large	3 3 0	2 2 1	1
Medium	2 2 0	2	
Small	2 1		

3. Requirement Coefficient is based on 1055 possible berth-shifts per year

Large Lines - lines exchanging 1,000 and more boxes per call, calling at a frequency of 7 days or less, and generating annual traffic of more than 100,000 TEU/year (most of the boxes are 40's).

Medium Lines - lines exchanging around 600 boxes per call, calling at a 7-10 day frequency, and generating an annual traffic of about 50,000 TEU/year (about 2/3 of the boxes are 40's)

Small Lines - lines exchanging 100-200 boxes per call, calling at a frequency of 15 or more days, and generating an annual traffic of 5-10,000 TEU/year (about 1/2 of the boxes are 40's).

Table 1. presents a typical selection of these three line groupings.

To repeat, the division of lines into these specific three groups is for practical reasons. Each port can pick a different selection or even deal with each line separately.

Loading Rules

The third component of the CTCM is a mechanism for assigning ("loading") lines to terminals. As mentioned before, the loading rules deal only with the two major terminal elements: berthage and container yard. Accordingly, a set of capacity limits and corresponding requirement coefficients were developed for each terminal element and for each one-group. One basic assumption employed in the following discussion is that terminals are of multi-user nature. This reflects recent trends in the industry where large terminals, even the known single-user terminals (such as APL, Sea-Land), look for additional tenants to spread overhead cost over larger volumes. Likewise, it is assumed that all terminal users are scheduled lines with fixed arrival time with limited randomness. Finally, it is assumed that efficient terminal management tries to maximize the utilization of terminal berths and yards—within the limits of convenient working conditions, to be defined below.

Following is a short discussion of the capacity calculation methods for each terminal element.

Berthage Capacity - first, an average shift and crane requirement calculated for each line according to average ship load (moves/call) and crane productivity recorded on this line-group (moves per crane shift). The higher crane productivity figures for large lines reflect the "double-cycle" ship operation practiced by them and the larger string of containers per hatch they usually have. The average figure was augmented to account for two uncertainties: a) fluctuations in ship loads and crane productivity; and b) changes in ship arrival times. A "Reasonably High Level" (RHL) situation reflecting high ship loads and/or lower productivity was defined and RHL crane and berth schedules were established accordingly. Secondly, margin between ship arrivals to assure that vessels will not have to wait for available berth was added.

Finally, the gross berth requirements, accounting for both RHL and arrival margins, was divided by possible berth annual output (assumed here to be 355 days times 3 shifts) and a berth requirement coefficient for each line-group was calculated.

Table 2 presents a sample calculation of berth requirement coefficients.

Yard Capacity - this calculation is similar to berth capacity. First, an average number of yard spots requirement was calculated for each line. RHL and double-cycle situation was considered; large lines don't need to store the entire ship moves in yard, but can double-store about ¾ of their moves and save on yard space. Then a base-line yard inventory (for storage of containers unrelated to vessel operation) was also added. Finally, the yard spots were translated into yard acres and yard requirements coefficients calculated.

As mentioned before, most of the existing terminals are, basically, common-users. To account for the combination of several lines sharing the same terminal yard it was assumed that large lines are the main terminal users and that medium and small lines adjust their schedule to call "in-between". In this type of efficient operation a portion of yard spots can be used by several lines. A yard-sharing factor for each line-group expresses this savings. Consequently, yard requirement coefficients, were calculated for two generic cases, for single-line terminals and for multi-line terminals.

Table 3 shows a sample calculation of yard requirement coefficients.

Table 3.
Yard Capacity Calculation

Line Type	Ship Moves per Call	Double-Cycle Saving Factor	Ship Moves Stored in Yard	Base-Line Yard Inventory	Total Moves Stored in Yard	RHL Factor	Total x RHL	TEU per Move	Total TEUs Stored in Yard	TEU per acre	Single-user Yard Requirement Coefficients	Fraction Saved In Combination	Multi-user yard Requirement Coefficients
Large	1,500	0.75	1,125	375	1,500	1.36	2,040	1.9	3,876	95	41	0.67	27
Medium	600	1.00	600	150	750	1.50	1,125	1.7	1,913	85	23	0.50	11
Small	200	1.00	200	50	250	1.80	450	1.5	675	65	10	0.33	3

Comments:
1. Yard-system assumed here is chassis. TEU/Acre values reflect different 20' and 40' container mix for line-types.

Table 4.
Terminal Capacity Calculations

	LINES			CAPACITY COEFFICIENTS		
Type	Move/Call	TEU/Year	Frequency	Berthage	Container Single-User	Yard Multi-Users
Large	1,500	144,696	7	0.64	37	27
Medium	600	53,186	7	0.49	23	11
Small	200	5,475	20	0.14	10	3

Terminal Capacity

Calculation of terminal capacity through the CTCM is based on a manual simulation: the planner chooses a terminal and loads it with lines, starting with a major one(s) then adding medium and small lines—until either terminal yard-acres are totally consumed, or berthage is entirely utilized (whichever comes first). It is imperative that terminal properties be based on area measurements, reflect actual work practices, and lines selection represent the port actual or expected tenants.

To illustrate the usage of the CTCM, a sample terminal with two different configurations (based on a recently rehabilitated Seattle terminal) was selected and loaded to its capacity. The loading process was performed according to the principle that one (or two) large line(s) will be major tenant(s), with several medium and small lines as "in-between" tenants. The selection of lines reflects the general line-mix of the Port of Seattle.

Table 4 presents two selected examples taken after recent re-habilitated terminal in Seattle: I. a 2-berth, 72 terminal-acre and 51 yard-acre configuration terminal; and II. the same terminal but with 3 berths. The example assume, for simplicity, chassis yard system.

Example I - the optimal line-mix found to generate maximum available capacity included 1 large, 2 medium and 1 small lines. First constraint to reach its limit in the loading process was the yard acres. The total capacity generated at this point was about 250,000 TEU/year. The berth capacity utilization of 88 percent is a very reasonable utilization rate. The ideal ratio between berthage and yard acre (assuming same utilization of both) in this case was 30 yard acres per berth. Different capacity potential can be generated by different line combinations; 2 large lines cannot, however, be assigned to this 2-berth terminal because they require 54 yard acres.

Example II - referred to the 3-berth terminal. This time the terminal was loaded to the capacity of its berthage. Here the total capacity generated reached 450,000 TEU/year, almost double the previous one. This volume cannot be supported by the yard. The required yard to support this volume is 93 acres, or almost double the available area.

Other findings:

- One clear conclusion of the examples above is that there is no point in providing a 51 yard-acre terminal with more than two berths. A desirable configuration for expected line mix and yard system as described above is 2 berths and 60 yard acres.
- Similarly: in order to insure appropriate utilization of 3 berths, part of the ancillary facilities (CFS, empty storage, parking) should be removed to an off-terminal location. If, for example, 15 acres were added to the container yard, the terminal capacity would grow by 60-80,000 TEUs.
- Terminal capacity can be substantially increased by assigning different lines and line combinations to terminals. It means that ports can affect their facilities capacity by affecting decisions on allocation of lines to terminals.
- Yard technology has crucial importance in determining terminal capacity. If the terminals in the above examples were equipped with yard cranes, with typical storage density of between 2.5 to 3 times the storage density of chassis (and the dwell times in the yard remain the same), yard capacity could have grown almost at the same ratio. Chassis system is not necessarily less productive than stack operation; Sea-Land, using chassis system, achieved yard productivity rates of 7-8,000 TEU per yard-acre and 150,000 TEU per berth in their Seattle terminal.

Productivity Indicators

To conclude this series, let's go back to the Terminal Management System and the Productivity Indicators which were discussed at length in the previous article. Comparing actual data with CTCM coefficients. The verified model can then be utilized as a *planning tool for analyzing port expansion projects.* This was the original purpose of developing the CTCM—to analyze various terminal configurations, impact of new technologies and possible assignments of lines to terminals for the Harbor Development Strategy at the Port of Seattle.

The CTCM can be also applied to existing port terminals according to their specific configurations and tenants' characteristics, and theoretical Productivity Indicators can be produced. Comparing actual results to theoretical ones provides a useful *management tool.* This tool is essential for those ports which strive for better utilization of their facilities before resorting to expensive expansions.

(*) Comments

The assumption behind the combination saving factors is that the multi-user yard is divided into two types of storage areas: line areas and common areas. In reality, each line has its specific area but the borders between areas are "floating" according to the changing storage needs (e.g. provide larger storage areas when there is a vessel at berth).

This author has also developed a more detailed simulation model, not discussed here, for the purpose of operational analysis of specific terminals. The model included in addition to the berth the gates and ancillary facilities, and the yard was analyzed in detail accounting for dwell time distribution (by shifts) and box differentiation (reefers, empty etc.) for specific lines and service requirements. □

Example I

TERMINAL DIMENSIONS			TERMINAL REQUIREMENTS					PRODUCTIVITY INDICATORS		
Berths	Total Acre	Yard Acre	Line Type	Lines in Terminal	TEUs per Lines	Berth Requirement	Yard-Acre Requirement	TEU per Berth	TEU per Yard-Acre	TEU per Total-Acre
			Large	1	144,696	0.64	27			
2	72	51	Medium	2	106,371	0.98	22	128,271	5,030	3,563
			Small	1	5,475	0.14	3			
			Total	4	256,543	1.76	52			

Example II

TERMINAL DIMENSIONS			TERMINAL REQUIREMENTS					PRODUCTIVITY INDICATORS		
Berths	Total Acre	Yard Acre	Line Type	Lines in Terminal	TEUs per Lines	Berth Requirement	Yard-Acre Requirement	TEU per Berth	TEU per Yard-Acre	TEU per Total-Acre
			Large	2	289,393	1.28	54			
3	72	51	Medium	3	159,557	1.47	33	153,300	9,018	6,388
			Small	2	10,950	0.28	6			
			Total	7	459,900	3.03	93			