

Next-Generation Container Vessels

Impacts on Transportation Infrastructure and Operations

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This article provides an overview of trends relating to world and U.S. container trade, with emphasis on U.S. Atlantic, Pacific, and Gulf coast ports. Current information is presented on the physical characteristics and projected utilization of next-generation containerships, and other significant trends are examined in the areas of terminal infrastructure, waterside access, landside access, terminal operations, and shipping logistics.

World and U.S. Container Trade

Between 1991 and 1995, world container trade grew at a remarkable rate of 9.5 percent per year, reaching more than 134 million 20-foot equivalent units (TEUs) in 1995. Growth in the U.S. container trade was somewhat slower but still extremely rapid, with a 6.0 percent per year increase resulting in more than 21 million TEUs in 1995. Worldwide growth is forecast at a compound annual growth rate of 8.0 percent through the year 2000, and total U.S. growth is forecast at 7.8 percent through 2010.

The leading world ports in 1995 were Hong Kong (12.5 million TEUs), Singapore (10.8 million TEUs), and Kaohsiung (5.2 million TEUs). Long Beach, the leading U.S. port, ranked seventh. Among U.S. ports, the leaders in 1995 were Long Beach (2.8 million TEUs), Los Angeles (2.6 million TEUs), and New York/New Jersey (2.3 million TEUs). According to 1996 figures, Long Beach has grown to 3.0 million TEUs and Los Angeles to nearly 2.7 million TEUs.

Next-Generation Vessels and Market Penetration

To move these increasing volumes, some shipping companies have ordered larger, faster vessels. One

advantage of these new vessels is that with increased size and speed, the transport cost per TEU slot is reduced—provided that the slots are filled with revenue cargo. As of November 1996, the great majority of vessels in the world container fleet were in the “feeder” class (less than 1,000 TEUs). The 36 megaships (post-Panamax vessels¹ in excess of 4,500 TEUs) in service accounted for only 1 percent of the total fleet by number. However, 45 megaships are currently on order, representing 8 percent of the order book and about 18 percent of the new capacity on order. Recent and planned deployments through 1997 include 16 ships in excess of 5,000 TEUs. The largest is the *Regina Maersk* class at 6,000+ TEUs, vessels that are currently in the Far East/Pacific and Far East/European trades. In addition to the planned 1997 deployments, there are another 28 megaships on order, including 6 containerships with official recorded capacities of 6,674 TEUs—the largest in the world.

In 1990 less than 6 percent of U.S. containerized cargo was handled on ships of 4,000 TEUs or more. By 2010, almost 30 percent is projected to be handled on ships in the 4,000- to 6,000-TEU class, with more than 9 percent in the 6,000- to 8,000-TEU class. It must be emphasized that these are maximum figures assuming unconstrained market and trade conditions. That is, they assume that (1) the infrastructure will be available to handle these vessels, and (2) carriers will find it profitable to deploy them on U.S. itineraries. To the extent that these assumptions fail to prove out, the share of cargo handled by megaships will be less (see Figure 1).

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¹ Ships in the Panamax class (the largest that can transit the Panama Canal) range from 2,500 to 3,999 TEUs.

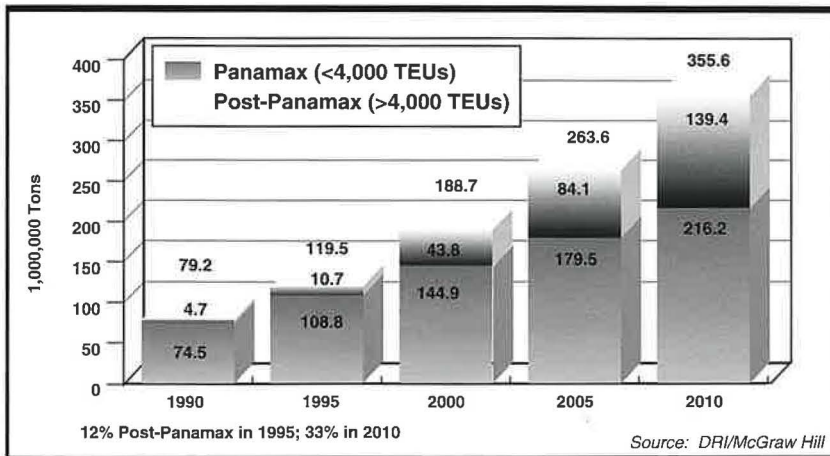


FIGURE 1 Share of containerized cargo handled by Panamax and post-Panamax vessels.

Ports that can accommodate megaships are in a position to capture this market. However, ships in the Panamax class are forecast to maintain their current share (36 percent) of cargo. In 1990, these ships moved more than 29 million TEUs to and from U.S. ports; just by maintaining share, their total tonnage will more than quadruple to 128 million TEUs in 2010, making them the most heavily used class of ship in U.S. service. This observation is critically important, because it suggests ports that can accommodate these ships, but not megaships, will continue to play a major role in future U.S. shipping.

Containership Size Limits

The physical and operational characteristics of ships change as their capacity increases, placing growing demands on navigation channels, port infrastructure, and landside access capabilities. Panamax vessels average 896 feet in length and not more than 106 feet across the beam, with a draft of just over 39 feet. The largest post-Panamax ships in the fleet today average around 925 feet in length and 125 feet across the beam, with a draft of more than 43 feet. Looking at four of the newest megaships—the *Regina Maersk*, *Hanjin London*, *Hyundai Independence*, and *APL C-11* class—the maximum length (1,049 feet) and beam (140 feet) belong to the *Regina Maersk*, while the maximum draft (46 feet) is shared by the other three vessels. HDW in Europe has proposed an 8,000-TEU ship that is 1,099 feet in length.

Much larger vessels are technically feasible. However, at between 8,000 and 9,000 TEUs it will become increasingly difficult for containerships to make required speed (24 knots or more) using today's single-engine propulsion machinery systems. This barrier may be overcome through advances in propulsion systems and hull design

or the addition of a second propulsion shaft. With a second shaft, vessel cost could rise dramatically, but the cost per TEU slot could be minimized by making the ship as large as the new propulsion capacity allows. In fact, P+O Containers has suggested that the largest single-propulsion vessel (say, 7,500 TEUs) could have double the capacity (15,000 TEUs) through the addition of a second propulsion shaft. The company opines that "the ship is a flight of fancy...but such a ship is within the current state of the shipbuilder's art."

Other factors may be more significant in establishing a maximum containership size. First, is there a deployment scenario that would allow a shipping company to keep the ship full enough and in motion often enough to pay for itself? Second, is there water sufficiently deep to meet vessel deployment requirements? Third, is there a terminal to handle the ship? Fourth, can the company afford the extensive transshipment/feeder and landside rail and truck transportation needed to serve markets outside its ports of call? With increasing vessel size, the deployment options and potential ports of call become sharply limited, and at some point it becomes uneconomical for U.S. ports, the U.S. Army Corps of Engineers, and others in the freight movement chain to fund their access and infrastructure to service these vessels.

It may be difficult to imagine much use for a ship larger than 8,000 TEUs or with a draft of more than 46 feet because of the limited itineraries such ships would have and the channel depth constraints that would have to be overcome. But history is clearly against such limit setting: 10 years ago few imagined a vessel of 6,000+ TEUs, and today such a vessel is in service. It is possible that certain high-traffic corridors—say, Hong Kong to Long Beach/Los Angeles or Seattle/Tacoma and conceivably Europe to U.S. East Coast—might see vessels larger than 8,000 TEUs employed in pendulum services or hub-and-spoke logistical strategies.

Navigation Channels

A Panamax vessel with a draft of 38 feet or more, plus 2 feet for vertical ship movement (squat) and 2 feet for underkeel clearance, requires a 42-foot channel. With post-Panamax vessels, draft increases to 42 feet or more (fully loaded), and a 46-foot channel is required. The typical fully loaded draft of megaships is estimated at 46 feet (fully loaded), requiring a 50-foot channel. (See Figure 2.)

To the extent that megaships call with less than full loads, ports might accommodate them

with shallower depths. However, ports that can provide channel depths approaching 50 feet or more will have a clear advantage, since they will be able to handle heavily loaded megaships as the sole U.S. port of call or as the first-in/last-out call on a multiport service. In any case, it appears that drafts of less than 45 feet will not be sufficient to handle megaship services effectively. Even so, shallower-draft Atlantic ports should do well during the next two decades because (1) smaller vessels are projected to handle the majority of tonnage through 2010; (2) lightly loaded megaships will be able to call at these ports on second-in/out services; and (3) overall demand for container capacity in the Atlantic is expected to nearly triple by 2010, with the largest share of cargo in the Panamax vessel class (which can be accommodated at shallower drafts).

Terminal Equipment, Design, and Operations

Terminal design and equipment will be substantially impacted by the deployment of megaships. This will be the case in particular with respect to wharf crane and backland storage requirements and the degree of transshipment that occurs at a facility.

As containerships have become larger and wider, wharf cranes have evolved to serve these vessels. Panamax cranes (less than 144 feet outreach) serve Panamax vessels (106-foot beam, with containers stacked in up to 13 rows across the beam). Post-Panamax cranes (144 to 158 feet outreach) serve vessels between 13 and 16 containers wide. In 1995 Panamax cranes dominated the world crane population (77 percent), while beyond post-Panamax (BPP) cranes accounted for just 3 percent. This situation is changing rapidly, however. Looking at deliveries from 1996 through 1998, BPP cranes represent 44 percent, with Panamax at 30 percent and post-Panamax at 23 percent. This trend is even more pronounced in North America, with BPP cranes representing 55 of 66 deliveries (83 percent).

How many BPP cranes will it take to unload a megaship? The answer depends on a number of variables, including the size of the vessel, the percentage of vessel cargo to be off-loaded/loaded, the productivity of the cranes, and the amount of time the vessel can remain at berth. In normal service, a ship makes several calls and off-loads/on-loads a relatively small percentage of its cargo at each port. With larger ships, fewer calls will be made, and a larger percentage of cargo will be off-loaded/on-loaded at each port. With an assumed BPP crane

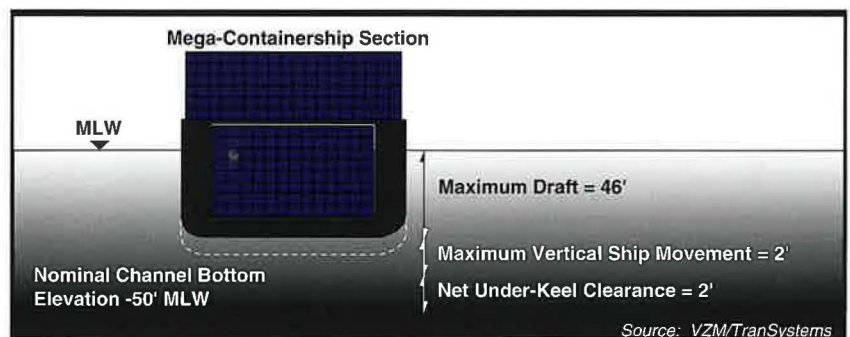
productivity of 25 lifts per hour (45 TEUs), a total of 189 crane-hours would be needed to transfer 2,500 TEUs on to and off of a megaship. With four cranes working the ship, time working at berth would be 28 hours, which is much longer than most current containership calls and may prove uneconomical. Substantially higher crane productivity will be demanded by carriers.

How much backland is needed to serve each berth? Historically, the ratio of backland to berth has increased with vessel size. The reason for this is the disconnect between wharf activity (rapid, round-the-clock transfer when vessels are at berth) and gate activity (more regular, 8-hours-a-day vehicle movements). Terminal storage serves as an intermediary buffer between these two flows, with dwell time (the amount of time a box spends stored in the terminal) as the key productivity variable. As larger vessels are unloaded more rapidly and the disconnect between land and water flow rates becomes greater, larger terminal storage areas become necessary.

Operationally, a terminal can take a number of measures to reduce the amount of storage required, such as denser stacking, longer operating hours, use of intelligent transportation systems technologies, and on-dock/near-dock rail. If, however, it is assumed that terminals will continue to operate more or less as they do now, backland-per-berth requirements will increase as a function of vessel size. The generally accepted ratio for state-of-the-art terminals for post-Panamax vessels is 50 to 60 acres per berth. With design vessel sizes increasing by nearly 50 percent, it may be appropriate to increase the backland per berth by a similar factor, to 75 acres per berth. More research and simulation modeling will be needed to fine-tune this number.

With this information, one can begin to define parameters for an optimized megaship terminal. It would have the following physical characteristics: minimum of 2,500 linear feet of berthing (two megaship berths at 1,250 feet each) and up to 3,000 linear feet of berthing (three post-Panamax

FIGURE 2 Required channel depth for handling fully loaded megaships.



berths at 1,000 feet each or two megaships plus feeder ships) to accommodate a mix of vessels; 50-foot water depths at berth; upgraded wharf load-bearing capacity for the BPP cranes, with three to five cranes per berth; up to 75 terminal acres per megaship berth or 50 acres per standard berth (150 acres for 2,500 to 3,000 linear feet of berthing); and a state-of-the-art gate complex and on-dock rail (see Figure 3). Such a terminal might reasonably provide a throughput of between 450,000 TEUs/year (3,000 TEUs/acre) and 900,000 TEUs/year (6,000 TEUs/acre), depending on operational factors such as storage density, working hours, use of advanced in-terminal equipment and information systems, intermodal rail utilization, and degree of transshipment to/from the terminal.

The terminal design parameters defined above assume an origin/destination port with very little ship-to-ship transfer. If ship-to-ship or ship-to-barge feeder transfer is a large percentage of overall terminal throughput, the need for wharf and crane capacity changes in direct proportion to the number of transshipped TEUs (which are counted on both inbound and outbound moves). Storage requirements change by half the number of transshipped TEUs (since there is one storage event for two wharf moves). Gate and landside access capacity is needed only for the nontransshipped TEUs. For example, assume a terminal with a throughput of 450,000 TEUs, of which half (225,000 TEUs) is transshipment. Looking at the above idealized terminal, two berths would still be needed, but 25 percent less terminal acreage (from 150 down to 112 acres), and gate and landside access capacity for only 225,000 TEUs would be required.

Alternatively, transshipment cargo could be handled at separate terminals designed specifically for that purpose, although typically transshipment cargo is commingled with conventional cargo. A 450,000 TEUs/year transshipment terminal might

have 2,500 linear feet of berthing (two megaship berths at 1,250 feet each), an area of 75 acres, and a very small gate. This terminal would be only 1,300 feet deep—about half the depth of a nontransshipment terminal.

Landside Access

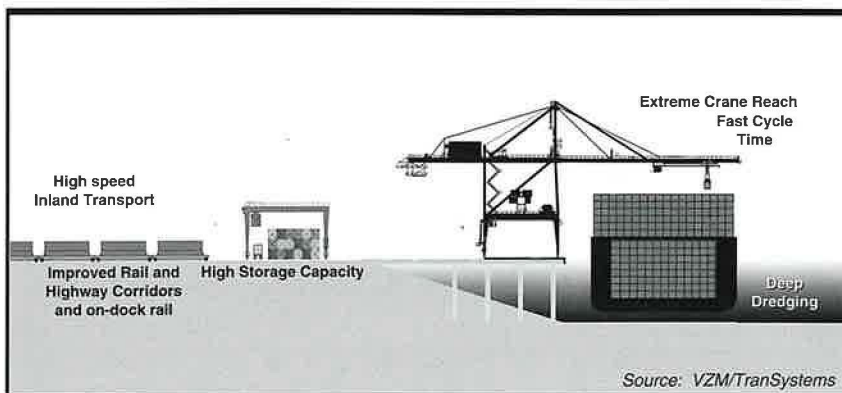
The landside access systems serving U.S. ports have been evolving as rapidly as vessel design. In particular, the rapid rise of intermodal rail service has had an enormous impact by facilitating the development of landbridge services. As much as 40 percent of West Coast international containers is handled by intermodal rail; this figure is lower elsewhere (generally between 10 and 25 percent), but appears to be rising. Three key trends are (1) the growing importance of intermodal rail, (2) the continuing importance of truck access, and (3) the degree to which effective landside access can decouple port locations from the metropolitan market areas they serve.

With increased use of intermodal rail, several effects are observed. First, trips that otherwise would require trucks can be made by rail, resulting in environmental benefits (fewer vehicle moves and lower emissions). Second, boxes that would otherwise remain in the terminal an average of 7 days or more tend to leave the terminal in around 2 days, freeing up storage area for other boxes and reducing the total storage acres needed. Third, intermodal rail is a key attraction for shipping lines, particularly if service by competing carriers is available, the facilities are on dock, and the lines are cleared for double-stack trains.

The recent round of rail mergers (UP/SP, BN/SF, and KCRC/TMM) and the division of Conrail between NS and CSX are expected to result in an improved, rationalized system. The mergers also pave the way for the formation of future transcontinental partnerships between remaining carriers, and for integrated long-term partnerships among rail companies, ocean carriers, and port complexes.

Post-Panamax vessels and megaships can generate extremely high peak box traffic. The successful megaship terminal will need to provide on-dock or near-dock rail to serve these vessels and minimize the truck traffic and environmental impacts associated with huge, rapid transfers of cargo. There will be growing demand on existing rail infrastructure and an increasing need for projects such as the Alameda Consolidated Transportation Corridor to rationalize rail access to ports. Other types of rail projects that may be needed include double-stack clearance and grade crossing elimination.

FIGURE 3 Optimized megaship terminal.



There is also significant concern about the inland impacts of rail traffic generated by ports. Midwestern railyards and cross-country mainlines are rapidly approaching capacity. Additional port-related intermodal traffic may trigger the need for significant improvements and for additional rail hardware hundreds or even thousands of miles inland from the ports themselves.

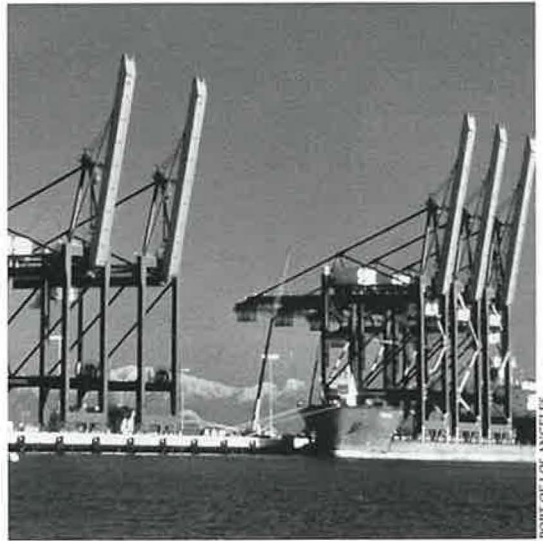
Despite the rapid growth of intermodal rail, trucks are expected to continue to carry the majority of U.S. port traffic, and the high number of trips resulting from the use of megaships means that highway access will remain a critical concern. Safe roads, adequate travel lane and gate queuing capacity, and clear signage within ports will be critical needs. There is also a growing awareness that freight movement is a statewide and even a multistate issue. In fact, an ongoing study by 13 southeastern states is looking at multistate freight corridors to handle future port-related traffic from Latin American trade. (See Figure 4.)

Historically, the water move was made up to the city dock. Now, with very expensive ships, the logistics objective shifts to minimizing vessel transit time and reducing the water move to the minimum possible within a total logistics system. At the same time, deregulation of trucking and the rise of intermodal rail are making the landside move to hinterland destinations increasingly affordable. Over time, these two trends may reinforce each other. One potential effect is that ports located nearest to shipping lanes and providing superior landside access may grow more rapidly, with proximity to urban consumption zones being of decreasing importance.

Vessel Logistics, Emergence of Hub Ports, and Vessel Deployment Strategies

A number of factors enter into a shipper's or carrier's decision to deploy a given vessel on a given itinerary. Among these factors are port capability and facilities, cost for use of port facilities, transit and turnaround time, market size at port, ability to fill the ship on backhaul, adequacy of landside connections, and customer preferences. Shippers and carriers regularly adjust their services in an effort to minimize costs and maximize service and revenue.

Along with the high capital cost of megaships, there is a huge cost associated with transit time. Calling at multiple ports is likely to incur a higher cost (in time) than the cost (in dollars) of serving these same markets with feeder ships or landside modes (truck or rail). The choice of services is also being driven by port capabilities to handle



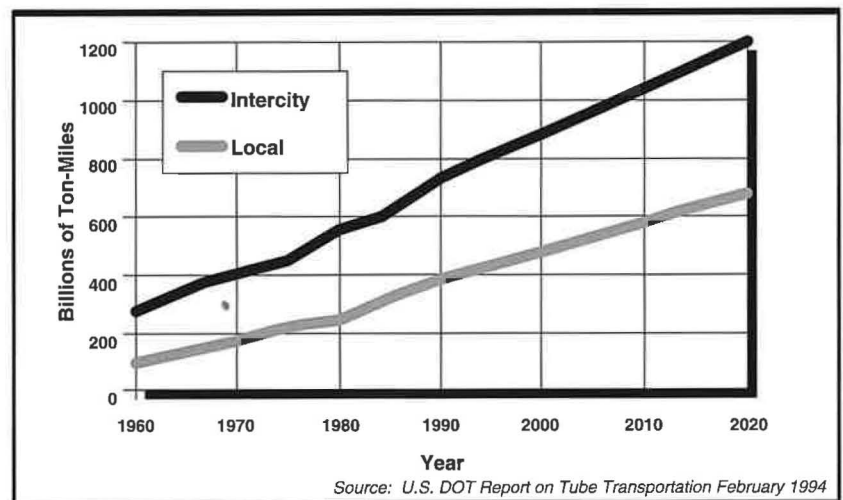
Profile of 12 new 100-foot-gauge container cranes at Pier 300, Port of Los Angeles, site of new APL Global Gateway South terminal.

these vessels and intermodal rail requirements, comparative facility costs (ports negotiate leases on a competitive basis), availability of landside connections, and locations of major customers.

An increasingly important factor is the trend on the part of shippers and carriers to consolidate services and assets (see Figure 5). In the past several years, as vessel and terminal development costs have increased, there has been tremendous growth in the number of shippers and carriers forming consortia/alliances to share assets, thus maximizing utilization and minimizing redundant investments. Together these factors make it likely that shippers and carriers will minimize their megaship ports of call and concentrate their operations in hub ports.

As ocean shippers and carriers become more integrated into the total trip chain, they will increasingly choose to consolidate at ports with

FIGURE 4 Anticipated growth in highway freight movement.



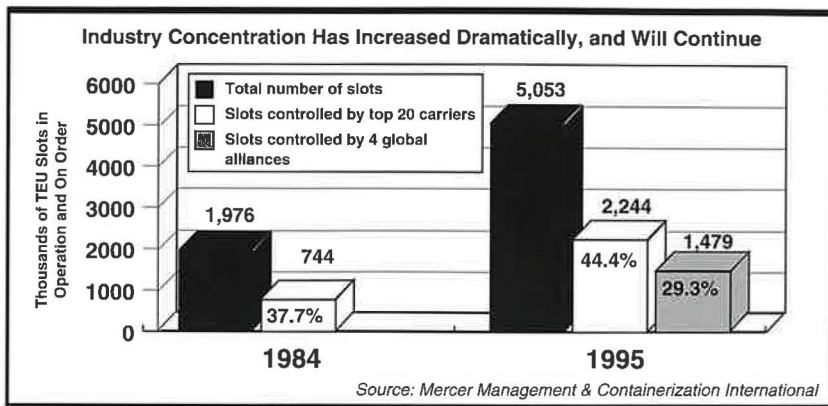


FIGURE 5 Increase in shipper and carrier consolidation.

superior intermodal connectivity. Services between hub and other ports and market areas could be provided using feeder vessels and transshipment (a hub-and-spoke system) and/or intermodal rail. As carriers concentrate at selected hub ports, more hinterland and coastal origins and destinations will fall outside of a 400- to 600-mile radius from the ports that serve them. Outside this radius, rail is cost-competitive with truck, so the result should be a substantial increase in intermodal rail activity.

Advanced Technologies and Labor Practices

The development of hub ports will place strong pressure on facilities to operate at peak efficiency. Improving the throughput per acre of U.S. terminals will allow them to handle a maximum amount of cargo with a minimum of investment. Yet on a per acre basis, terminal productivity in the United States lags behind that in the rest of the world. U.S. ports handle an average of 2,144 TEUs/acre/year, versus 8,834 for Asian ports and 2,974 for European ports. U.S. ports on the West Coast do substantially better (3,567 TEUs/acre) than those on the East Coast (1,281 TEUs/acre).

The best Asian ports achieve their high throughput through a combination of factors: (1) high rates of transshipment, (2) widespread use of advanced terminal equipment, (3) very intensive storage and berth utilization, and (4) round-the-clock operations. In most respects, this makes them noncomparable with U.S. ports. The best non-Asian ports handle an average of 4,000 TEUs/acre. Rotterdam, for example, achieves 4,400 TEUs/acre. Several West Coast terminals in the United States already achieve this number. The question is, then, how the current levels of performance elsewhere in the nation can be raised to meet or exceed this standard.

One strategy to this end is the use of intermodal rail. The average dwell time for an intermodal box is about 2 days; for a nonintermodal box it is anywhere from 6 to 28 days, depending on the port. Thus for every box that is handled intermodally, the storage capacity of the terminal is effectively tripled (at a minimum).

Another strategy is intensive stacking. Chassis storage is extremely convenient in that it allows direct pickup and delivery by truckers without the need to manipulate the box. However, four times as much storage per acre can be achieved by stacking four high. The trade-off, of course, is higher capital costs (e.g., rubber-tired gantry cranes, straddle carriers, "top picks") and operating costs (labor to handle the boxes).

Terminal operating costs can be reduced by using advanced terminal equipment. For example, terminals in Rotterdam are using automatic driverless "bomb carts" and "elephant trains" (strings of chassis pulled by a single power unit) to handle containers in the yard.

Terminal operating costs can also be reduced by using advanced information technologies. Many terminals have developed paperless systems for processing gate documentation. Other systems are in the early stages of deployment. Global Positioning System (GPS) tags and digital visual scanning readers are being used to identify and track yard equipment and containers in storage. Other systems have been developed to automatically weigh vehicles in motion, inspect containers for damage, and optimize the storage and retrieval of boxes using real-time computer simulation modeling.

Customs inspection is a key issue. With larger vessels off-loading at ports as quickly as possible (in the case of a 5,000-TEU vessel, perhaps 4,250 TEUs in a 32-hour period), the demand on customs will be sharply increased. The application of new information technologies may be part of the response to this challenge.

Ultimately, a cooperative partnership between labor and management may be the most important factor in maintaining and improving the productivity of U.S. ports. It may not be possible or desirable to duplicate the management and labor practices of Asian ports, but there are lessons to be learned from those practices. One lesson is that a terminal operating 24 hours a day can handle substantially more cargo than a terminal operating 8 hours a day with a comparable level of capital investment. To date, the operating costs of such a strategy have been prohibitively high, although many ports operate for extended hours (and all work around the clock with a containership at berth). But as ships get larger and the costs and

impacts of capital improvements to serve them become increasingly high, this strategy may become more feasible.

Conclusion

Private shippers and public agencies share an interest in creating a transportation system that can move the most goods and people with the widest range of logistics choices at the lowest cost and highest productivity. Yet private shippers and carriers and public port authorities are economic players in an intensely competitive business. To be successful, they must maximize their services and minimize their costs primarily within their own sphere of influence in the overall logistics chain.

On the other hand, the federal government is charged with supporting port investments in a manner that promotes the national interest.

Yearly major investments in U.S. marine and landside infrastructure will be needed in the next decade. Part of this need will be due to megaship deployment, but it must be noted that much, if not most, of this need will be the result of growth in cargo handled by conventional vessels. Investments in channel improvements, next-generation terminals, and highway and rail corridors will determine shipping patterns for decades to come, and must be undertaken with an equitable and appropriate balance of local and national interests in mind.

Megaships: A Word of Caution

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M. John Vickerman's article on impacts of next-generation container vessels clearly sets forth the arguments for the growth in the number of megaships around the world. The assumptions presented are indeed valid, and history has shown that growth in the marine industry is paced by physical growth in the dimensions of the ships on which the industry is based. If that growth is to be sustained, the industry must also develop fast, cost-effective means of handling cargo. In the case of containerships, the container port becomes the vital point at which all the various systems must be optimized to achieve the desired economic efficiency.

The capital cost of investments to refit container ports to handle megaships will be substantial. To recoup that investment, port authorities will need to ensure that berths are kept as full as possible. To optimize the economics of a container port, the sum of the cost of ships waiting for an empty berth and the capital cost of idle port facilities when no ships are calling must be minimized. Classically, queuing theory has been used to calculate the waiting cost for ships, and the results have been used to determine the number of berths needed to minimize demurrage cost (the cost of detaining a ship beyond the time allowed for loading or unloading) at a port. As ships get larger, the cost of facilities will also grow, making that cost a significant contributor to the optimizing equation.

A second factor must also be considered. As larger ships call, the time required to unload and reload those ships will increase. This change in the service rate will impact the average demurrage for smaller ships. As waiting times increase for smaller ships, shippers will seek more efficient ports of call.

When all the parameters of this dynamic process are considered, one must argue for a cautious approach to the entry of megaships into the container shipping industry. While there is certainly a strong economic incentive to shippers, port authorities must carefully evaluate the potential impact on their facilities and their market share.

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