Vessel and Port Technologies at the Turn of the Century

MARK L. CHADWIN AND WAYNE K. TALLEY

Developments in the design and operation of container vessels and ports at the start of the 21st century are discussed. Most changes will be evolutionary, not revolutionary. Techniques and equipment previously used in the most advanced countries or ports will appear in developing countries and smaller ports and terminals. Computerized operating and planning systems now used only in the most advanced terminals will become widespread, and electronically transmitted documentation will become the norm. Among the predictions developed are the following: the trend toward containerization will continue but at a slower rate; surplus capacity will persist; larger, faster gearless cellular vessels will dominate the major trades, but RO-ROs and other types will persist because they are more flexible and ideal for military uses and "ocean ferry" operations; unmanned containerships will not appear, but crews of less than 10 will be commonplace; radical new designs (SWATHs, Trisecs, and "megacontainers") will not be built, but smaller hydrofoils or hovercraft that transport priority containers on short routes will; container terminals will operate 24 hr a day, store containers in stacks rather than on chassis, apply techniques that move multiple containers, and vastly expand use of automated systems and computers; and domestic containerization and the use of "roadrailer" technology will grow rapidly.

Developments in the design and operation of vessels and seaports will influence how international commerce evolves at the start of the 21st century. Those developments are discussed, focusing especially on containerized cargo. Expected changes through the end of this century in the characteristics of the world fleet, ocean carriers' operations, port technology and operation, and intermodal systems are addressed.

Most changes that will occur by 2000 will be evolutionary rather than revolutionary—that is, the application of existing patterns will be widened and technologies already invented will be better exploited. Techniques and equipment previously seen only in the most advanced countries or ports will appear in developing countries and smaller ports and terminals. Large investments that already have been committed will be completed, including bigger and somewhat faster containerships as well as terminal equipment that can move and store containers more quickly. Computerized operating and planning systems now used only in the most advanced terminals will become widespread and standardized, and electronically transmitted documentation will be the norm wherever significant flows of commerce occur.

M. L. Chadwin, Department of Management, and W. K. Talley, Department of Economics, Old Dominion University, Norfolk, Va. 23529.

Rationalization of services and concentration among firms in the industry will continue, and giant multimodal providers of transport services will dominate the major markets. This process, well advanced in the United States, will proceed rapidly in Asia and Europe as well, stimulated by high growth rates in Pacific Rim countries and the likelihood that Europe will be an increasingly unified market from the Atlantic to the Urals. Companies with roots in air transport as well as firms whose origins are in ocean shipping, railroading, trucking, and freight forwarding will play major roles in this process.

THE CHANGING FLEET

Continuation of Containerization

Containerization of cargoes will continue through the 1990s, although probably at a slower rate than in the past. Like other industrial innovations, containerization has experienced S-curve growth, and we are now onto the second curve of the S, the one correlated with industry maturity and more moderate growth rates. Perhaps 60 percent of what had been break-bulk cargo in the 1960s was containerized during the 1970s and 1980s. Even if one expects containerization to reach 85 or 90 percent of the types of general cargoes by the turn of the century, the rate of expansion to new cargoes will necessarily be lower. If world trade overall, including cargoes already containerized, continues to expand as it has during the past two decades (3 to 5 percent a year in tonnage), containerized cargoes will continue grow, although more slowly than in the recent past (*1–7*).

Three factors propel the continued conversion to containers. One is the rapid advance of refrigerated and climate-controlled container technology. Today the containerization of all sorts of perishables—fruit, vegetables, meat, even live seafood—is feasible. Recent advances allow humidity, temperature, damaging gas levels, and other conditions inside a container to be carefully monitored and regulated. Thus, many products transported break-bulk on refrigerator ships will be shifted to containers. As the reefer fleet ages, much of it will be replaced by refrigerated containers carried by containerships and jumbo jets (*8–15*).

Second, the containerization of low value break-bulk and "neobulk" cargoes will grow, partly because carriers' surplus capacity will continue to drive them to find new cargoes to fill vessels and cover costs. This pattern is already obvious in backhauls. Technology will contribute here, too. Specialized liners for containers, like the inflatable Seabulk-Powerliner system, make it possible to pour a messy bulk commodity into and out of a standard container. Cleaning and sterilizing techniques such as Sea-Land's Sea-Clean system allow the same container to be prepared in a few minutes for a more conventional cargo (*16,17*). However, traditional methods of shipping bulk and neobulk commodities will usually be less expensive and, thus, will remain dominant.

Third, trade to and from newly industrialized and developing countries will move increasingly in containers. Through the work of the World Bank, many third-world governments have come to understand the linkage between entry into the mainstream global economy and containerization. As a result, container facilities and related infrastructure have become priority items for development programs.

Faster Growth of Capacity

During the 1980s global container-carrying capacity generally ran 20 to 30 percent ahead of demand. According to research by NYK Line, at the end of 1989 the world containership fleet consisted of 1,387 vessels with a total capacity of 1.68 million TEUs. Whereas the fleet grew more slowly toward the end of the 1980s (7 to 11 percent annually from 1987 through 1989), new orders escalated again in 1989 and 1990. Most of these orders are for vessels of more than 2,000 TEUs. Indeed, by the middle of 1991 many carriers had either ordered or put into service "jumbos" in the 3,500- to 5,000-TEU range. Some analyses indicate that carrying capacity in the mainstream East-West trades between Western Europe, North America, and East Asia will grow more than 60 percent before 1995.

Furthermore, expectations that older, smaller containerships would be scrapped as the larger vessels come into service are not being fulfilled. Instead, many of these vessels are being acquired by other operators. They remain in the global fleet, aggravating the surplus problem (*18–21*).

Thus, chronic excess capacity seems inevitable through the first half of the decade. Thereafter, the relationship between supply and demand is less clear. For example, according to a recent forecast by Temple, Barker and Sloane, Inc., if future orders roughly equal capacity eliminated during the 1990s, by 2000 demand will just about catch up with supply. Recent behavior concerning both ordering and scrapping, however, renders such optimism suspect (*22*).

The situation at the turn of the century will almost surely reflect developments in other shipping sectors. If the 1991–1992 recession is long and its effects widespread, energy demand worldwide could stagnate, resulting in lower tanker charter rates. That should be reflected in fewer orders for new tankers and lower prices for new containerships from shipyards desperate to attract customers. Conversely, a strong global economy and a boom in the tanker and bulk trades could raise new containership prices, causing orders for additional container-carrying capacity to be cut back. The Oil Pollution Law of 1990 should have a similar effect, since it will keep some yards busy with refits or with new buildings. Major uncertainties include possible changes in shipyard capacities and scrap prices and alternative technologies to double-hulling (*23–29*).

The containerships themselves will grow larger and somewhat faster. In the early 1980s experts suggested that containership size was approaching geographic, commercial, and technical limits. The geographic bound was the width and depth of the Panama Canal, which limited maximum capacity to about 3,500 TEUs. During the decade trans-Pacific trade grew rapidly, however, and landbridging across the United States increased, facilitated by the introduction of unit trains and double-stack railcars. By 1991 American President Lines had put bigger-than-Panamax vessels into service, and other carriers were operating or building ships with 3,500- to 4,000-TEU capacities.

One commercial concern in the 1980s was that there might not be enough cargo to warrant much bigger ships (a point that is still sometimes troubling). Another was that containers might not be concentrated in sufficient numbers at a small enough number of ports. Cargo concentrations at the largest load-centers—such as Singapore, Hong Kong, Rotterdam, and Los Angeles–Long Beach—have continued to increase, however, allaying the latter anxiety.

There also were technical concerns about the vessels themselves as well as yard equipment and infrastructure in and around the container terminal. There were fears that structural problems with these very large vessels might result in excessive flexing and catastrophic failures. Some adjustments in design and in operation have provided assurance in this regard. Another problem was that the new vessels would be wider than the outreach of existing ship-to-shore cranes. However, by 1991 many terminals had purchased cranes that could work across 16 rows of containers on the ship, accommodating the widest vessels on order. A third fear was that the cranes, yard equipment, and yard operating systems were so slow and inefficient that they would neutralize the advantages of very large vessels. By the early 1990s, however, a few terminals (such as ECT Maasvlatke) were operating with cranes, yard equipment, and computerized management systems efficient enough to strip and reload a 3,000-TEU vessel carrying 40-ft containers in less than 1 day, using three high-speed cranes.

Therefore, many of the concerns that previously constrained containership size have diminished. It appears likely that 2000 will see containerships twice as big as the largest being built just a decade before—jumbos of 5,000 to 6,000 TEUs (*30*). Vessels much larger than that, however, once again raise renewed technical, commercial, and channel depth concerns. Thus, they appear unlikely within the next decade.

The jumbos entering the fleet, at least during the first half of the 1990s, will be somewhat faster than their predecessors, operating at speeds of 22 to 25 knots. Analysis of trade-offs between speed, fuel consumption, and vessel productivity is tricky in a world of volatile fuel prices. However, the consensus is that dramatically higher prices are unlikely during the next several years (*31,32*). Containership operators, therefore, are opting for new vessels that burn more fuel but are 2 to 5 knots faster than their predecessors.

Domination of Cellular Vessels

The trend toward non-self-sustaining or gearless cellular containerships also should continue. All of the jumbos being built or on order at the beginning of the 1990s were of this type, and they appear certain to dominate the major East-West trade routes in the years to come. Vessels of this size and type will compose the bulk of the world containership fleet in tonnage terms.

For a number of reasons, however, containerships with their own gear as well as RO-ROs, LO-ROs, and combination carriers (semicontainerships) will not disappear, even though they use their space less efficiently than gearless cellular vessels. For one thing, they offer the small operator greater flexibility in serving feeder ports and ports in developing countries without wharfside container cranes.

RO-RO vessels and other vessels with independent discharging capabilities will remain attractive for military purposes, as Operations Desert Shield and Desert Storm demonstrated. Therefore, the United States government and others may well subsidize the construction and operation of such vessels (*33,34*). RO-ROs also are useful in the movement of large vehicles and heavy construction equipment and are ideal for shortsea operations, for example along the European and East Asian coasts and among the island nations of the Pacific. Such operations, in fact, are container ferries. Their attraction is the speed with which containers already on chassis can be debarked and depart the terminal on arrival.

Container barging also should grow. Candidates for container barging include shortsea, coastal feeders, and inland waterway operations. Even where ports are equipped with big cranes, the use of seagoing barges and tugs to provide feeder service may be preferable to containerships whose capital and operating costs are much greater. Container barging, already firmly in place along the U.S. East Coast, appears to be an economically attractive alternative for a number of short routes in northern Europe and the Mediterranean as well as Asia and the Pacific (*35–38*).

If the shipping industry were entirely rational, a pattern would emerge by 2000 in which three different kinds of vessels provided three different kinds of service: (*a*) very large, fast, non-self-sustaining containerships that cross oceans and stop at only one or two ports on a range, loading and discharging 1,000 or more containers at each call; (*b*) RO-RO and LO-RO vessels as well as smaller containerships and combination ships (semicontainerships) that serve secondary ports, lower-volume trades, and LDCs; and (*c*) pushbarges, tows, and smaller combination ships that carry 50 to 500 containers at a time and provide coastal, shortsea, and feeder services between load centers and "outports."

Such orderliness is unlikely, however, in the light of the predicted excess capacity. Instead, crossovers of vessel types from one kind of service to another will persist as carriers seek higher load factors and better profits.

Shrinkage, Not Disappearance, of Crews

The technology is at hand to permit the operation of vessels on the high seas without anyone aboard. All necessary information about the vessel's location, the status of its operating systems, and conditions being encountered (weather, sea state, and traffic) could be transmitted automatically to land-based personnel. They could make decisions and transmit instructions back to the vessel that actuated whatever adjustments were needed. Multiple backup systems could ensure against failure. Shore-based emergency teams could be airlifted aboard in a few hours if necessary. Small crews could be put aboard for the portion of a leg in pilot waters, although theoretically even that would be unnecessary.

Unmanned containership operations are unlikely during this decade, however, because of concerns about safety and the environment. Nevertheless, experiments with crews as small as eight were being reported by the end of 1990. Furthermore, there are already some cargo vessels in service (including two Hapag-Lloyd jumbo containerships) that can be "single-handed"; all their systems can be monitored and controlled by one person on the bridge. It appears certain that many containerships of the next generation will have crews less than half the size of their predecessors (*39–45*).

Futuristic Designs

If a vessel could run at 40 knots, it could cross the Pacific in 5 days, cutting current transit times in half. Usually, however, it is more economical to make a ship larger than faster, because of the relatively rigid relationships that exist between hull shapes, material costs, power requirements, and speed (*46*). Thus, the commercial utility of such speeds, when applied to conventional displacement vessels, depends on development of propulsion systems much more powerful but nearly as economical and compact as present ones. Currently, only nuclear power plants appear to offer this combination of characteristics. However, concerns about long-term cost efficiency as well as environmental dangers appear likely to deter widespread application in cargo vessels. An intriguing alternative, superconductivity, also is unlikely to appear in commercial applications before the end of the century (*47*).

Another way to increase speed is to design vessels that move in one medium—only water or only air. Container-carrying submarines appear unlikely because of high construction and fuel costs. Containerships that operate above the water surface, however, such as hydrofoils or hovercraft, appear more feasible. Such vessels currently operate as ferry, sightseeing, or naval craft, so the technology is proven.

Hydrofoils are theoretically capable of 60 to 100 knots, and air cushion craft can attain even higher speeds. Either, if priced appropriately, would broaden the choices available to transportation consumers. Such vessels could move cargo two to four times faster than the fastest displacement ships but could accommodate cargo that was heavier or bulkier than generally appropriate for air freighters. Surface effect vessels would not need to occupy a berth when they reach port. Instead, they could move up a ramp to an inland location where they could be worked with relatively inexpensive yard equipment.

Transoceanic hydrofoils or hovercraft are unlikely before the 21st century due to problems of propulsion, fuel consumption, and durability and stability in heavy weather. However, smaller "air" craft able to transport 50 to 100 high-priority boxes on ferry runs, inland waterways, and short sea routes—for example, in northern Europe, the Mediterranean, and East Asia—appear to be a more reasonable prospect (*48,49*).

Among the innovations in displacement vessels that could occur are new RO-RO ships designed for exceptionally fast loading and discharging. Such vessels could have multiple openings and ramps along their sides, rather than a single one at the quarter or stern.

Megacontainers are another possibility. Since ever-faster port calls are desired, containership design could be rethought in terms of leaving and picking up whole chunks of the vessel—megacontainers—each one of which might hold dozens of containers. Departing megs would be completely prestowed at the terminal before the vessel arrived, and arriving megs could be stripped after the ship departed. The technology for floating or lifting megs off and on the ship already exists in LASH vessels and construction yards.

However, the practicality of megs would depend in part on whether they made discharging and loading a vessel substantially faster and more cost-efficient than simply ganging several high-speed cranes. The terminals' ability to stuff and strip the megs quickly would have to be proven, too; shippers care about speed from door-to-door, not port-to-port. Finally, repositioning of empty megs would pose a costly challenge (*5,50–52*).

A variant on the meg could use existing technology such as LUF-frames or other rolling devices to move blocks of containers on and off a vessel through openings in its side rather than hatches in its deck. Such refits or redesigns could speed the loading and discharging process substantially and reduce reliance on expensive wharfside container cranes.

Even more radical designs have been proposed, including huge container-carrying catamarans (SWATHs or Trisecs) and vessels that would be "made up" like freight trains. Trisecs apply the hydrodynamic advantages of the hydrofoil (low wetted surface, less water resistance) to much larger vessels. They might result in very large-capacity vessels powered by conventional propulsion systems but traveling nearly twice as fast as today's containerships. Although catamarans sidestep some of the constraints of displacement hulls, they pose serious stress and structure challenges of their own (*53*). Like the catamaran, the componentized vessel offers some intriguing advantages but poses engineering headaches. The turn of the century could witness small-scale experiments with both, but neither is likely to be in regular blue water operation.

CARRIERS AND OPERATIONS

If the last years of the century are a period of surplus carrying capacity, carriers will continue to confront the prospect of cutthroat competition, especially in the major East-West markets where overtonnaging appears chronic. Rate wars are one possible reaction. Other responses include increasing concentration and rationalization, capacity-limiting arrangements, government intervention, and product differentiation. These responses are not mutually exclusive. All are being applied already to some degree.

Responses to Competition and Excess Capacity

The 1980s saw a spate of mergers, buyouts, and consolidations. These are likely to continue, resulting in increased concentration. A few ocean carriers (giant transportation firms in many cases) are likely to dominate the biggest trades.

Rationalization among carriers should continue and expand in scope. This means not only traditional methods of collaboration on the water (slot sharing, consortia, and joint services) but landside cooperation as well—the sharing of terminals and inland facilities, box and chassis pooling, and interactive communication and computer systems. Even organizations that have long traditions of self-reliance, Sea-Land and Maersk for example, are finding that they cannot go it alone.

Where traditional liner experiences are unable to curb excess capacity and cutthroat competition, experiments with new mechanisms will occur. The Transpacific Discussion Agreement, which includes independent as well as conference carriers, has succeeded in reducing capacity among its participants, first by 10 and more recently by 13 percent. Such arrangements appear to be spreading elsewhere, for example, the North Atlantic and Europe-Asia trades. Even if they do, they will be under constant pressure—from the signatories themselves, new entrants, and shippers and regulators who question competition-restraining agreements (H. Takakashi, unpublished data, *54–58*).

Governments can facilitate capacity restraint by requiring ship lines they own or subsidize to privatize, operate profitably, or die. Ironically, movement in this direction now appears more rapid in the former centrally planned economies of Eastern Europe than elsewhere, although similar changes are occurring in several developing and newly industrialized countries. However, the arguments in favor of maintaining (or even increasing) carrying and building capacity—national security, employment, and national prestige—remain potent. Thus, governments may well continue to vacillate between policies that stimulate efficiency and encourage expansion (*59*).

Carriers have developed a variety of marketing techniques to cope with intensified competition. Ship lines seek to differentiate themselves by marketing their reliability (fixed day service), their speed (fast transits, dedicated unit trains), the high quality of service (special handling, point-to-point pricing, automated cargo information systems), or their expertise in particular markets or cargoes. Some firms offer comprehensive door-to-door service by internalizing trucking, rail, and other intermediary services. Others sell comprehensive service, too, but use external providers. A third group offers lower cost but lower quality (slower transit times, for example, or port-to-port service only). Some firms lease or own their own terminals; others rely on common-user facilities. Some operate their own feeder networks or unit trains; others depend on common carriers. The pressures on carriers to differentiate themselves—in perception and in reality—will continue unabated.

Choice of Ports, Routes, and Networks

At the heart of product differentiation as well as other strategic issues for the carrier is the choice of ports, routes, and networks. Dramatic options like round-the-world services fire the imagination, but most decisions are much more subtle. In 2000, as now, the choice of network as well as the size and type of ship to use will be heavily influenced by vessel operating costs. Cellular containerships exhibit cost economies of scale when at sea; as the size of ship increases, cost per TEU transported declines. However, while in port these vessels display cost diseconomies; the cost per TEU rises as the ship's size grows. To minimize costs an operator tries to shorten the time in port and maximize the time at sea (*46,60–62*).

Revenue generated and costs incurred are influenced by port consignment size (the amount of cargo awaiting the ship at each call), liner pricing policies, and convexity ratios. Larger port consignment sizes permit fewer calls, allowing a carrier to take advantage of the cost economies of using a larger ship.

Before containerization, ship lines generally used "equalization pricing." The rate for a given type of cargo was the same from any port on one side of an ocean to any port on the other side. Since the shipper was responsible for inland transport to and from the port, total transport cost could be minimized by shipping the cargo out of the nearest port. Thus, ports developed "natural" hinterlands, and an ocean carrier needed to call at each port if it desired to obtain the cargo from each hinterland. This resulted in multiport itineraries (*63–68*).

As vessels have grown in size, however, the economies of containership size while at sea and the diseconomies while in port have driven carriers toward very different network structures. To justify a port call by a jumbo, a relatively large port consignment size is needed. Thus, a liner pricing structure has developed, "absorption pricing," under which shippers are charged a door-to-door rate independent of port choice. Under absorption pricing the choice of port has shifted from the shipper to the ship line, and natural hinterlands have dissipated. The decision to call at a port now hinges on economic trade-offs between diverting a large mainline ship, using a feeder vessel, or using an intermodal transport system (*69*).

PORTS AND TERMINALS

Continuation of Contests

During the 1980s competition between seaports intensified because of multiple factors: government deregulation, landbridging, and the demands of ocean carriers beset with cost, capacity, and profitability problems of their own. None of these factors is likely to disappear during this decade, so intense interport competition generally will persist. In some regions, however, the competition for load-center status will diminish. Long-term terminal contracts and large landside investments will lock carriers into a port for longer periods. Lines will load-center in different ports, with each line achieving a competitive advantage for cargo originating near its chosen port. Some unsuccessful competitors in the load-center game will accept feeder ports status, finding consolation in lower break-even points and in the fact that stuffing and stripping containers generates more jobs and incomes than just handling them. Some ports will attempt to stay in the race by offering very low rates (often subsidized) in the hope of attracting carriers unhappy with the congestion at their region's principal load center.

In the contests that continue, certain traditional competitive advantages will become even more significant—deep channels, speedy access to major shipping lanes, large affluent populations that generate large volumes of imports, and industry bases that generate both exports and imports. A port's competitive situation also is likely to be stronger if it already has well-developed rail, truck, air, and barge services. All of these elements, already important, become more so in an era of 5,000-TEU vessels.

New Foci of Investment

In recent years investments in industrialized countries typically have included deepened channels and berths as well as wharf lengthening to accommodate jumbo containerships. In some ports (Rotterdam and Baltimore, for example) entirely new terminals have been built designed exclusively for container operations. Elsewhere, on-terminal rail facilities, new gates, and access roads have been constructed.

If some of the radical changes in vessel design and container-handling technology become realities, extensive port redevelopment will be required, even in Western industrialized countries. Otherwise, port investment is likely to shift toward rapidly developing countries in Asia and the Pacific as well as Eastern Europe and Latin America. According to some forecasts, 6 of the world's top 10 container ports will be in the newly industrialized countries of East Asia by 2001 (*6,70*).

Protection of the Environment

Seaports, particularly those in large cities, will be confronted by continuing problems of gentrification. More and more ports also will be under public pressure because of concern about road congestion, dredge spoil dumping, dangerous cargoes, air quality, noise, and other environmental considerations.

Environmental concerns and gentrification will force ports to develop terminal sites outside central cities. These forces (together with the ship lines' preference for being nearer the open sea) are likely to lead to the development of terminal sites on newly reclaimed land near the coastline (like Maasvlatke near Rotterdam), on artificial islands within an existing harbor (as in Tokyo and Kobe), or possibly offshore. Where terminal space becomes particularly precious, container marshaling yards and intermodal rail facilities will be shifted to inexpensive inland locations (*71*).

Improvement of Terminal Efficiency

Within the terminals themselves techniques will be applied that vastly improve container-handling efficiency. One change that requires no new technology is operating 24 hr a day, 7 days a week. For the terminal operator, around-the-clock operation is a way to increase effective terminal capacity and smooth peak loads. For the customer it offers greater speed of delivery and convenience. To be cost-effective, however, this innovation usually will require changes in long-standing overtime pay and labor hiring practices.

Terminals will become more stack oriented. A growing proportion of the containers arriving at terminals will arrive by train, barge, and cellular containership—in short, without chassis. Second, busy terminals usually face space constraints. Keeping containers in stacks and chassis in racks saves two to three times the space of chassis-mounted containers (*46*). Third, computer programs for planning and performing complex, interactive yard activities are becoming widely available. They will make reliance on stack operations more acceptable for everyone. Lastly, except in the United States, chassis usually belong to truckers, not ship lines. Containers arriving on truckers' chassis must be dismounted promptly anyway.

Increasing use of stacks is directly tied to the application of advanced container-handling technologies. One group of techniques uses interconnected mechanisms to move individual containers more quickly between storage area and vessel. Another set involves moving more than one container at a time.

A number of mechanically connected ship-to-storage-stack systems for handling containers have been designed, although only one, belonging to Matson Lines, is reportedly in operation. These systems use an oversized transtainer that receives the container directly from the crane, a conveyer monorail system, or a mechanical "merry-go-round" that keeps flows to and from the vessel continuous. Terminals and carriers are likely to remain hesitant to embrace these systems. Their capital costs are very large, and their inflexibility raises questions about their practicality, especially in common user terminals. Furthermore, it is not clear that they would be any faster than several high-speed, dual-trolley cranes supported by appropriate yard equipment and management systems.

Many existing ship-to-shore cranes, transtainers, and straddle carriers can perform "twin-twenty" lifts, in which two containers stacked on top of each other and locked together are moved as a unit. This is rarely done with loaded containers, but there appears to be no mechanical reason why heftier terminal equipment could not lift blocks of four or more containers simultaneously. Other systems for multiple container movement already exist, for example, the LUF system, in which a large tractor tows a platform carrying blocks of four or more containers, and ECT's container "trains," which pull a string of five 40-footers using oversized yard hustlers.

An alternative using automated guidance technologies to move individual containers at high speeds is being tested by ECT. The system uses existing dual-trolley high-speed wharfside cranes, which are served by a fleet of automated guided vehicles (AGVs)—unmanned straddle carriers. At the storage areas the containers carried by the AGVs are removed and stacked by oversized yard gantry cranes that also are unmanned. Under ideal conditions the system reportedly can run at rates up to three times those of conventional terminals. It appears to avoid many of the rigidities that make the mechanically integrated systems unattractive.

The Pervasive Computer

The effects of computerization will become even more widespread. Inexpensive desktop PCs that can perform functions that used to require a mainframe will allow smaller marine terminals to apply sophisticated techniques for tracking and organizing containers. In the yard or at the wharf, workers with hand-held computer terminals will be able to input information immediately, eliminating time lags and errors caused by manual procedures. Artificial intelligence and expert systems will assist in stack layout, stowage planning, and work scheduling. Standardized transponders, bar codes, or other identification devices will facilitate container tracking and storing. Heuristics and optimizing algorithms will replace guesswork in yard management and stowage planning. Menu structures and decision trees will lead even workers who are inexperienced with computers through complicated applications. All sorts of operational and analytic tasks will be done more quickly and accurately than today (*46*).

Labor

These tasks and others will be carried out in an environment of continued pressure to increase productivity caused by tighter intermodal linkages as well as competition between carriers and between ports. One persistent challenge is likely to lie in the area of labor costs and productivity, since labor still often makes up more than half the operating expenditures of a container terminal.

Workers must be more highly educated, and they must undertake more extensive training before they go to work and periodically thereafter. Changes are necessary in the arm's length relationship between terminal managers and unionized workers; restrictive job jurisdictions and work rules; the irregular nature of terminal employment; expensive, often self-defeating job preservation schemes; and the reluctance of both management and labor to consider new methods and technologies. The ports and terminals that make these transitions quickly and smoothly are likely to be the winners in the 1990s and beyond.

INTERMODALISM

Intermodalism will continue to advance, filling out the spectrum of transportation services in terms of speed and cost. Inevitably, this will mean increased competition between transportation modes, for example, a contest for higher value and perishable cargoes between ships and planes. As containerized cargoes become lighter and more valuable, they become more likely candidates for air freight. Furthermore, shippers are concerned about door-to-door speed. They don't care how fast the ship is, if their cargo is delayed at the port or if inland transportation systems are underdeveloped or unreliable. In parts of East Asia, the Pacific, and the former Soviet Union, inadequate ground infrastructure combined with difficult topography or great distances should make ocean-air intermodalism an attractive alternative. If so, attempts to make air and ocean containers compatible or interchangeable may be resumed.

The continued development of domestic containerization appears to be a necessary corollary of the rapid expansion of intermodalism. (The term "domestic" will be technically inaccurate because many of these containers will cross national borders, for example, within the European Economic Community or between the United States and Mexico. However, they will not have a water leg.)

The operating and capital costs of intermodal systems (double-stack railcars and tunnel, bridge, and roadbed modifications) are so heavy that railroads find them hard to justify on the basis of transoceanic cargoes alone. Thus, domestic moves are becoming an important way for container owners and transporters not only to fill empty backhauls and smooth imbalances in international flows, but also to spread costs and maximize net revenues. Railroads are likely to encourage their customers to switch from piggyback shipment of trailers on flatcars to containers carried by double-stack trains.

As a corollary, the 1990s should see the application to containers of the "roadrailer" technology that is currently used for domestic trailer chassis in the United States. The adaptation would involve building container chassis that have two sets of wheels—one steel, the other rubber. This would allow a container to be converted, in effect, from a railcar to an over-the-road truck body in a matter of minutes.

The issue of container equipment standardization remains a major uncertainty. Many ocean carriers and box lessors continue to offer nonstandard heights, and several major carriers offer lengths in excess of 40 ft. Firms interested in attracting domestic as well as transoceanic cargoes are interested in larger cubes that can compete with 48-ft over-the-road trailers. Efforts are currently under way, especially in Europe, to establish new standard sizes, 49 and 23 ft. Whatever standards the ISO adopts, substantial variations are likely to persist, and the constraints they impose on interchangeability of equipment and flexibility of operation will continue to be a source of inefficiency and expense (*72–75*).

Propelling the continued development of intermodalism are global commercial realities. Just-in-time inventory management techniques and "quick response" retailing were innovations in the 1980s. They will be nearly universal in the 1990s. Growing masses of consumers in an ever-widening number of countries will insist on current fashion, product quality, and producer responsiveness. Product life cycles will continue to shorten, and minimizing inventories of potentially obsolete products will become even more important. Multinationals will use a network of facilities around the world to develop, source, and assemble. The resulting products will be marketed to increasingly affluent populations across the globe.

In such a world, successful international transportation firms must offer not just cargo carriage but a total logistics package that provides frequent and reliable service for goods moving between any origin and destination. Some of the earliest firms to move in this direction have been American, namely CSX-Sealand and APL. They will be joined and perhaps overtaken in the 1990s by European and Asian challengers who can respond effectively to the growing market for door-to-door management of freight movement and for a continuum of transportation products that vary in speed, frequency, dependability, and cost (*76–79*).

CONCLUSION

An attempt has been made to forecast operational realities in ocean container transport at the advent of the 21st century by examining patterns and trends already visible. The predicted changes, therefore, have tended to be evolutionary rather than revolutionary.

Any such forecast is only as robust as the assumptions on which it is based. Optimistically, perhaps, the forecast is premised on moderate, midrange expectations regarding energy consumption and prices, growth trends in the global economy and cargo, the absence of great power conflict, and continued progress toward a globalized economy. Similarly, it was assumed that the discovery and widespread use of wholly new energy sources or materials will not occur in the next decade.

If recent history offers any guidance, it is that some of what appears reasonable and probable may not come to pass.

REFERENCES

1. M. Magnier. Experts See Falling Barometer in World's Shipping Industry. *The Journal of Commerce,* April 4, 1990.
2. L. Ryan. Box Cargo Growth Predicted. *The Journal of Commerce,* June 7, 1990.
3. B. Vail. Outlook Dims a Bit for Liner Shipping. *The Journal of Commerce,* Dec. 31, 1990.
4. *Maritime Transport: 1989.* Organization for Economic Cooperation and Development, Paris, 1990.
5. R. Schonknecht, J. Lusch, M. Schelzel, and H. Obenaus. *Ships and Shipping of Tomorrow.* Cornell Maritime Press, Centreville, Md., 1983.
6. R. F. Gibney. *World Wide Container Data: 1985.* Container Data, Ltd., Dalry, Scotland, Oct. 1985.
7. G. Joseph. Container Trade Rise Slowdown Forecast. *The Journal of Commerce,* Sept. 14, 1988.
8. C. Dunlap. Reefer Cargo Trade Forecast To Grow About 3% a Year After Slow 1991. *The Journal of Commerce,* Jan. 29, 1991.
9. C. Dunlap. Refrigerated Container Advances Add to Ship Lines' Burdens. *The Journal of Commerce,* Jan. 29, 1991.
10. J. Davies. Ships May Win Perishables Trade with New Box. *The Journal of Commerce,* Jan. 9, 1991.
11. B. Mongelluzzo. Mitsui O.S.K. Line Expect New Box To Lure Fish Cargoes. *The Journal of Commerce,* Nov. 21, 1990.
12. J. Porter. Experts Divided on Box Impact on Reefer Trade. *The Journal of Commerce,* June 29, 1990.
13. L. Hall. Smarter Containers Keeping Meat Cool. *The Journal of Commerce,* June 27, 1990.
14. *The Reefer Market: Trends and Prospects in Refrigerated Cargo Trade and Shipping, 1985–95.* Drewry Shipping Consultants, London, 1988.
15. *Refrigerated Transportation.* Container Marketing, London, 1988.
16. Sea-Land Makes Reefers Squeaky Clean. *The Journal of Commerce,* Dec. 2, 1990.
17. Sea Bulk and Powerliner. *The Journal of Commerce,* Oct. 21, 1991, p. 1.
18. A. E. Cullison. Worldwide Box Capacity Seen Soaring by 1995. *The Journal of Commerce,* June 18, 1991.
19. A. Wastler. Shipowners Bearing Brunt of Overcapacity Problem. *The Journal of Commerce,* Dec. 10, 1990.
20. J. Davies. Is Overcapacity Dilemma for Big Ships Here To Stay? The Journal of Commerce, June 27, 1990.
21. R. F. Gibney. Jumbo Fleet to Grow by 60%. *Container Insight,* Report 17, July 1988.
22. M. Sclar. Presentation at Port of the Future seminar. American Association of Port Authorities, Montreal, Quebec, Canada, June 6, 1990.
23. A. E. Cullison. Japan Plans To Design, Launch "Spill-Proof" Tanker by 1997. *The Journal of Commerce,* Dec. 10, 1990.
24. J. Jacobs. German Research Group Predicts 60% to 120% Jump in Yard Output. *The Journal of Commerce,* Nov. 30, 1990.
25. J. Porter. Big Growth Reported in Bulk Carrier Fleet. *The Journal of Commerce,* Nov. 23, 1990.
26. A. E. Cullison. Japanese Yards Expected To Increase Ship Launchings by 10% in 1991. *The Journal of Commerce,* Dec. 24, 1990.

27. E. E. Toll. Gradual Tanker Fleet Renewal Urged. *The Journal of Commerce,* June 5, 1989.
28. J. Porter. How To Replace Aging World Fleet. *The Journal of Commerce,* May 3, 1989.
29. R. F. Gibney. Jumbo Fleet May Rise 45% by 1990. *Container Insight,* Report 16, April 1988.
30. J. L. Eyre. The Containerships of 1999. *Maritime Policy and Management,* Vol. 16, 1989, pp. 133–145.
31. M. Lelyveld. Oil Prices Should Fall Sharply When Gulf Crisis Ends. *The Journal of Commerce,* Jan. 3, 1991.
32. M. Lelyveld. Bearish Pressure on Oil Prices Likely To Last into '92. *The Journal of Commerce,* Oct. 24, 1991.
33. W. Dibenedetto. Delivery Set for First of Navy's New Sealift Fleet. *The Journal of Commerce,* Oct. 24, 1991.
34. T. McNiff, Jr. Sealift Chief Sees More Roll-On Ships. *The Journal of Commerce,* June 18, 1991.
35. B. Barnard. Report Urges EC To Use Marine Transport Better. *The Journal of Commerce,* Feb. 7, 1991.
36. C. Dunlap. Sea-Barge To Serve Jacksonville. *The Journal of Commerce,* Aug. 14, 1990.
37. C. Dunlap. New Barge Line Set To Enter Risky Puerto Rico Venture; Service Links NC, San Juan. *The Journal of Commerce,* Aug. 15, 1990.
38. J. Porter. Trading Blocs Seen Encouraging Growth in Short-Haul Services. *The Journal of Commerce,* Oct. 9, 1991.
39. W. DiBenedetto. Study Claims Smaller Crews Can Run Ships of the US Safely. *The Journal of Commerce,* Dec. 11, 1990.
40. E. Unsworth. Ship Line To Extend Reduced Crew Test. *The Journal of Commerce,* March 8, 1989.
41. D. C. Becker. Publisher's Notebook. *The Journal of Commerce,* March 22, 1989.
42. B. Vail. Crew Cuts Please Ship Lines but Take Toll on Seafarers. *The Journal of Commerce,* Nov. 28, 1988.
43. V. W. Stove. Futuristic Ships Worry Insurers. *The Journal of Commerce,* Sept. 22, 1988.
44. A. E. Cullison. "K" Line To Increase Mixed Crews. *The Journal of Commerce,* Nov. 29, 1990.
45. P. Bangsberg. Seamen Ranks Continue To Decline in Asia. *The Journal of Commerce,* Dec. 26, 1990.
46. M. Chadwin, J. Pope, and W. Talley. *Ocean Container Transportation: An Operational Perspective.* Taylor & Francis, New York, 1990.
47. A. E. Cullison. Sea Trials Planned for Japanese Ship Driven by Magnets. *The Journal of Commerce,* Feb. 6, 1991.
48. J. Davies. Japanese Shipyards To Design High-Speed Containership. *The Journal of Commerce,* Dec. 6, 1990.
49. Aeroconversion Develops Skimmer. *The Journal of Commerce,* Nov. 6, 1990.
50. J. Davies. Designer Lauds Concept of Super-Barge Carrier. *The Journal of Commerce,* Oct. 4, 1988.
51. J. Davies. Experts Dispute the Validity of Super-Barge Concept. *The Journal of Commerce,* Oct. 5, 1988.
52. 1-Box Ship Idea Endures. *The Journal of Commerce,* Sept. 12, 1989.
53. C. A. Marchaj. *Sailing Theory and Practice.* Dodd, Mead & Co., New York, 1964.
54. H. Yamada. In Celebration of the Birth of TDA. Presented at the International Cargo Handling and Containerization Association Meeting, Stockholm, Sweden, May 31, 1989.
55. M. Magnier. Ship Lines in Pacific Question Crisis Plan. *The Journal of Commerce,* Nov. 14, 1988.
56. B. Mongelluzzo. Quartel Offers Suggestions To Improve Ship Law. *The Journal of Commerce,* Nov. 25, 1990.
57. E. E. Toll. Ship Lines May Reduce Mediterranean Sailings. *The Journal of Commerce,* Oct. 22, 1991.
58. B. Mongelluzzo. Vessel-Sharing Partnerships in Pacific Prove Beneficial. *The Journal of Commerce,* Oct. 21, 1991.
59. J. L. Eyre. Maritime Privatization. *Maritime Policy and Management,* Vol. 17, 1990, pp. 113–121.
60. W. K. Talley. Optimal Containership Size. *Maritime Policy and Management,* Vol. 17, 1990, pp. 165–175.
61. R. Robinson. Size of Vessels and Turnround Time: Further Evidence from the Port of Hong Kong. *Journal of Transport Economics and Policy,* Vol. 12, 1978, pp. 161–178.
62. T. D. Heaver and K. R. Studer. Ship Size and Turnround Time: Some Empirical Evidence. *Journal of Transport Economics and Policy,* Vol. 6, 1972, pp. 32–50.
63. T. D. Heaver. Trans-Pacific Trade, Liner Shipping and Conference Rates. *The Logistics and Transportation Review,* Vol. 8, 1972, pp. 3–28.
64. T. D. Heaver. The Structure of Liner Conference Rates. *Journal of Industrial Economics,* Vol. 21, 1973, pp. 257–265.
65. I. Bryan. Regression Analysis of Ocean Liner Freight Rates on Some Canadian Export Routes. *Journal of Transport Economics and Policy,* Vol. 8, 1974, pp. 161–173.
66. D. Shneerson. The Structure of Liner Freight Rates: A Comparative Route Study. *Journal of Transport Economics and Policy,* Vol. 10, 1976, pp. 52–67.
67. E. T. Laing. The Rationality of Conference Pricing and Output Policies, Part 1. *Maritime Studies and Management,* Vol. 3, 1976, pp. 141–151.
68. R. Byington and G. Olin. An Econometric Analysis of Freight Rate Disparities in U.S. Liner Trades. *Applied Economics,* Vol. 15, 1983, pp. 403–407.
69. S. Gilman. *Container Logistics and Terminal Design.* International Bank for Reconstruction and Development, Washington, D.C., 1981.
70. J. Jacobs. Far East Ports Adopt Bold New Strategies. *The Journal of Commerce,* April 28, 1989.
71. A. Ashar. On-Off Terminal Vessel-to-Rail Intermodal Transfer and the Case of Long Beach Port. *Maritime Policy and Management,* Vol. 17, 1990, pp. 235–247.
72. T. McNiff. New Standards Ahead for Sizes of Containers. *The Journal of Commerce,* Dec. 10, 1990.
73. J. Goldstein. Box Standards Still Far Off: UN Unit Fails To Reach Accord. *The Journal of Commerce,* Feb. 28, 1989.
74. J. Porter. EC Seeks Genuine Intermodal Network. *The Journal of Commerce,* May 25, 1989.
75. L. Ryan. Canada Rails Weigh Box Compatibility. *The Journal of Commerce,* June 13, 1989.
76. R. C. Waters. The Race for Seamless Service. *The Journal of Commerce,* June 21, 1991.
77. T. Seideman. Ship Lines Swapping More Data with Vessel-Sharing Agreements. *The Journal of Commerce,* June 20, 1991.
78. E. E. Toll. CGM Chief Sees More Consolidation. *The Journal of Commerce,* June 19, 1991.
79. B. Mongelluzzo. Carrier Changes Reflect Pacific, Intermodal Focus. *The Journal of Commerce,* Oct. 1, 1991.

Publication of this paper sponsored by Committee on Ports and Waterways.