Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-00/1833-1		

4. Title and Subtitle	5. Report Date
MEGA-CONTAINERSHIPS AND MEGA-CONTAINERPORTS IN THE GULF OF MEXICO: A LITERATURE REVIEW AND ANNOTATED BIBLIOGRAPHY	May 1999/Revised October 1999 Second Revision May 2000
	6. Performing Organization Code
7. Author(s): Robert Harrison, Miguel A. Figliozzi, and C. Michael Walton	8. Performing Organization Report No. Research Report 1833-1
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, Texas 78705-2650	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. Project No. 0-1833
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Section/Construction Division P.O. Box 5080 Austin, TX 78763-5080	13. Type of Report and Period Covered Research Report: 9/1998–5/1999
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

Container shipping plays a key role in international transshipments and is currently the system of choice for most global shippers handling non-bulk commodities. In the competitive maritime industry, steamship companies are looking for ways in which further economies can be achieved. One of the areas examined has been the maritime portion of the trip, wherein ship economies of scale can be obtained through the use of larger vessels.

During the 1990s, technical constraints associated with very large or mega-containership designs were overcome, and the operation of such vessels (in the range of 4,500 to 7,000 TEUs) offered the promise of lower container shipment costs over the densest trade routes. This report represents the findings of a literature review largely undertaken during the period from August 1998 to June 1999. The report includes chapters on international trade and maritime economics, maritime industry, containerization, mega-containerships, and mega-containerport infrastructure, and concludes with recommendations concerning the deliverables required for Research Project 0-1833. An annotated bibliography containing material used in the report is given in the Appendix.

17. Key Words	18. Distribution Statement
Containers, international trade, Gulf of Mexico, mega-containerships, containerports, mega-containerports	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	130	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Research Report Number 1833-1

Research Project 0-1833
Project Title: *Infrastructure Impacts of Containerships (Including Mega-Containerships) on the Texas Transportation System*

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

May 1999

Revised: October 1999

Second Revision: May 2000

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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ACKNOWLEDGMENTS

The research supervisor wishes to recognize the contributions made to this report by participants in the 1998 fall semester graduate course, "Intermodal Transportation Systems" (CE397). Their contribution was the development of the class report, "Design Guidelines: Megaship Facility." The students focused on the evolving strategies, techniques, and technology of accommodating the expanding global trade, growing demands of intermodal container movements, and the trends toward larger capacity containerships. The graduate students in the transportation program contributing to this report include: Kristin Belfield, Sam Belfield, Zeina El-Nazer, Becky Hobson, Scott James, Katsuhiko Nakamura, David Ory, and Glenn Standifer. The work undertaken formed a basis for Chapters 4, 5, and 6.

Becky Hobson continued to make modifications to the class document before turning the effort over to study investigators. Further expansion and refinements to the report were made by Robert Harrison, Senior Research Scientist, and Miguel Figliozzi, Research Engineer Associate II, as supported by Michael Bomba, LBJ School graduate student intern.

Also significant to the accomplishment of this product has been the involvement and direction of the Texas Department of Transportation (TxDOT) project steering committee, which includes project director Jim Pavone (FIN) and project monitoring committee members Jim Randall (MMO), Kelly Kirkland (MMO), Raul Cantu (TPP), Chris Olavson (HOU), and Carol Nixon (HOU). Particular thanks are due to Jim Pavone for his careful and constructive editing of the first and second drafts of this report.

C. Michael Walton, Research Supervisor

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CHAPTER 1.
INTRODUCTION TO THE RESEARCH PROJECT

BACKGROUND

The decade of the 1990s was characterized by substantial growth in U.S. and world trade. To a large degree, such trade growth has been a response to a general stimulation of international trade reflected in the establishment of the World Trade Organization in 1995 and in the signing of the North American Free Trade Agreement in 1993. Worldwide initiatives to reduce tariffs and other restrictive practices, along with efforts to stabilize currency policies, have resulted in the expansion of world trade to the benefit of U.S. companies.

Transportation systems have been a critical element in this trade expansion, helping to (1) lower ton-mile costs for many commodities, (2) ensure the higher service levels required by shippers, and (3) improve all transportation modes, especially rail. Many companies that before managed their own transportation services have outsourced these services to third-party entities that are now responsible for meeting the service schedules and cost limits set by the market. The success of third-party logistics has contributed to the growth of U.S. companies' share of international trade.

Container shipping is a key element in international transshipments and is currently the system of choice for most global shippers. This has resulted in a growing demand for container shipping, not only among major trading regions like the Far East, North America, and Europe, but also between the U.S. and Latin America. Over the densest container routes, shippers are looking for ways in which further economies can be achieved. One of the areas examined has been the maritime portion of the trip, wherein ship economies of scale can be achieved. Problems with naval architecture, port facilities, and demand levels previously constrained the move toward larger containerships. In the 1990s, however, the technical design features were overcome, and large containerships provided real commercial opportunities to lower costs for boxes over the key routes over which these vessels could operate.

The Texas Department of Transportation (TxDOT) commissioned a research project in late 1998 to examine infrastructure impacts and operational requirements associated with these larger vessels, particularly as they affected the Texas transportation system. The project was designed to assist decision-makers in (1) addressing the planning, institutional, and financial issues associated with increased containerized freight traffic, and (2) assessing the demands on the multimodal transportation system in Texas made by the operation of these large containerships in the Gulf of Mexico. In 1999, the project scope was expanded to include all containership operations, including the large vessels now coming into world service.

The ship designs now being brought into operation represent the fifth generation in the historical development of the containership *(1)*. These ship designs are variously termed *mega-containership* or *Post-Panamax Plus* vessels. Panamax refers to those ships that are able to meet the physical constraints imposed by both the locks and the channel of the Panama Canal; they can be regarded as the third generation of containerships, given their container capacity of around 4,000 20-foot equivalent units (TEUs). Post-Panamax vessels comprise the fourth generation and have capacities in the range of 4,000–5,000 TEUs. These are the dominant class of containerships currently operating over the key world maritime trade routes. This report defines mega-containerships in terms of their current capacities, which range from 5,000 to around 7,000 TEUs, although some in the 7,000- to 8,000-TEU capacity are likely to be built in the early part of this decade. There are plans for capacities up to 14,000 TEUs, with twin engines and propulsion systems, on the drawing board. Maritime limitations on ship size are based on two critical factors: container demand and port infrastructure. Demand is based on the general growth of international container traffic and on the ability of the port to attain hub status or to achieve levels of container throughput consistent with a load center or regional hub. Port infrastructure includes channel depth, turning basin size, berth size, crane efficiencies, handling equipment, storage, and intermodal access.

This report on mega-containership issues and impacts is based on a literature review and on preliminary analyses of trade data and port policies. Chapter 2 examines the economics of trade and maritime systems and identifies some economic principles that are appropriate for the analysis of container operations and the choice of port. It argues that the evaluation process for identifying a port facility capable of handling a mega-containership should use a variety of economic indicators. Chapter 3 discusses the maritime industry, which has undergone substantial changes recently after a century of relative stability. With alliances replacing conferences, these new global entities have the resources to both purchase and fill mega-containerships. Chapter 4 addresses the development of containerization and covers demand, container fleet, composition, and routes. Chapter 5 focuses specifically on mega-containerships and covers dimension, capacity, routes, and economies of scale. Chapter 6 examines port infrastructure, particularly as it is affected by mega-containership operations. It addresses issues related to maritime access, port operations, and landside access. Chapter 7 summarizes the findings of the report and relates these findings to other deliverables of this project, including a process of evaluating Texas containerports (including potential load centers) and an analysis of containership routes, size, and container demand in the Gulf of Mexico. Finally, Appendix A provides an annotated bibliography of key reports, articles, and books used in the production of this report.

CHAPTER 2.
INTERNATIONAL TRADE AND MARITIME ECONOMICS

WORLD TRADE

For more than 500 years, international trade has been studied as a formal branch of economics. Following the European medieval era (roughly from A.D. 500 to 1500), when domestic economies in Europe began to grow steadily, there developed a school of thought centered on the establishment of the power of the merchant and on the relationship between a nation's wealth and its balance of foreign trade. The mercantilists, as these thinkers were termed, recognized the growing power of the national economy and favored the intervention of the state in economic activity to maximize national wealth *(2).* Policies that mercantilists recommended between 1550 and 1700 centered on using import tariffs to deter the import of products and commodities from other economies. Because trade was not measured (and therefore not easily examined), the benefits derived from international trade were difficult to discern, while the costs were easy to exaggerate. In spite of these arguments, international trade continued to grow slowly during the period from 1700 to 1815, and with it the significance of ships and ports. Indeed, the empires of Portugal, Spain, and Britain, including the growth of trade among members within each empire, were based on mercantile fleets and naval power.

By the early 1800s, the strong growth of industrial production in many countries prompted further academic examination of the role of international trade. Foremost among the theorists of developing trade was British economist David Ricardo (1772–1823), who recognized the influence of costs on price levels, particularly the influence of wages on relative prices, and the fact that both capital and wage costs represented the two key factors of production of various commodities *(3).* Specifically addressing the theory of international trade, Ricardo was the first to explicitly formulate the law of comparative costs in 1817. This economic principle suggested that international trade would take place between countries where there exist substantial cost differences in the factors of production. In addition, the law of comparative costs defines conditions under which trade will take place even when *all* commodities could be produced more cheaply in one country than in another. Ricardo's law of comparative costs survives as an important part of the theory of international trade today, as does his use of models to measure the trade effect *(4).*

The 20th Century

In the last hundred years, countries that industrialized, particularly after Europe and the U.S., tended to protect their newly formed industries behind high tariff walls. For some countries, this protectionism began to change only in recent years, as in the cases of Mexico and Brazil. The difficulties of managing international trade and the variations in economic output related to major wars and economic recessions in the 20th Century led to the development of a reorganized world economic system in the late 1940s that critically impacted trade. The instabilities in currencies and economic performance among the world countries led to the formation in 1946 of the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD), which became operational in 1947 *(5).* The IBRD was formed to allow those countries devastated by World War II to rebuild their economies under loans and conditions framed by the IMF. In addition, the IMF would provide regular tracking data on all its members and help to counter potential problems by supplying capital at reasonable rates. The monetary policies and agreements that emanated from this process stabilized the key national economies and promoted the growth of international trade that has characterized the world economy since 1950. Related to this program was the formation of the General Agreement on Tariffs and Trade (GATT) in 1948 *(6).* While providing a forum for international tariff bargaining, the GATT articles of agreement pledged member countries to the expansion of multi-lateral trade with a minimum of trade barriers, reduction in import tariffs and quotas, and the abolition of preferential trade agreements. GATT, which lasted for 47 years, was replaced by the World Trade Organization (WTO), which came into being January 1, 1995, with 104 countries as its founding members *(7).* While GATT was small and provisional (it was not even recognized by international law as an organization), the WTO is larger, incorporating into it not only all the GATT agreements, but also agreements covering trade in services, intellectual property, and commodities.

Underpinned by the legal ground rules for international commerce and for trade policy, the WTO is now the only international body dealing with the rules of trade between nations. The agreements have three main objectives: (1) to promote free trade flow, (2) to liberalize trade policies gradually through negotiation, and (3) to establish an impartial means of settling disputes. The principles underlying the agreements are straightforward and include nondiscrimination, free trade, predictable policies, competition, and the protection of weak economies, particularly those of less developed countries *(7).*

Trading Blocks

In the last 15 years, trading blocks, varying widely in terms of makeup, authority, and economic power, have emerged as new members of the WTO. In the most complex (and powerful) of these trading blocks, countries merge economic policies and lose some sovereignty. For example, the European Union (EU) is now beginning to utilize a common currency and adopt common economic policies *(8).* Because the decisions reached at EU headquarters in Brussels impact all member countries, EU membership entails an acceptance of some loss of sovereignty.

Another type of trading block is a customs union, in which common agreements are reached not only among the member organizations trading among themselves, but also among other trading blocks or nations (e.g., with respect to the degree and standardization of external tariffs). The Southern Common Market (MERCOSUR), formed in 1991 and comprised of Brazil, Argentina, Paraguay, and Uruguay, is an example of this kind of arrangement *(9).* Finally, there is the type of trading block that places emphasis on reducing or standardizing the procedures among the countries that trade, with no common policy on external tariffs. The North American Free Trade Agreement (NAFTA) is an example of this type of arrangement. NAFTA aims at ensuring the strongest possible trading union between members without loss of sovereignty or the ability to frame and alter external tariffs *(10).*

Maritime Routes

The economic development of the various major industrialized countries, together with the formation of a wide variety of trade blocks (first under the aegis of GATT and then of WTO), has framed the current world trade picture. The growth of international trade and the concentration of specific commodities or commodity groups among these major trade blocks have given rise to a concentration of trade densities across certain geographic areas. Links between these areas may be broadly thought of as "routes," and since routes inevitably involve maritime shipping between continental areas, there are continual opportunities for the maritime industry to respond to changes in the patterns of trade. A review of the current world trade literature suggests that despite the problems in Russia and the slow recovery of some Asian economies, the era of trade growth will continue, much of it based on the principles established by Ricardo almost 200 years ago *(11).*

The ability of the maritime industry to lower its rates in real terms and to offer highly competitive prices on particular commodity routes is a testament to the effectiveness of the changes in the industry. In part, these changes, which include improved port operations, have come in response to containerization and the demand for more efficient intermodal transfers. Containerization, which has grown in tandem with world trade, represents an opportunity for the maritime industry to become more efficient. That efficiency can come in two major areas: (1) the opportunity to lower maritime costs through the use of larger and/or more fuel-efficient vessels, and (2) the improvements being made in terms of port efficiencies and costs. These efficiencies suggest that there is a growing opportunity to introduce larger vessels on key routes whereby the cost characteristics best fit the market. These characteristics are described below.

COST ELEMENTS OF CONTAINERSHIPS

With economic analysis, the viability of changes in transportation systems—such as the adoption of mega-containerships on container routes—can be examined. Five key economic characteristics that can be applied to maritime shipping and vessel choice *(12)* are now presented.

Fixed and Variable Costs

Variations in costs drive the decision to implement mega-containership operations. Costs, in part, include those that may be regarded as fixed and incurred irrespective of the utilization of the vessel. Purchase or lease costs, related insurance costs, and registration fees are fixed costs. When the vessel begins to operate, variable costs, including those associated with the crew, fuel, and port fees, are incurred. All such costs are generally nonlinear with respect to size and display a U-shaped curve, suggesting that there are ranges of operation wherein efficiencies (and therefore profit) can be gained or even maximized. In any event, because cost curves are the essential measures contributing to the decision to implement mega-containership operations, the literature abounds with examples of how such costs can be analyzed.

Life Cycle

Each maritime vessel is designed to operate over a specific life cycle. Containerships, like commercial aircraft, have a relatively long operational life (over 20 years) and tend to be rendered obsolete by improvements in technology and propulsion systems. In any event, the projected vessel life is a critical part of vessel operating costs, particularly those related to depreciation. Depreciation can be defined, for project purposes, as the money set aside annually by steamship companies so that at the end of its useful life, the vessel can be replaced with one of equal size and efficiency.

Opportunity Costs

Trade volumes, as shown during the Asian crisis of the late 1990s, can vary substantially and quickly; consequently, maritime vessels that have multiple uses have a better potential for finding regular work and for generating revenue for the owners. In the case of some container operations, this improved revenue potential has given rise to joint-use vessels, on which different types of cargo handling can be accommodated within a single vessel design. In the case of mega-containerships, there is a high opportunity cost. Not only is the vessel committed solely to container movement, but its size allows a move to other, more profitable routes only when the port infrastructure on those routes is adequate. In such cases, the issue of opportunity cost represents a business risk, given the difficulty in maintaining profitability when world trade is not growing strongly or is in recession.

Economies of Scale

Scale economies represent the predominant advantages of mega-containership adoption. The basic rationale for utilizing larger ships was laid down many decades ago with the growth in crude oil tankers *(13)*, and the central scale advantages are clearly captured by mega-containership design. Once it is sailing, a loaded mega-containership offers substantially lower container/kilometer costs across the route. Economies of this magnitude drive the adoption of such vessels by the world's ship owners. However, it must be remembered that in terms of ship operating costs, the economies of scale gained by mega-containerships need to be matched by port operations and demand levels that permit the full benefit of size to be gained. Thompson *(12)* argues that economies of scale were recognized many decades before the advent of very large crude oil carriers and larger containerships. The delay in adopting such economies had more to do with port infrastructure inadequacies than it did with technical considerations related to the architectural design of these ships. Only when the economies of scale are absolutely compelling can justification be made for infrastructure investment of the magnitude required for the efficient handling of such vessels. Accordingly, it may be expected that, unlike ports that initially adopted containership operations, fewer ports today will be in a position to justify investments in mega-containerships purely on economic grounds.

Time Costs

Like large commercial jet aircraft, large vessels like mega-containerships have an overall cost structure (fixed plus variable) that requires them to be intensively utilized. In order to maintain the compelling economic arguments for utilizing larger ships, operations will have to be undertaken that result in higher levels of utilization at sea and lower amounts of time in port. This requirement has profound implications not only for the routing of these large vessels, but also for the likely development of emerging container handling systems identified many years ago in the literature *(12)*. If indeed there are relatively few ports willing or able to accommodate these large vessels (because of the magnitude of the investment), then there may be a profound change in how containerships are operated and routed. Such a change in operations would involve the scheduling of container movements through load centers (including the potential for hub-and-spoke systems), altering the current pattern of container movements over the entire trip, from production to consumption centers.

PORT-VESSEL INTERFACE

The advent of containerships was accompanied by a major change in the way ports handled cargo and paid its labor force. Prior to containerization, ship size was constrained by the high proportion of time spent loading and discharging cargo; for example, it was not uncommon for conventional general cargo ships to spend up to two weeks in key ports, while up to 60 percent of a voyage could sometimes be spent at a berth *(14).* Although it is convenient to identify cargo management as the major factor for delay in port operations, other factors that include berth availability, tides, work delays, availability of handling equipment, breakdowns, meal breaks, nonwork shifts, weather delays, tank cleaning, and documentation are not wholly under the control of a single organization. Quite probably it will always be a challenge to maintain high levels of port efficiency with respect to vessel management, and problems tend to grow with ship size and the need to turn around large ships as quickly as possible.

The time spent in port incurring costs and not earning revenues will be a critical factor in the mega-containership routes chosen by owners. The literature suggests that, given the current ability of world ports to service such large vessels at high levels of efficiency, ports (load centers) capable of providing such levels may be few in number, potentially imposing new constraints on route choice and influencing the way in which containers are moved to serve world trade.

AVERAGE COSTS FOR LOAD CENTERS AND CONVENTIONAL PORTS

Economic principles can be used to show how load centers differ, in terms of average costs, from conventional ports. Different port operations require various levels of investment and funding. The consequences of the various strategies may be represented in a series of short-run average cost curves. Figure 2.1, showing hypothetical average cost curves for both conventional and mega-containership (load center) ports, demonstrates the efficiencies to be gained when moving increasing amounts of containers through a load center.

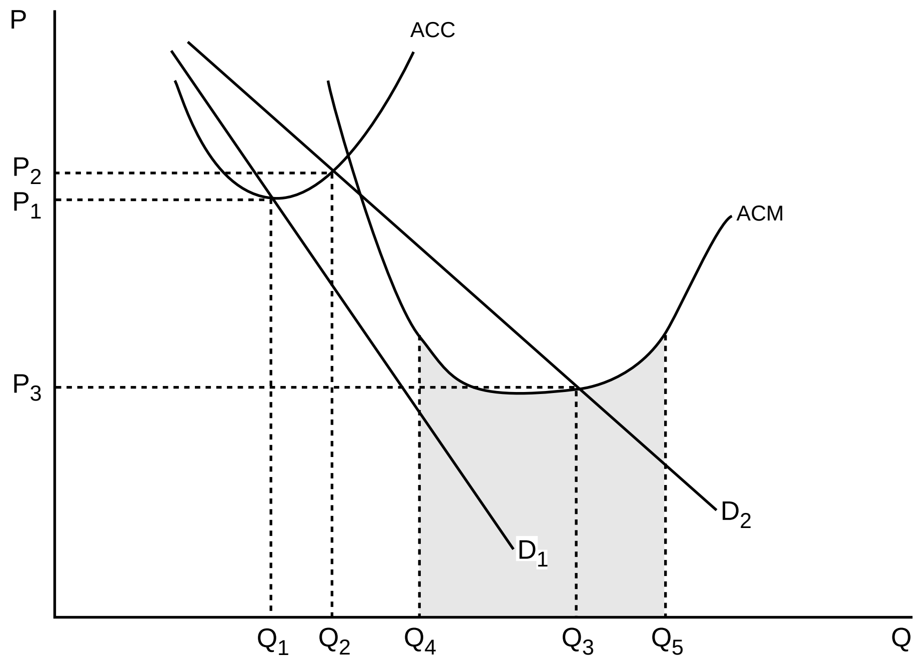

Figure 2.1. Hypothetical average cost curves for conventional and mega-containership ports

When demand is relatively low (D_1), the conventional port is efficient and generates an average price of P_1 at a volume of Q_1. However, if demand shifts out to higher levels (represented by D_2), the average cost for the conventional port now rises to P_2 but with only a modest increase in volume to that of Q_2. Point Q_2 would be inappropriate for load center operation, as shown by the average cost curve for megaports (ACM). The load center cost curve is substantially lower and remains extremely efficient over a wider range of container volumes. If the new demand level (D_2) is served by a mega-containerport, then a lower average price of P_3 is derived, which relates to a higher level of container handling of Q_3.

Moreover, mega-containerships have been defined over a range of TEU capacities; if load centers can be configured so that their average cost curves look similar to that shown in

Figure 2.1, then they can remain efficient (competitive) over a wider range of TEU moves. In Figure 2.1, this efficiency is reflected in the shaded area approximately bounded by Q_4 to Q_5. If a load center has these cost characteristics, economic analysis suggests that it has the ability to handle varying sizes of mega-containerships efficiently and profitably.

Economic analysis of this type can also help to determine the curves (even when approximate), while further analysis would allow the derivation of marginal cost curves that could be associated with different port operations. For the purposes of this research project, marginal cost per hour may be defined as the increase in port costs resulting from the movement of one additional container. When congestion sets in, marginal costs rise faster than average costs. The derivation of marginal costs would be critical if a port authority desires to develop the most efficient policies with respect to port congestion and container handling at peak and off-peak times. A comprehensive treatment of port pricing, investment policy, and marginal costs may be found in Bennathan and Walters *(15).*

CONTRIBUTION OF ECONOMICS TO THIS PROJECT

The economic literature contains much relevant information regarding both the underlying reasons for the adoption of large ships and the ways in which their impact might best be measured. Microeconomic techniques, particularly those related to pricing and cost issues, can evaluate in detail the impacts of ship design and can determine load center potential. Change in ship size is not a new phenomenon. Between the 1950s and 1970s, there was a tenfold increase in ship size for vessels carrying petroleum products. By the mid-1970s, tankers had reached the half-million-ton mark, incurring both physical and systemic constraints that formed a barrier to further development. These barriers essentially identified the limits wherein diseconomies of scale became significant *(14).* Systemic constraints are of interest to this project because they emphasize the interface between vessel characteristics and port operations. Such constraints include the need for storage and accumulation at each point in the route, longer loading and discharging time, investment cost in new port terminal facilities, frequency of mega-containership services, operational cost and cash flows (particularly important for bond issuance) at the port level, and the vulnerability of the new systems to competition and market fluctuations.

Land transport modes, ports, and maritime shippers comprise the transportation system that serves containerized international trade. Commodities and transportation modes form a diverse system wherein changes in the cost (price) of one component impact other components (cross elasticities). It is important to recognize the full system when considering impacts of one particular element like mega-containership operations. The following areas are identified as economic contributions to a full-system cost analysis.

System Analysis

Much of the literature concentrates on issues related to naval architecture, port operations, and the impact of containerization on world trade. In terms of modeling and technical evaluation, there is literature concerning the evaluation of the vessel-port interface. The recent growth of logistics and the emphasis on providing service across the entire supply chain suggests that the mega-containership issue should be treated as an element in the transshipment of commodities from producer to consumer. Such a treatment widens the system approach and has important implications for the highway and rail elements at the landside access. The literature suggests that the research team should examine a supply-chain analysis, in which the benefits of mega-containerships are aggregated into the full cost of all modes moving goods from producer to consumer. Economics teaches that total cost—not simply the costs that are associated with the maritime part of the supply chain function—ultimately affects the demand for various commodities.

Trade Data Needs

The maxim "ships serve trade and ports serve ships" is a reminder of the critical role trade plays in maritime operations. Though today ports serve industrial sectors, regional markets, and commodity flows in addition to ships and shippers, trade remains a key engine of freight flows and the demand for port services. It is world trade that drives commodity flows between the regions of the world. The impacts that world trade flows have in terms of commodity movements and the future prospects for growth represent an area that is critical to this project. There is strong evidence in the literature that new products continue to be moved by container, thus suggesting a growth in this mode *(16)*. However, the Asian crisis of the 1990s also clearly showed that flows are vulnerable to macroeconomic changes which can critically impact the revenue-earning capability of the transportation systems put in place to move the commodities between key regions *(17).* Trade data are generally not collected for transportation purposes and in the U.S. are provided for fiscal and legal needs. Moreover, there is a tendency in the industry to share as little data as possible to maintain company competitiveness. This situation is likely to increase with the decline of the conference system and the emergence of steamship alliances that deal with major shippers on a case-by-case basis. However, in order to determine the broad patterns of trade, some form of data analysis, disaggregated into key commodities, needs to be undertaken.

Maritime Routes

The literature suggests that when containerization was first introduced, there was speculation about the degree of change that would take place in the routing of ships throughout the world. Some forecasters projected a future in which giant terminals would be constructed at each end of a trading route, served by small fleets of large "mother" ships with distribution undertaken by smaller "feeder" vessels *(18).* This scenario appears to have predated current speculation concerning hub-and-spokes by about 30 years. Although containerization reduced the number of port calls for many liner services, there has not been the degree of rationalization projected by these early forecasters, a result of national and regional factors (including politics) rather than economic factors. Every country and region (for both political and strategic reasons) wanted to have a containerport capable of serving the ships then coming into operation. Because these ships were relatively small (under 2,200 TEUs), neither draft considerations nor the costs associated with the provision of cranes plus a storage area were issues. However, based on the literature review conducted for this project, it seems likely that the era of a global network of giant terminals (or load centers) is now fast approaching. This, in turn, will change the routing systems for containers shipped over the high-density corridors. The ports serving the larger ships that move over such routes will not only serve their regional land markets; they will also transship onto smaller vessels for onward delivery to other, smaller containerports. Therefore, identification should be made of the key routes to and from the Gulf of Mexico (based on analysis of trade flows) so that different routing scenarios can be included in the project analysis.

Load Center Analysis

A critical task of this research project is to propose an equitable and transparent method of assessing the potential for a regional site to serve as a load center for the newly emerging mega-containership operations. Results of the literature review suggest that such an evaluation should include economic characteristics to strengthen the analytical element of the process and to firmly link it to the realities of the commercial world. Serving a mega-containership liner route will involve large investments in channels, port operations, and landside access connectivity, including that of rail and (in Europe at least) barge operations. For many ports, improving the competitiveness and efficiencies of conventional container operations is a more realistic strategic goal. A comprehensive load center analysis should include a forecasting element to suggest likely break-even points in the container demand function, which will signal the financial desirability of serving these large vessels.

Much of the economics addressed in this chapter is based on microeconomic principles, namely, those related to the firm and to its responses to economic stimuli that impact its cost structure. Also considered are the larger macroeconomic issues, which are principally the responsibilities of governments and trading blocks. These issues form the environment in which decisions concerning pricing and schedules are developed. Currently, the maritime industry is going through a major transitional stage that will result in a restructuring of the industry and the way in which containers are handled, and this topic is addressed in the next chapter.

CHAPTER 3.
MARITIME INDUSTRY

INTRODUCTION

The conference system originated in 1875 when, following a period of instability and cutthroat competition, the British shipping lines carrying cargo to the UK from Calcutta agreed to charge the same freight rates. This rate agreement arose as much from the desire of importers and exporters for a stable rate of freight as from the ship owners' need for more predictable earning power in an increasingly capital-intensive industry *(19).* The rate agreement also coincided with the change from wind to steam propulsion and the consequent emergence of liner companies that were able to provide regular services between ports. Liners offer scheduled services moving over fixed routes at published (and generally stable) rates, unlike tramp ships that generally ply for hire. Liners can be regarded as the trains of international seaborne trade and do not, under normal circumstances, offer their whole ship for hire. Traditionally, liners advertise the days that they will accept cargo for loading, when the vessel will close for loading and sail, and the day that the vessel will arrive at the discharging port. While many liner companies have historically chosen to operate as conference members, any liner company is permitted to offer scheduled services outside the conference, and many do so. By the mid-20th Century, a comprehensive system of liner services and approximately 350 conferences were provided worldwide; presently, the future of such conferences is less certain.

The common elements of a conference association are as follows:

- common freight rates,
- agreed frequency and allocation of sailings,
- common approach to membership,
- arrangements regarding different sections of the trade,
- a common approach to surcharges, and
- pooling of cargo and/or pooling of revenue through some joint integrated service arrangement in the larger conferences.

Due to changes in the structure of the maritime industry in recent years, concentration of market share in containerized traffic has become controlled by a few large companies and alliances, thereby weakening the conference system such that it is a shadow of its former self. Whatever the pattern of containerized trade, however, the essentials of liner trading still exist: fixed schedules and published (or negotiated) rates of freight moving over a particular trade route for the carriage of individual parcels of (mostly) manufactured goods. Competition is maintained through route choice, service levels, and sailing frequency.

DEREGULATION

While conferences currently influence substantial parts of the world market, such influence has been weakened by the onset of deregulation. The U.S. government passed the Ocean Shipping Reform Act (OSRA) on October 14, 1998 (effective May 1, 1999), which amended the Shipping Act of 1984. OSRA allows shippers and ocean carriers to enter into confidential agreements for service (*20*), thus allowing importers and exporters to keep their contracts with shipping companies private. Under the Shipping Act of 1984, such vital information as rates, origin, destination, and routes served had historically been made public to keep American shippers from colluding with other companies. The Shipping Act was found acceptable in the U.S. insofar as shipping lines were often viewed as public utilities. In lobbying for OSRA, however, American companies successfully argued that the earlier Shipping Act put them at a disadvantage to overseas competitors not subject to similar laws.

Changing the regulatory agreements will substantially impact the industry. Table 3.1 provides an outline of the key provisions found within the 1998 deregulation bill *(21).*

As of May 1, 1999, shipping lines could make special arrangements that do not have to be shared with competitors. One example would be a company paying a shipping line extra to transport goods to a well-established market in exchange for the same shipping line transporting other goods to other, possibly new, markets at a cheaper rate. Many sponsors of the amendment expected that such confidential agreements would undermine the market dominance of groups of ship lines known as conferences *(22*). Indeed, amendment sponsors were correct in their expectations; the Trans-Atlantic Conference Agreement (TACA) has lost membership over the past year as shipping lines prepared for the onset of deregulation.

More details concerning the change in TACA membership over the period 1998–1999 are given in Table 3.2.

Table 3.1. Key provisions of the 1998 OSRA

Confidential Contracts Shippers and ocean carriers will for the first time be allowed to negotiate and reach confidential service contracts. The law allows contracts among combinations of multiple shippers and carriers in associations and conferences and other groupings. Shippers remain subject to standard U.S. antitrust law. Carriers are subject to Federal Maritime Commission regulation.
FMC Authority A streamlined Federal Maritime Commission will still have the authority to regulate ship line conferences operating under antitrust immunity. The Federal Maritime Commission's enforcement tools are sharpened in some areas. Tariff-publishing responsibilities have been reduced. Contracts will still be filed with the Federal Maritime Commission for agency oversight.
Tariffs Eliminated Tariff filing requirements have been eliminated for individual carriers. Carriers now are required to publish rates via the Internet or other media. Some group filing requirements remain, providing an intended "baseline" or "ceiling" of market rates.
Discrimination Prohibited Vessel operators will continue to be prohibited from engaging in anticompetitive behavior as per the 1984 act. The new law eases common carriage standards by allowing carriers to differentiate more between customers. But discrimination against freight middlemen, shipper associations, or nonvessel operators is expressly forbidden. The Federal Maritime Commission will set fairness standards.
Independent Action Ship lines are afforded unilateral authority to reach contracts with customers outside the bound of conferences, which have historically dominated major trade lanes.
Union Disclosure This requires ocean carriers engaged in confidential arrangements with big shippers to disclose contractual information regarding specific dock and port movement to longshore unions. Disputes over cargo remain within the collective bargaining process.

Source: *(21)*

While the legislation does take a huge step towards deregulating the industry, conferences will still be allowed to set rates collectively under a system of regulated antitrust immunity *(22)*. The legislation allows the lines to move away from the conferences and to arrange private contracts with individual companies.

Table 3.2. Shrinking TACA membership

January 1, 1998	January 1, 1999
Sea-Land Service (U.S.)	Sea-Land Service (U.S.)
AP Moller-Maersk (Denmark)	AP Moller-Maersk (Denmark)
Atlantic Container Line (Sweden)	Atlantic Container Line (Sweden)
Hapag-Lloyd AG (Germany)	Hapag-Lloyd AG (Germany)
P&O/Nedlloyd Ltd.	P&O/Nedlloyd Ltd.
Mediterranean Shipping Co. (Switzerland)	Mediterranean Shipping Co. (Switzerland)
Orient Overseas Container Line (Hong Kong)	Orient Overseas Container Line (Hong Kong)
POL Atlantic Line (Poland)	POL Atlantic Line (Poland)
NYK Line (Europe) Ltd. (Japan)	NYK Line (Europe) Ltd. (Japan)
DSR Senator Lines GmbH (Germany)	------
Cho Yang Shipping Co. (Korea)	------
Neptune Orient Shipping Co. (Singapore)	------
Hyundai Merchant Marine Co. (Korea)	------
Transportacion Maritima Mexicana (Mexico)	------
Tecomar SA (Mexico)	------
Total: 15 members	Total: 9 members

Source: *(23)*

CURRENT DYNAMICS IN THE MARITIME INDUSTRY

As conference influence wanes, many shipping lines are repositioning themselves to maintain a competitive edge. Therefore, it may be expected that more shipping lines will move toward alliances or mergers or will be taken over to maintain competitiveness and earn reasonable investment returns in the sector.

Alliances and Mergers

Consolidation among shipping companies carrying containerized trade has been a feature of the 1990s. In 1991, for example, Sea-Land entered into a vessel sharing agreement (VSA) with Maersk Line, first covering the North Atlantic-to-Asia routes. The arrangement has a number of advantages, the most important being the sharing of risk by agreeing to allocate container space (slots) based on the market shares of the alliance members over that specific route. Sea-Land and Maersk expanded these VSAs to other routes, including those in the Gulf of Mexico. In January 1999, the alliance partners required Maersk to fill only a 10-percent slot quota on the Houston-to-Europe liner schedule, because Maersk was not strong in the Gulf of Mexico regional market. By mid-1999, Maersk and Sea-Land had merged, forming one of the most powerful companies in the maritime industry with as-yet unknown consequences for container shipping in the Gulf of Mexico. Alliances have grown, and some currently in place include the New World Alliance, the Grand Alliance, and separate, unnamed alliances led by China Ocean Shipping Co. (COSCO) and Hanjin. Table 3.3 summarizes some of the major alliances and their key members. As steamship companies continue to merge (or be taken over), the nature of alliances is highly dynamic and somewhat transitory. Shipping giants American Presidents Line (APL) and Neptune Orient Lines (NOL) have recently merged, as have P&O Containers and Nedlloyd Lines *(24)*, and it is clear that more companies will be formed or will merge in the coming years.

Table 3.3. A selection of shipping line alliances

Name	Main members
New World Alliance	APL
	Hyundai M.M.
	Mitsui O.S.K. Line
Grand Alliance	P&O/Nedlloyd
	NYK Line
	Hapag-Lloyd
	OOCL
	Malaysia International
COSCO-K Line	COSCO
	"K" Line
	Yangming Marine
Hanjin	Hanjin
	Cho Yang
	DSR – Senator

Source: *(25)*

Influence of Alliances. As shipping lines form alliances, it becomes easier to deploy larger vessels and fund changes in ship design and technology. The deployment of larger vessels is therefore poised to impact world trade. Figure 3.1 compares the market in 1984, before alliances, to the market in 1995, when alliances held nearly 30 percent of the total container slots *(26)*.

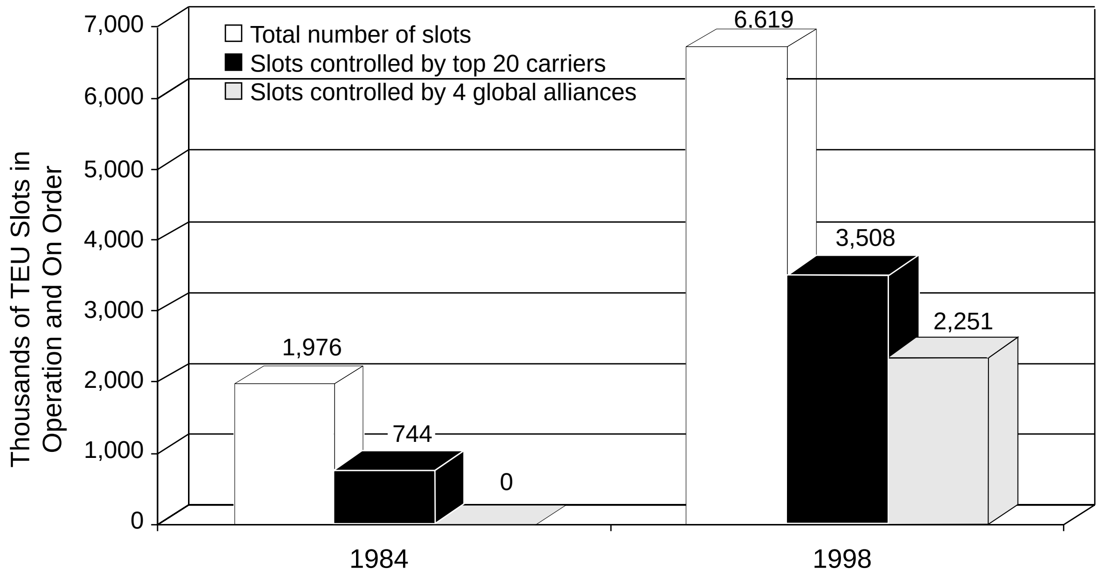

Figure 3.1. Industry concentration of shipping lines *(17)*

As already noted, alliances can offer space-charter agreements (VSAs) between the members of the lines, resulting in the ability to more easily fill a large ship. In this manner, an alliance can increase vessel load factors and reduce the number of ships needed for a particular trade route, resulting in lower costs. Further, alliances also work to coordinate container and port handling equipment pools and procurement, as well as to integrate feeder networks between shipping lines to more easily enter new markets *(27).* All these points offer compelling arguments for an alliance's potential effectiveness as a competitive enterprise in the new millennium.

As demonstrated in the marketplace, involvement in alliances provides shipping lines with a greater ability to invest in larger vessels. Lines such as Maersk and P&O/Nedlloyd, who are dominant members of large alliances, are ordering large vessels (>6,000 TEUs) while Evergreen, which primarily operates independently, is ordering vessels in the 5,000–6,000 TEU range. Evergreen Chairman Yung-fa Chang stated recently in the *Journal of Commerce* that these vessels are difficult to fill unless the carrier is part of an alliance *(28).* Looking at likely future containership orders, Evergreen is aggressively building its strategy on the use of 5,000–6,000-TEU ships, while Maersk and P&O/Nedlloyd and Hapag-Lloyd are leading the way for the operation of 6,600-or-greater-TEU-capacity vessels.

Impact of Alliances on Ports. As the market becomes more competitive, alliances are seeking ways to cut costs and become more operationally efficient. Because of mergers, carriers and alliances are calling on fewer hub ports, forcing ports to become more receptive to the needs of the larger alliances, particularly with regard to servicing larger ships. A 1999 report by Moody's Investors Service indicated that "Hub ports need to be able to accommodate Post-Panamax vessels at competitive prices, with good service in terms of productivity, reliability and intermodal connections" *(29).* The report also implied that both the shipping lines and the ports would be operating under "difficult financial conditions." Meeting the needs of mega-containerships requires large amounts of capital financing that most ports simply cannot raise, even if they had the necessary levels of container demand, which most do not.

With market conditions changing in response to the formation of alliances, ports are under pressure to construct large, expensive terminals to service the shipping industry, forcing the ports to compete more fiercely as more shipping lines consolidate and identify one port as their regional hub *(26).* Ports that do not begin to take measures to accommodate these alliances are finding themselves isolated and even marginalized. Take, for example, the influence that Sea-Land/Maersk mega-containership demands have had on the ports located along the East Coast of the U.S. In late 1998, the alliance formed by Sea-Land/Maersk began to seek out a mega-containership hub port located on the East Coast. The three ports selected were New York/New Jersey, Baltimore, and Halifax. Political, economic, and financial elements at all three sites were brought into play to form the best response to the Sea-Land/Maersk conditions. The consortium finally made a choice in May 1999, selecting New York/New Jersey as its North Atlantic superhub. It is likely that such "horse trading" will be a feature of U.S. East Coast ports that face additional dredging costs to accommodate the largest vessels.

The volume of containers arriving at these hubs (or load centers), both from sea and from land, will significantly impact regional transportation systems. In some cases, more containers will travel by rail, thereby reducing the traffic that would otherwise travel by highway. This contingency constitutes a key reason why state departments of transportation have an interest in monitoring the way the global system of container transportation is changing.

The maritime industry is currently undergoing one of its most important restructuring phases since the advent of conferences over a century ago. It is clear that fewer companies, incorporated into strategic alliances, will dominate world container trade. More than 40 years after hub terminals were first proposed, a small number of world ports are poised to become the regional conduits for containerships and transshipments. These ports, variously termed megaports, hubs, or load centers, will herald new routes and more efficient shipments in the form of lower container costs, presupposing that industrial concentration does not result in cartel or monopoly pricing. In this and in the preceding chapter, reference was made to containerships, particularly related to their size. The evolution of containerships and related issues are the subject of the next chapter.

CHAPTER 4.
CONTAINERIZATION

DEVELOPMENT OF CONTAINERSHIPS

On April 26, 1956, in Port Newark, New Jersey, 58 trailer vans (eight feet wide by 35 feet long) were placed onto the deck of a specially adapted World War II tanker—the Ideal X—sailing to Houston, Texas. This was the result of an intermodal strategy devised by Malcolm P. McLean (later to form Sea-Land) and is now widely regarded as the beginning of modern maritime containerized trade *(30).* Although various forms of containerization had been tried by a variety of modes in the U.S. since the 1920s, McLean's operation established the technical feasibility of a competitive land-sea intermodal system capable of challenging the preconceived notions of how shipping should function and the procedures associated with maritime efficiencies. Containerization now allows for efficient switching of modes between rail, truck, and container vessel, providing an integrated network among the modes of transportation more suitable for global trade.

At the start of the 21st Century, the world containership fleet consists of five generations of containerships. The first-generation containerships were dry cargo vessels modified to hold a small number of containers; as the industry grew, oil tankers were also converted to hold containers. As the 1970s approached, the first vessel specifically made to carry containers was put into service, thus introducing the second generation of containerships. As the industry realized the benefits associated with larger containerships, ship size grew to a limit set by the lock size of the Panama Canal. This size limit was critical because of the significance of the Canal in moving the growing trade between the Far East and Europe. These ships, which became known as Panamax vessels, can be considered as the third generation of containerships. In the 1980s, ships were built larger than the lock and channel depth dimensions of the Panama Canal in the hopes that the economies of scale these ships could offer would offset the losses incurred by avoiding the Canal and utilizing a "dry canal," the U.S. rail land bridge. More commonly, these large ships were used to move cargo over routes that needed to cross the North American continent, for example from Asia to Europe or from Asia to the U.S. These vessels, dubbed "Post-Panamax," represent the fourth generation of containerships. As shipbuilders began to fill the shipping lines' orders for these larger vessels, they soon encountered naval architectural constraints. With the evolution of technology, these constraints were overcome and ships beyond 5,000 TEUs were designed, fabricated, and began to be placed into service in the 1990s. These ships are considerably larger than Post-Panamax vessels in terms of size and have a variety of names, including Post-Panamax Plus, jumbo container vessels, ultra large container vessels, megaships, and mega-containerships. The research team adopted the term "mega-containership" principally because of the association of megaships with large crude oil tankers in the literature. Table 4.1 illustrates the evolution in containership design, citing years when first introduced into service, ranges in capacity, and typical lengths.

Table 4.1. Containership evolution

Generation	Years produced	Typical capacity (TEUs)	Typical length (ft)
First	Pre-1960–1970	<1,000	450–630
Second	1970–1980	1,000–2,199	700
Third	1985–onwards	2,200–3,199	860–950
Fourth	1986–2000	3,200–4,799	900–1,000
Fifth	1996–onward	4,800	1,100

Source: *(1)*

CURRENT STANDING OF CONTAINERSHIPS

The world maritime fleet structure reflects the evolution of containerships and the dominance (numerical) of the smaller ships. The 1999 version of the Containerization International Yearbook *(17)* indicates that in 1998, around one percent of the fleet (85 units) were containerships of 4,500 TEUs or greater, while there were 6,738 vessels deployed in the less-than-4,500-TEU categories.

There were also a number of container vessels on order as of November 1998, as seen in Table 4.2, with 47 firm orders for ships exceeding 4,500 TEU capacity. It is interesting to note the substantial number of vessels under 3,000 TEUs still being ordered; annual figures have increased regularly since the early 1990s, evidence that the workhorse of the world container industry is relatively small and fast, capable of serving a wide variety of ports, and of being turned around in port rapidly. Gulf of Mexico container business is currently carried on such vessels, particularly on those serving Latin American ports.

Though the number of vessels greater than 3,000 TEUs, including those on order and those currently existing in the fleet, seems relatively small, the tonnage moved by the larger ships is substantial. Taking into account total slot capacity and ships both existing and on order, ships greater than 4,500 TEUs account for over 11 percent of total slots in the world fleet, a trend likely to grow as long as the world economy continues to expand. Results of a research project by DRI/McGraw Hill indicated that by the year 2010, close to 40 percent of U.S. cargo will be carried on Post-Panamax vessels (defined as vessels greater than 4,000 TEUs), as compared with 12 percent in 1995 *(31)*. However, these forecasts need to be treated with circumspection. Most of the world ports will not be served directly by mega-containerships and, if hub-and-spoke operations develop from load centers, smaller ships will continue to play critical roles.

Table 4.2. New containerships on order in 1998

TEU category	On order (ships)	On order (slots)	Avgerage slots/ship
<1,000	186	98,438	529
1,000–1,999	123	187,742	1,526
2,000–2,999	47	108,742	2,314
3,000–4,499	16	62,874	3,930
>4,500	47	254,372	5,412
Totals	419	712,142	

Source: *(17)*

CONTAINER DEMAND

As world trade increases and as more commodities are stuffed into containers, container demand at the shipper level increases. Larger ships, with lower average cost per TEU-mile, offer attractive returns on high demand routes. The critical point to recognize is that the reduction in operating cost from mega-containership economies of scale is dependent on high vessel utilization. In the following sections, information concerning world, U.S., and Gulf of Mexico container demand is presented to indicate where mega-containerships may be deployed.

Worldwide

DRI/McGraw Hill reported in 1997 that the world container trade growth rate between 1991 and 1995 was 9.5 percent per year, reaching 134 million TEUs *(31)*. Yet a report released by Germanischer Lloyd in 1998 reported that average worldwide container transport growth over recent years was only seven percent *(32)*. Differences between these two reports could be an indication that container growth is difficult to predict and could be slowing. DRI/McGraw Hill also predicts worldwide container growth to be eight percent (compound annual growth rate) through 2000. These averages may have incorporated high historic growth rates over Far East-based shipping trade routes. The optimism of the early 1990s was tempered by the Asian financial crisis of 1996–1997, which had an immediate and profound impact on Asian imports. Worldwide growth rates are not useful in transportation planning unless they can be disaggregated into route sectors. Though average growth rates have been successfully employed to show the importance of containers, potential mega-containership operators are too shrewd to rely on these data alone. What they must look for are those *routes* that have the densities necessary to make large vessels effective. These are rather few in number and currently link only a handful of world ports.

U.S. and Gulf of Mexico Ports

Total container movements through the U.S. in 1997 are given in Figure 4.1. The bi-state port of New York/New Jersey remains the leading U.S. containerport with a 1997 throughput of 4.1 million TEUs. New York/New Jersey showed a 17 percent gain over the previous 12 months, which was the largest increase outside Asia with the exception of Gioia Tauro in Italy *(17)*. Now that New York/New Jersey has been selected as a Sea-Land/Maersk load center, the port should continue to dominate the Atlantic ports in the early part of the 21st Century. A gain of one-half million TEUs in 1997 helped Long Beach to move to seventh in worldwide containerport rankings. As shown in Figure 4.1, the Pacific Southwest and Atlantic Northeast ports dominated U.S. container movements, reflecting regional markets as well as the double-stack international trade flows. The Gulf Coast ports, while reflecting a modest share of total U.S. TEU moves, also showed strong growth.

Houston handled an additional 18 percent (year-on-year) to reach 936,000 TEUs and captured the tenth place ranking in U.S. containerports.

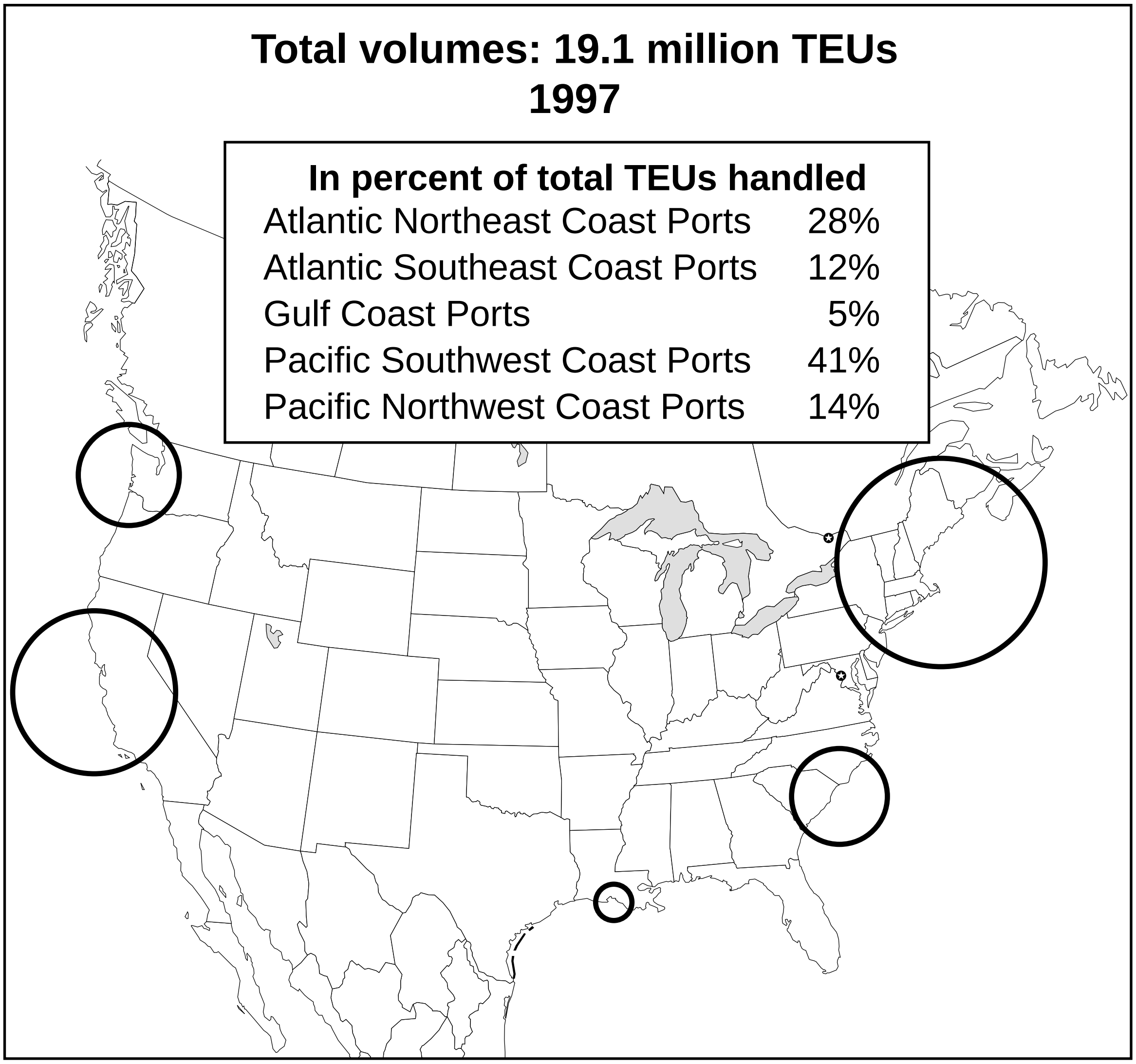

Figure 4.1. North American coastal port gateways market share for international loaded container traffic *(17)*

The U.S. container trade is dominated by a few regions, as shown in Table 4.3. In terms of forecasted TEUs for 1999, Northeast Asia is predicted to hold a 34 percent export share and 50 percent impact share, while Northern Europe was predicted to hold a 17 percent export share and a 14 percent import share. Smaller markets, however, are showing strong growth and may emerge to influence route structure in the future. Comparing the 1998–1999 forecasts in Table 4.3, Eastern Europe showed around an 18 percent increase, African imports a ten percent increase, and Central American exports a 14 percent increase.

Table 4.3. Regional forecasts of U.S. container trade

	Thousands of TEUs			**Thousands of TEUs**		
	1998 exports	**1999 exports**	**Percent change**	**1998 imports**	**1999 imports**	**Percent change**
Northeast Asia includes Japan, Taiwan, South Korea, Hong Kong, China	2,370	2,430	2.5	4,250	4,670	9.8
Southeast Asia includes Thailand, Indonesia, Malaysia, Philippines, Singapore	390	394	0.9	916	1,007	9.9
Northern Europe includes Britain, Belgium, Germany, Netherlands, France	1,120	1,180	6.0	1,210	1,290	6.4
Eastern Europe	126	147	17.3	55	64	18.0
South America	831	889	6.9	540	587	8.8
Caribbean	449	489	9.0	128	141	9.9
South Asia	102	109	6.7	286	311	8.9
Africa	124	136	9.3	78	85	10.0
Oceania includes Australia, New Zealand, South Pacific Islands	206	216	4.8	104	113	8.6
Mideast	231	255	10.3	66	72	9.2
Central America	494	565	14.2	481	530	10.1
Mediterranean includes Italy, Turkey, Greece, Malta, Cyprus, Portugal, Spain, Azores, Gibraltar	277	313	12.9	538	574	6.6
Total	6,720	7,130	6.0	8,660	9,440	9.1

Source: *(33)*

Although the growth rate estimates for the Gulf of Mexico are impressive, container moves at a single site are not an adequate basis for planning. An understanding of the whole supply chain, tracking product from origin to destination through the string of seaports, now drives the logistics planning process. In addition, the trade relationships between the Gulf of Mexico and other regions may change over time. Therefore, it is important to focus on worldwide supply chains, not solely on the Gulf of Mexico's current leading trade partners and who currently handles the volumes.

Currently, the majority of trade in the Gulf of Mexico (Gulf) is between Northern Europe and Central America. Table 4.4 shows the Gulf container traffic by world market from 1989 through 1996. It has been stated that some Gulf port authorities have been using growth rates for container traffic on the order of six to seven percent annually *(25)*. This broadly equates to the annual total growth shown in Table 4.4. However, it can be seen that there is a wide variation in actual growth rates for specific markets, reflecting the economic strength of those countries and the types of commodities being shipped in containers. This argues for a more disaggregated market analysis when forecasting container growth rather than using global or average rates.

Table 4.4. Gulf container traffic by share of world market 1989–1996

	Total TEUs (1000's)			
	1989	**1996**	**Percent of 1996 total**	**Percent change**
Northern Europe	157	180	34	15
Caribbean/C. America	69	137	26	99
South America	25	100	19	300
Mediterranean	27	36	7	37
All Other	55	75	14	36
Total	333	528	100	59

Source: *(26, 34)*

FACTORS AFFECTING DEMAND

Container demand is influenced by a number of macro- and microeconomic factors. Such factors include the increased containerization of dry bulk goods and changes in the world economy, especially in regions where production is taking place. The recent decrease in the Asian economy negatively affected trade along the West Coast (albeit temporarily), while an increase in the production and trade with countries in South America has had a positive impact on the Gulf export trade.

Effect of the Asian Crisis

The Asian crisis, triggered by a series of currency devaluations in 1997–1998, represents a regional recession that influenced U.S. exports and container rates *(35)*. It should also be noted that the European Union (especially in light of the move to a unified currency) continues to lag in overall economic growth compared with the U.S. Only the U.S. economy has remained strong over the last few years, a situation that has led to larger trade imbalances with its partners. These events impact world trade (and consequently, containerized shipping), although the total effect, particularly its duration, is not known at this time.[1]

Table 4.5 shows current capacity utilization and deployment for 1997. All trade lanes are well below 100 percent capacity utilization—an indication of the condition of the world's economies at that time.

[1] Conversations with industry professionals suggest that the U.S. trade deficit is clearly seen in the numbers and weight of containers moving through ports. At the Port of Houston, more loaded containers of greater value are imported than exported.

Table 4.5. 1997 capacity utilization by trade lane

Imports					Exports			
Trade lane U.S. to:	TEUs lifted	Capacity deployed	Capacity utilization	Voyage count	TEUs lifted	Capacity deployed	Capacity utilization	Voyage count
Africa	29,129	53,450	54%	135	33,571	53,559	63%	243
Caribbean	143,537	477,847	30%	1,283	431,316	704,823	61%	1,510
Central America	308,361	526,273	59%	2,068	279,567	511,499	55%	2,210
East Coast South America	236,795	488,903	48%	1,368	318,138	524,065	61%	1,538
India/other Asia	67,886	89,508	76%	615	7,586	11,225	68%	489
Mediterranean	482,840	708,994	68%	1,138	334,645	509,595	66%	1,172
Mideast	5,314	6,876	77%	173	57,665	82,552	70%	668
North Europe	1,124,569	1,655,683	68%	2,327	1,079,901	1,627,472	66%	2,351
Northeast Asia	4,269,983	5,582,375	76%	5,640	2,523,313	4,462,970	57%	5,202
Oceania	82,328	205,000	40%	266	139,869	275,307	51%	402
Other Regions	8,949	14,523	62%	106	8,491	14,114	60%	144
Southeast Asia	478,120	579,803	82%	2,310	301,967	508,488	59%	2,286
West Coast South America	145,529	243,067	60%	17,985	5,660,945	9,540,941	59%	36,889
Total	7,383,340	10,632,302	69%	17,985	5,660,945	9,540,941	59%	36,889

Source: *(36)*

Latin American Trade Growth

The emergence of north-south trade routes between the U.S., Central, and South America is changing the nature of trade in the Gulf. It is possible that major developments in these countries' economies could increase trade movements within the Gulf region. The engineering firm VZM/TranSystems has completed a conceptual design report for a mega-containership facility in Texas City, Texas, located southwest of Houston. The report suggested that Latin American trade and improved access to inland and West Coast markets should lead to increased container activity and could bring about demand sufficient to warrant a mega-containership route between Latin America and the U.S. Gulf *(37)*. However, the research findings did not report the probable mix of ships and routes. Also important are the types of commodities moving to Texas Gulf ports in containers. They reflect the key sectors of the Central Texas economy—chemicals, machinery, industrial equipment—rather than the mix of commodities driving the flows between Northern Europe, Northeast Asia, and the U.S.

This chapter characterized key attributes both of containerships and of the demand for container moves. It recognizes not only the strong growth of world container usage since 1980, but also the likely use of larger containerships linking the major world markets. As heavily used routes emerge, vessel owners will consider operating mega-containerships. The Asian crisis was characterized by loaded containers traveling to the U.S. and mostly empty ones returning (only a slight exaggeration on some routes in 1998–1999), causing imbalances in container availability, rate changes, narrowing of profit margins, and financial losses on some operations *(35)*. Such an imbalance demonstrates the risks associated with maritime shipping—risks that could be heightened by the need to fill large vessels and establish viable feeder routes to and from hub ports.

However, port authorities need to be aware of the different ways in which large containerships could impact their operations. The next chapter examines the key characteristics of these vessels, particularly as they affect port investment programs.

CHAPTER 5.
MEGA-CONTAINERSHIPS

INTRODUCTION

Previous chapters have described the growth in intermodal container services and the restructuring of the maritime industry. Since the mid-1980s, a number of shipping lines operating over high-density routes have been increasing the size of their containerships, seeking higher profit margins through economies of scale. A new generation of ships—dubbed *mega-containerships*—is now starting to come into operation, varying in size from 5,000 to 6,600 TEUs. Mega-containerships have distinct characteristics that must be incorporated into the operations of ports wishing to serve them. This chapter is divided into three sections. The first section considers the physical dimensions of a typical mega-containership; the second considers routes and operational deployment; the third considers the extent to which mega-containerships will impact the market and includes a discussion of the role of smaller containerships in future operations.

MEGA-CONTAINERSHIP DIMENSIONS

The key dimensions of a mega-containership that impact current port infrastructure include draft, capacity, length, and width. Other dimensions and characteristics of mega-containerships that are important include crew size, gross weight, type and power of engine, speed capabilities, and hull design. While those characteristics in the latter category play key roles in determining economies of scale, they have little impact on port infrastructure needs and will not be discussed in this chapter.

Draft

The draft of a ship is the primary concern of many of today's ports. The draft of a ship is usually referred to as the depth of the vessel that is below the water. It is measured from the waterline to the lowest point of the hull, usually the bottom of the propeller or screw. Most of the mega-containerships currently in operation and many of the vessels to be deployed in the future have a fully loaded draft of 46 feet. While some future vessel designs call for ships as large as 15,000 TEUs, their capacity will be achieved by increasing their length and width in order to maintain the 46-foot draft *(26).* The ship's draft is important because of its impact on the shipping channel that links a port to deep ocean water; Table 5.1 gives typical channel and draft depths for large containerships. The draft of a ship is particularly critical on the U.S. eastern seaboard and in the Gulf because of the material deposited by rivers and coastal systems. A 46-foot draft needs a two-foot allowance for hull movement and another two feet for flotation, indicating a minimum draft of 50 feet. Even though most containerships are rarely fully loaded (because many boxes are empty), port authorities must design a channel capable of handling a fully laden ship. Constructing and maintaining a 50-foot channel on the U.S. eastern and Gulf seaboard is an extremely expensive proposition for almost all ports.

Table 5.1. Typical drafts and minimum channel depths for large containerships

Ship size	**Draft (fully loaded)**	**Required channel depth**
Panamax Vessel (<4000 TEU)	38 feet	42 feet
Post-Panamax (4000–6000 TEU)	42 feet	46 feet
Beyond Post-Panamax (6000+ TEU)	46 feet	50 feet

Source: *(25)*

Capacity

Scale economies in container movement are driven by capacity. Recall that the capacity of containerships is typically measured in 20-foot equivalent units, or TEUs, and that current mega-containership designs range between 5,500–8,000 TEUs. Such large container volumes, if unloaded at a single port, could dramatically impact a port's efficiency. At some point, a complete rethinking of port operations will have to be undertaken to handle the largest ships (e.g., unloading from both sides in a slip berth). This rethinking could lead to the realization that ports serving such large containerships require substantially more investment than has typically occurred during the period 1980–2000.

Length

The length of a vessel determines the geometrics needed in the layout of docking berths and turning basins. The length is not as critical as the other dimensions because the shipping berths are often continuous and a berthing length is not as fixed as is the channel depth, for instance. The maximum length of a ship is currently constrained by shipbuilding technology. A ship on the high seas may often be lifted by a wave and supported only at the ends of the ship, resulting in extreme stress at the center of the ship, which can cause the vessel to break at the middle *(25).* Thus, because shipbuilding technology has not yet sufficiently addressed this issue of center stress, the larger containerships are wider, rather than longer, when compared with earlier designs.

Width

The final key dimension is the ship's width, which is important in loading and unloading operations. New mega-containerships are often 17 containers wide, meaning that a crane needs to stretch across 136 feet of containers in order to load and unload the vessels. In future designs, containerships may reach widths equivalent to 21–28 containers, thus increasing the demands on crane technology *(17)*. The width of these vessels is also critical for future port designs. Ports are now considering "finger pier" designs, in which the ship berths between two piers and is unloaded on both sides *(25).* While such a design would eliminate the need for a crane to stretch over 28 containers, it would mean that the distance *between adjacent piers* becomes the key dimension. If too narrow, future vessels may not be able to utilize the piers; if too wide, the advantage of unloading and loading from both sides is diminished, as the cranes have to stretch a certain distance to reach the ship. For instance, during a given operation, a crane may have to stretch across only a ten-container width; yet if the ship's distance from the finger pier is the equivalent of eight containers, then the crane would have to accommodate that distance—which exceeds the 17-container limit—as well. As future ship designs aim to maintain a draft of 46 feet, the width will increase and, consequently, width could become the more critical dimension.

CURRENT MEGA-CONTAINERSHIP CAPACITY AND ROUTES OF DEPLOYMENT

Mega-containerships are presently deployed over a few Far East/Pacific and Far East/European "pendulum" trade routes linked by passage through the eastern Mediterranean and Suez Canal. Future markets may include European/Atlantic routes and, possibly, Asian/European/Atlantic routes.

In November 1998, 85 cellular[2] containerships exceeding 4,500 TEU capacity were operating throughout the world, with another 47 on order *(17)*. Though few in number, this class represents eight percent of total world slot capacity in 1998, a figure which rises to 11 percent if new orders are taken into account *(17)*. Most of the current ships in this class are closer to 5,000 TEUs than 6,500 TEUs; Table 5.2 shows that more shipping lines seem to favor smaller versions at this time. Smaller versions will be able to be positioned on a wide variety of trade routes, leaving the bigger models to focus on the key container routes between large, mature markets. As larger ships are deployed, there may be a "knock-down" effect by which the displaced vessels are repositioned on other world routes, such as Europe to the Gulf of Mexico.

Table 5.2. A selection of shipping line mega-containership deployments in 1998

Carrier	Size (TEU)	Number	Builder
COSCO	5,250	6	Kawasaki Heavy Industries
Evergreen	5,364	5	Mitsubishi
Hanjin	5,300	7	Hanjin Heavy Industries
Hyundai Merchant Marine	5,500	7	Hyundai Heavy Industries
Maersk	6,000+	6	Odense Shipyard (Moller Group)
Maersk	6,600+	1	Odense Shipyard (Moller Group)
P&O/Nedlloyd	6,674	4	Ishikawajima–Harima Heavy Industries

Source: *(37)*

[2] Ship design with holds or cells arranged so the containers are lowered and stowed in a vertical plane and restrained at all four corners by vertical posts.

FUTURE GROWTH

While mega-containerships are not presently dominating trade routes, many believe they will on several key routes in the near future. This belief is evident in the forecasts of leading economic analysts as well as in the changing fleet orders of major shipping lines. VZM/TranSystems, using DRI/McGraw Hill data, estimates that a larger share of containerized cargo will be transported by mega-containerships in future years. Estimates have placed 30 percent of containerized cargo on ships in the 4,000–6,000-TEU class by the year 2010, and nine percent of all cargo in 2010 is expected to be handled by ships larger than 6,000 TEUs. These statistics must be interpreted carefully, as they are formulated under unconstrained conditions. In other words, they assume adequate future port infrastructure as well as a market demand for containers. While the latter assumption is relatively solid, the infrastructure assumption is weak *(26).*

Shipping lines, such as APL and Evergreen, are increasing the number of ships in their fleets of 5,000 TEUs or greater. Maersk Line, for example, is currently the most aggressive player in the mega-containership market. It currently owns the world's largest container vessel, with eight more of similar size to be delivered over the next few years *(38).* In early 1999, it sailed one of its mega-containerships into various Northeastern U.S. ports in an effort to encourage authorities to undertake investments that would make it possible to run liner services with this size of ship.

The shipbuilder Germanischer Lloyd, along with Howaldtswerke-Deutsch Werft (HDW), has designed an 8,000-TEU containership. Germanischer Lloyd believes such a model could become the standard for containerships and that this model is the optimum design. The company's conclusions, reported by Hans Payer, are based on a research project that investigated 40 basic ship designs from 5,000 to 8,000 TEUs and the impacts of those 40 ships on nine roundtrip alternatives. The cost of sea transport was studied in relation to such variables as total distance, number of ports visited, ship size, and ship speed (*39*), and three critical conclusions were reported:

1. The longer the sea leg, the greater the fuel load, which influences total cost.

2. Forming a mega-containership shuttle between two markets can reduce cost per TEU.
3. The more ports a vessel calls on, the higher the cost per TEU. Interestingly, the maritime savings from reducing the ports of call may not be sufficient to outweigh the additional costs incurred through the need to use more inland transport to move containers to final destinations.

From these conclusions, it was determined that an 8,000-TEU vessel with an operating speed of 24 knots would return the highest yearly income. The impact of a vessel of this size on port operations is dramatic. Containers would be spaced 28 wide and therefore require new unloading technologies/systems that are still being developed and tested. The landside impacts of such a vessel also pose substantial challenges.

The German consortium is one among a number of entities designing large ships. South Korean firms, such as Samsung, Daewoo, and Hyundai, have similar blueprints for 8,000-TEU designs, and a few Japanese shipbuilders have plans for a 9,000-TEU ship. The shipping line P&O/Nedlloyd believes 8,000-TEU designs may be only a starting point. The company has visions of a 15,000-TEU containership dubbed the "Flight of Fancy." Although the ship is in the conceptual stage, its design and construction are based on current shipbuilding technology. Table 5.3 identifies some of the characteristics of proposed mega-containership designs. However, at present and in the near future, most industry observers seem to believe that the 5,000–6,000-TEU vessel will dominate the market *(26, 40).*

Table 5.3. Some future mega-containership plans

Ship designer	TEU capacity	Length (ft)	Beam (ft)	Max. draft (ft)
HDW CS 6800	6,800	1,000	131	46
HDW "Jumbo"	8,000	1,099	151	46
P&O "Flight of Fancy"	15,000	1,312	226	46

Source: *(25)*

As of September 1, 1998, the top ranked carriers by TEU capacity in service were Maersk (346,100), Evergreen/Uniglory Marine (280,200), P&O/Nedlloyd (250,900), Mediterranean Shipping (220,700), Hanjin (213,000), Sea-Land (211,358), and Cosco (202,100). The merger between Sea-Land and Maersk clearly puts the new company in a dominant, market-leading position. Decisions made by this company regarding very large containership deployment will create new marketing opportunities for customers and ports alike, including those in the Gulf.

MEGA-CONTAINERSHIP IMPACTS AND CONSTRAINTS

If the largest shippers, whether individually or as members of alliances, operate mega-containerships, they will need to incorporate these vessels into their global marketing operations, serving load centers with a variety of land based modal options or transshipping at mega-containerports to smaller vessels, using a hub-and-spoke system.

Because so many ports in different countries now handle containers for their local markets, smaller containerships will continue to call on and serve smaller markets, arguing that integrated operations between mega-containerships and smaller containerships must be a central strategy in the adoption of larger ships.

Smaller 2,000–3,000-TEU ships have certain characteristics that enable them to play important roles on new routes, especially those that hub and spoke. Such ships are often easier to manage and operate and, more importantly, offer greater flexibility in scheduling than do mega-containerships, a result of the fact that mega-containerships call at only a few ports, while the smaller vessels can more cost-effectively make numerous calls *(41).* Shipping firms may be realizing that the infrastructure improvements needed to handle vessels of 6,000 TEUs or greater are not progressing as quickly as they had hoped and that the current land-based infrastructure in many ports is simply incapable of handling the container volumes produced by vessels as large as mega-containerships *(41).*

It has already been pointed out that, while mega-containerships have drawn much attention, smaller ships have maintained their market share. Many lines are looking to north-south lanes, wherein the infrastructure is not yet capable of handling ships of 6,000 TEUs or greater, to expand smaller containership services. Ports in South America, South Africa, and Europe are examples of areas in which small ships may remain competitive in the future. Ports may be quite successful in the near and distant future without having to handle mega-containerships. Using a hub-and-spoke strategy from key transshipment points, the majority of ports may choose to focus on handling smaller containerships *(41).*

This chapter, along with the previous chapter, focused on the characteristics of the mega-containership, particularly its ability to lower box/sea-mile rates as compared with conventional designs. However, this is only one part—albeit an important part—of the systems analysis. Chapter 6 focuses on the major investments port authorities will need to undertake to accommodate mega-containerships.

CHAPTER 6.
MEGA-CONTAINERSHIP IMPACTS ON PORT INFRASTRUCTURE

INTRODUCTION

Port authorities have always recognized that servicing containerships required new investment in container handling equipment. Initially, some container vessels were equipped with gantry cranes, making it possible to dock at ports without proper on-dock equipment to load/unload containers. However, carrying cranes aboard created a number of problems, including extra weight, less cargo space, and an inefficient use of equipment, since cranes were idle during the time at sea *(30).* At relatively low levels of container throughput, on-dock cranes were more efficient, given their longer outreach and superior productivity in terms of container lifts. The first on-dock cranes were purchased for approximately $1 million, and while the cost was reflected in the docking charge, it was still considerably less than the cost of providing cranes aboard every vessel *(30).*

The evolution of the on-dock cranes enabled naval architects to concentrate on developing ship designs that would efficiently move large numbers of boxes without the need to incorporate container handling equipment. As container demand grew and new markets developed, relatively small ports provided container handling berths and storage areas, even in the smaller, less developed countries. Thus, the ports became a starting point for a wide range of crucial steps in the system that moved boxes from producer to consumer. In business parlance, ports became a critical link in the supply chain and stimulated the area of logistics management.

In the early days of containerport development, environmental and permit issues were not as critical as they are today. In the (relative) absence of such sensitive, complex, and time-consuming issues, ports were typically able to construct a container terminal within one to two years, while construction now takes from five to seven years. Construction time is also a function of the necessary equipment that is needed in a yard. When container terminals were first built, they consisted of only gates, a yard, docks, and cranes. Today it is necessary to include intermodal yards, connections, and technologies to increase the efficiency of the port *(42).*

Cost and financing are also factors that must be considered in the construction of a port facility. In the time it took to move from third- to fifth-generation containerships, the cost of land for terminal development increased about four-fold, excluding the purchase of cranes *(42).*

As the total cost of constructing containerports (land, permits, construction, and equipment) rises, some ports specialized in one commodity type (like chemicals or petroleum). The other development is a move to leasing space at port facilities, so that the port authority serves as a landlord, rather than the owner of the equipment and facility. Such specialized ports are sometimes called "niche ports" because they have found a profitable way to provide transshipment services or to serve particular types of ships or commodities. Whereas all ports can serve the early containership, a point has now been reached in which only a few will be able to serve the mega-containership—a development that will herald a new era in the way boxes are distributed over the world shipping routes.

Shipping lines now typically sign a 30-year lease and renegotiate the annual cost with the port every five to seven years. Such increases, along with greater penalties for leaving a terminal prior to completing the lease, are why some lines are operating as alliances, an arrangement wherein several steamship companies' lines run over the same trade routes and hub at load centers along these routes. An example of this need for hubs was the 1998 search by Sea-Land/Maersk to establish a mega-containership load center along the U.S. East Coast, as mentioned in Chapter 5. American Presidents Line (APL) has also realized a need for a load center and has secured two along the U.S. West Coast—one in Seattle, Washington, and the other in Los Angeles, California—and one on the U.S. East Coast, at the Port of New York/New Jersey.

CONTAINERPORT INFRASTRUCTURE

A containerport is composed of three main components: marine access (channel, navigation system, holding areas, turning bays, etc.), port operations (cranes, storage, handling, transshipment, etc.), and land access (by truck, rail, barge, etc.). In some instances, deep-water siting simplifies sea access issues, but in the Gulf it represents a serious and costly issue. The three components are now described in greater detail, as they are impacted by the introduction of mega-containerships. Since dredging is a critical component of port operations in the Gulf, it receives particular attention.

Marine Access

Marine access focuses on the characteristics that allow a mega-containership to enter a port. It includes channel and harbor depths as well as the requirements necessary to accommodate vessels of different sizes. This section covers not only marine access issues, but also dredging and related complexities.

Channel and Harbor Characteristics. Mega-containership operations require that a 50-foot minimum depth be present throughout the ship channel, the turning basin, and the ship berths. Many U.S. ports, especially those on the Eastern seaboard, do not have the required 50-foot draft. Those on the Western seaboard that do (e.g., Seattle and Los Angeles/Long Beach) are attracting and servicing today's mega-containerships, while those that do not (e.g., Oakland) are losing business as a result. Many ports would like to dredge their channels deeper, but doing so is difficult. Obstacles to dredging include not having the approval of the Army Corps of Engineers, inadequate financing, the presence of pipelines (as at Houston and Corpus Christi), and difficulties owing to bedrock or environmental constraints. The presence of tunnels can also limit depths (or, as in the case of Houston, require their removal) at some locations. Underscoring the importance of maintaining a competitive channel depth is the recent history of the Port of Oakland, which was a dominant player in the Pacific container industry during the 1970s and 1980s and which served as headquarters for the shipping giant, APL. When the port failed to aggressively pursue the permits needed for a 50-foot draft in the early 1990s, container traffic moved to the now-dominant ports of Long Beach and Seattle *(43).* In attempting to reclaim its position as a dominant port, Oakland now has a plan that includes deepening its channel from 42 to 50 feet *(44).*

Ports wishing to attract regular, fully laden mega-containerships will have to provide channel depths of 50 feet. The only way ports having channel depths less than 45 feet will be able to service these mega-containerships is if the ships are carrying less than full loads.

Tables 6.1–6.4 provide water depths and throughputs for several Atlantic, Pacific, and Gulf ports. The term *berth* refers to the water area at the waterfront edge of a wharf that is reserved for a vessel *(45).*

Given the size of mega-containerships, other harbor design elements, such as adequate turning basins and finger piers, may be needed to accommodate the new generation of containerships. In a recent investigation by VZM/TranSystems for the proposed mega-containership facility at the Port of Texas City, the recommended turning basin design included a 1,450-foot diameter circular area. The existing turning basin dimensions at the port are 40 feet deep, 4,253 feet long, and 1,000–1,200 feet wide *(46).*

Table 6.1. Water depth and throughput—Atlantic ports, northern

Port	Channel depth	Berth depth	1997 throughput (TEUs)
Montreal	36 feet	35 feet	870,368
Halifax	60 feet	45–47 feet	459,176
Boston	40 feet	40 feet	143,943
New York/New Jersey	40 feet*	35–45 feet	4,127,568
Philadelphia	40 feet	40 feet	112,588
Wilmington, DE	38 feet	38 feet	164,912
Baltimore	50 feet	36–42 feet	476,012
Hampton Roads	50 feet	32–45 feet	1,232,725

*45-foot project authorized
Source: *(17, 26)*

Table 6.2. Water depth and throughput—Atlantic ports, southern

Port	Channel depth	Berth depth	1997 throughput (TEUs)
Wilmington, NC	40 feet	40 feet	105,786
Charleston	42 feet*	40 feet	1,217,544
Savannah	42 feet	42 feet	736,522
Jacksonville	38 feet	38 feet	1,161,337
Palm Beach	33 feet	33 feet	183,400
Everglades	47 feet	37–44 feet	719,146
Miami	42 feet	42 feet	685,000
Freeport	47 feet	47 feet	148,798
San Juan	35 feet	35 feet	1,781,250

*45-foot project authorized
Source: *(17, 26)*

Table 6.3. Water depth and throughput—Pacific ports

Port	Channel depth	Berth depth	1997 throughput (TEUs)
Anchorage	30–70 feet	35 feet	341,509
Vancouver	50 feet	40–50 feet	724,154
Seattle	175 feet	40–50 feet	1,475,814
Tacoma	40–50 feet	40–50 feet	1,142,700
Portland	40 feet	40 feet	294,930
Oakland	42 feet	35–42 feet	1,357,400
Los Angeles	45 feet*	45 feet	2,959,715
Long Beach	76 feet	35–50 feet	3,504,603
Honolulu	45 feet	40 feet	702,947

*50-foot project authorized
Source: *(17, 26)*

Table 6.4. Water depth and throughput—Gulf ports

Port	Channel depth	Berth depth	1997 throughput (TEUs)
Houston	40 feet*	38–40 feet	935,600
Gulfport	36 feet	36 feet	152,164
New Orleans	36–45 feet	35 feet	263,050

*45-foot project authorized
Source: *(17, 26)*

Since port productivity is directly proportional to the number of cranes and crane lifts per ship work hour, it is critical that harbor designs are made as efficient as possible. One solution proposed by Ceres Terminals Inc. (CTI) and Port Management of Amsterdam (PMA) involves putting the ship in a slip using finger piers, which allows it to be serviced from both sides *(47).* Because the deployment of finger piers addresses the productivity demands of mega-containership vessels, such piers have gained increased popularity in feasibility designs.

Dredging. Every year in the U.S., ports must dredge approximately 400 million cubic yards of sediment. A major concern is the disposal of this material, since about five to seven percent represents run-off from seriously polluted soil *(48).* Land constraints and environmental concerns, which will be discussed later in this chapter, also contribute to the problem of disposing of dredged material.

Obtaining Dredging Rights. Dredging a U.S. waterway requires the prior approval of the Army Corps of Engineers *(49)*. The Corps works with Congress to identify those projects of greatest benefit to the national economy; it ensures that the operation will not negatively impact the environment and is responsible for the economic feasibility study for dredging projects.

Identification of the most beneficial dredging projects is accomplished by undertaking an analysis of any proposed dredging. The analysis focuses on two primary economic areas: first, the overall benefit to the national economy that dredging will provide versus the cost of the project, and, second, the availability of a nonfederal partner (such as a port authority) to share in the expense of the project. Based on these two considerations, the Corps can effectively rank projects. The ranking is determined by the methodology described in the Corps' "Principles and Guidelines for Water and Related Land Resources Implementation Studies," which has been in place since the early 1980s. While the Corps does conduct the economic feasibility study, it does not initiate projects independently. Such projects are determined by Congress and the administration in response to the needs of constituents. A state may bring the need for deepening a channel before Congress, which will then enlist the Corps to analyze the project. Congress then uses the Water Resource Development Act to grant the Corps authority for maritime improvements *(26).* Often, the time taken to obtain congressional approval causes delays, and recently seven major dredging projects have been delayed by slow progress through the congressional process *(44).*

Once a project is determined to be economically beneficial, the Corps is responsible for dredging and maintaining the channel. The state or local sponsoring group (such as TxDOT) is held responsible for finding adequate land and right-of-way for disposal of the dredged spoil.

Financing of Dredging. The cost of dredging is shared by the federal government and a local sponsor, such as a port authority. The federal and local sponsors share the initial costs of performing the analysis (at least $2 million) and of dredging the channel or berth area. A typical split may call for the federal sponsor to pick up 75 percent of the cost, with the remaining amount being the responsibility of the local sponsor *(43).* However, if the spoil is contaminated with heavy metals or other toxins, that cost can increase dramatically; every year, the U.S. dredges approximately 400 million cubic yards of sediment, of which five to seven percent is seriously polluted *(48).*

The long-term cost of dredging stems mostly from the disposal of dredged spoil and is entirely the responsibility of the local sponsor. Environmental guidelines must be followed, and the amount of dredged spoil is often quite voluminous, requiring a large area of land (above or below water). Local sponsors may typically allocate around ten percent of the dredging cost to locating land and disposing of the spoil; however, polluted spoil can greatly increase these costs *(43).*

The financial benefits to ports of dredging deeper channels can be quite high. An additional foot of draft translates into more cargo and higher port revenues. It has been estimated that one additional foot of draft will allow a ship to handle 8,000 extra barrels of petroleum, 500 additional TEUs, or 300,000 pounds of general cargo, depending on the type of ship *(44).*

<u>Disposing of Spoil.</u> Locating waste sites for spoil is a major task. Many ports are located in urbanized regions where open land, if available, is expensive. A conventional practice in disposing of dredged spoil first includes finding an adequate open space for the waste to be located. Ideally, the open space would be located alongside or in proximity to the navigable channel. If the dumping site is adjacent to the navigable channel, the spoil can be pumped directly from the dredging apparatus to the open land. If the land is not adjacent, the spoil must be transported via long, flexible pipe, barge, or other means, drastically increasing the cost. When it is removed from the waterway, the dredge is usually 80 percent water, which allows for easy pumping. However, the water-laden material requires a large dump area and sufficient time to allow for evaporation. Compounding that problem is the fact that a crust often forms over the top of the layer, trapping the moisture and increasing the volume of the dredged material, which, in turn, limits the capacity of the disposal site *(43).*

Another option for port authorities is to simply deposit the spoil in the open sea. However, as environmental concerns move to the forefront in policymaking, this practice is becoming increasingly unacceptable. The Port of New York/New Jersey dealt directly with this issue: For decades, the spoil from New York Harbor was deposited in the Atlantic Ocean. The site, known as the Mud Dump and located six miles east of Sandy Hook, raised the ire of local fishermen and environmentalists. The ocean floor was being contaminated with heavy metals and other harmful matter, which negatively affected the ocean ecology in the area. After considerable lobbying, the Mud Dump was closed in September 1997. New York Harbor was forced to use more innovative and environmentally friendly methods in disposing of its dredged spoil *(50).* Currently, the port is planning to dredge two more vital channels at an estimated cost of $623 million in 1998 prices *(51).*

Environmental concerns extend well beyond protecting the open ocean. Because depositing spoil on land is opposed in many communities, cities are being forced to find innovative solutions to the disposal of dredged spoil. For example, in numerous cities from Rotterdam to Texas City, dredged spoil is being used to create landmasses used to extend the port, thereby creating valuable real estate. In Texas City, Texas, the created landmass may be used to protect the channel linking the proposed new container terminal at Shoal Point *(46).*

The City of Houston, Texas, is working to find the most efficient method of utilizing its current disposal sites. The city has developed what it terms a "crust management" program. In this scheme, ditches and trenches are formed along the perimeter of the dredging site to form what appears to be a large lake. As the material settles out of the water, clean, sediment-free water can then be pumped off the top of the pond into the waterway (disposal sights are adjacent to the waterway). Removal of the water decreases the drying time of the spoil by 60 percent, according to the Port Authority. The dry material can then be used to build and raise levees, saving around $1 per cubic yard over the conventional method and doubling the life of the disposal site *(52).*

Another innovative solution for disposing of dredged spoil is to create an artificial wetland, which could serve as a bird habitat (as the water content found in the dredging is very high). In many modern projects, port agencies agree to set aside some of the dredged spoil to be used for this service, to address some of the environmental concerns that are often associated with dredging activity. In a project that has become a national standard for the use of dredged material, the Port of Oakland used its dredged spoil to establish the Sonoma Wetlands *(43).*

Limits to Dredging. The obstacles to dredging may range from funding to environmental constraints. The federal government primarily funds the largest portion of all port dredging projects, with smaller contributions obtained from state and local entities. Given the budget constraints that exist at all levels of government, many projects never proceed beyond the conceptual stage. In other situations, the man-made and/or the natural environment limit the depth to which a channel can be dredged. For example, in Jacksonville (Florida), the Port's channel cannot be made any deeper than 41 feet because of the underlying bedrock *(43).* In large metropolitan areas, roadway and utility tunnels may create restrictions, while in other areas there are environmental concerns, such as the encroachment of saltwater into freshwater bodies. In many Texas ports, underwater pipelines have been repositioned at great cost. As a result of these and many other issues, obtaining congressional approval and the approval of the Army Corps of Engineers is probably the most difficult hurdle to overcome for ports that want to increase their channel depth.

Some Current Dredging Projects. In one of the larger dredging projects currently being planned in the U.S., the Port of Oakland intends to deepen its port channel from 42 to 50 feet. This project, scheduled to begin in February 2000, would allow the largest containerships to operate freely between deepwater ports in the U.S. and Asia. The cost has been estimated at $250 million, and the project will take three to four years to complete *(53)*. As mentioned in the previous section, the Port of Jacksonville is awaiting authorization from Congress to deepen its 14-mile channel from the Atlantic to the St. Johns River *(44).*

The Port of New York/New Jersey has been seeking federal funds to improve its inadequate access channels and to deter key container lines (like Sea-Land Service Inc. and Maersk) from switching to other East Coast ports, like Halifax. The Port's plan to deepen two vital channels will cost an estimated $623 million, though project approval is dependent on the availability of federal funds. The acquisition of these funds may be further complicated by the Port's history of environmental problems, particularly those surrounding the disposal of dredging spoil. However, since the announcement of the proposed improvements, several container lines have decided to stay with the Port. These carriers include the Compagnie Maritime d' Affretement (France), CMA-CGM Inc. (U.S.), and the Italia line (Italy) *(51).*

If fully laden mega-containerships are to call regularly at a Gulf load center, new investment plans will be needed to design, construct, and maintain channel access to the containership berths. This substantially raises not only the cost of providing port access, but also the costs associated with port land-based operations. These operational needs are now discussed.

Port Operational Needs

Port Operations and Equipment. A containerport performs the basic functions of receiving, storing, staging, and loading containers. To initiate the operation, a container is first received from either a truck, a train carrying a load of containers, another containership, or, as at Rotterdam, from a barge.

In the case of a truck, receiving begins at the entrance gate to the terminal, where the driver's credentials, load, and other necessary information are checked. The time required to pass through the entry gates varies depending on the length of the truck queues at the entrance to the terminal. The driver is instructed to either drop the container at a designated parking spot for storage or take the container to the staging area for direct loading onto the ship. The driver is then instructed to pick up another container in a specific parking spot to take it out of the port terminal for delivery. The total time necessary for a truck to go through the process depends on the size of the facility as well as on the coordination of each component—including the location of the container, when it will be ready at that location, when it needs to be shipped, and its final destination. As an example, the average turnaround time for a truck driver to complete the process at the Port of Houston is about 52 minutes. However, if a truck is not first cleared at the gate to drop off the container, it is required to wait in a particular area until it has authorization to continue on its route, and this increases the total time. The average wait for trucks that simply want to enter the port at the gate can be as high as one hour during peak traffic periods and is a source of irritation to truckers. Recently, truckers staged strikes at the Port of Vancouver because of the long wait times that reduced profitability *(55, 56).* The application of electronic data interchange (EDI) or automatic vehicle identification technology (AVI) could significantly speed up the check-in process at the gate. Such technologies, however, require union support prior to implementation at most U.S. ports, resulting in the delay of most technologies.

For an arrival by rail, the containers are either unloaded into a temporary storage area alongside the rail line or are unloaded directly onto various chassis sizes. A chassis is a special trailer or undercarriage on which containers are moved. The chassis is pulled by a small tractor, generally referred to as a "hostler/hustler" or "mule." These small tractors move containers and cargo within a storage yard *(26).* The chassis transfers a container from a train or truck to either the storage area or the staging area. The conventional, relatively simple layout of the port operations (excluding rail/truck moves to the gate) is shown in Figure 6.1, which illustrates the movement required of a container in order to be loaded onto a ship. When containers are offloaded, the process is reversed. In the case of a mega-containerport, the port layout shown in Figure 6.1 could include on-dock rail, to reduce storage, speed loading, and increase container throughput.

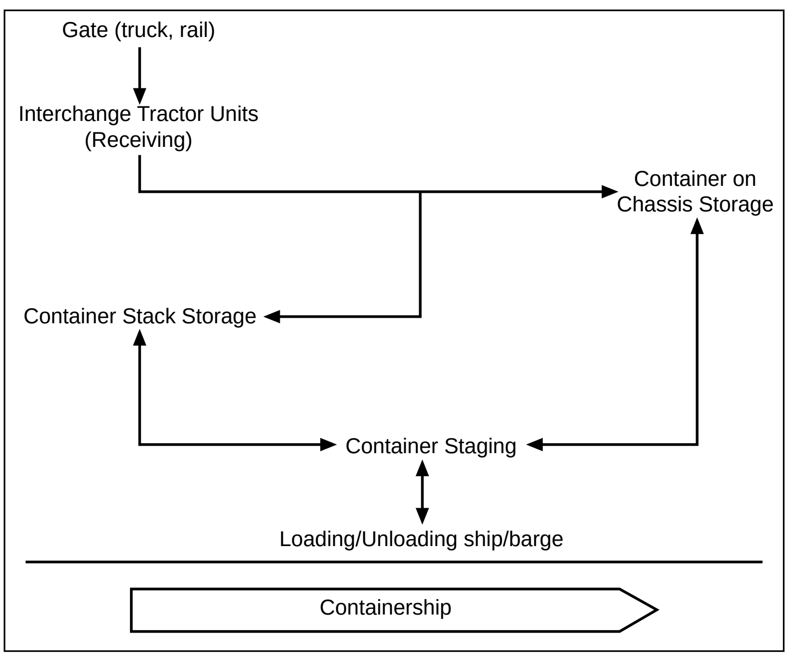

Figure 6.1. Container movement through a port *(54)*

The storage area is the location at which a container is held until a ship, train, or truck picks it up for transport to its final destination. The storage area may be one of several types, depending on terminal operations, and may include chassis storage, stack-with-transtainer (yard gantry crane) storage, or stack-with-straddle carrier storage. Chassis storage involves loading a container onto a chassis until it is ready for loading onto a ship. This method, however, decreases the storage capability of an area, as containers are stacked only one unit high. Transtainer (yard gantry crane) storage involves moving the container into and out of a stack by a transtainer using a chassis. Straddle carriers can transport as well as stack a container *(54)*, and are self-propelled, steerable vehicles on wheels that straddle a container or container-on-chassis and move it to another destination in the container yard. These vehicles are able to straddle a single row of containers that are stacked two to five containers high. This idea was developed from the method used by old lumber carriers to move timber around the lumberyard. Mega-containership operations will create the need for greater container transit and storage needs, and such vehicles as the straddle carrier will play an important role in raising cargo transfer efficiency *(45)*. Other equipment used to maneuver and transport containers around the storage yard or in stacks include side loaders (heavy-duty fork-lift trucks), top loaders (fork-lift trucks equipped with spreader bars), and reach stackers (small mobile cranes).

Containers are placed in the staging area before they are loaded onto a ship or just after they are unloaded from a ship. This area, called the "apron," is located immediately behind the ship's loading/offloading cranes. It should consist of an area of at least several hundred feet free of storage sheds, warehouses, and other buildings in order for these ship-to-shore cranes to temporarily place containers before or after they are loaded onto or off of the ship. In addition, the apron should be paved with reinforced rigid concrete in order to provide support for the stacks of full containers.

Cranes. The final stage in the operations process involves the loading or unloading to/from a ship using ship-to-shore cranes. As containerships increase in size, larger, more efficient cranes will be needed to facilitate the efficient movement of boxes. In response to recent advances in containership design, crane manufacturers have been working to provide ports with the “mega-crane,” sometimes termed “Extra” or “Beyond” Post-Panamax by the industry. One of the largest containership vessels in service in 1998 is the Regina Maersk, which has a container-carrying capacity of 6,600 TEUs, a length of 1,061 feet (318.2 m), a beam of 142.7 feet (42.8 m), and 17 rows of containers on-deck *(48).* One common problem for containerships of this size is that many containerports do not have cranes capable of reaching across all the on-board containers. Other pressing issues involve the cranes’ speed and the port’s ability to adequately process the containers. Furthermore, on some routes, today’s large carriers are stopping more frequently before sailing on the sea leg of the voyage owing to the inability of many ports to off- or on-load the entire ship. Carriers would prefer fewer calls on high-density routes at ports willing to make infrastructure improvements *(57).* Examples of terminal facilities at the Port of Long Beach that have improved their container cranes are summarized in Table 6.5.

Table 6.5. Examples of crane upgrades at various Port of Long Beach facilities 1996–1997

Crane improvements made
• Acquired 20 Post-Panamax cranes (capable of serving up to 16 container rows). • Purchased three cranes ($1–$2 million each), with a maximum horizontal reach of 141 ft. This improvement has allowed Hyundai’s 4,400-TEU-capacity ships to operate at this facility. • The California United terminal facility has recently modified these cranes’ total height to 105 ft (original height = 76 ft). This improvement has allowed Hyundai’s 5,551-TEU-capacity ships to operate at this facility. • Purchased six cranes with horizontal reach of 151 ft each (capable of serving over 18 rows of containers) for its new facility in 1997. • Ordered several cranes with horizontal reach of 180 ft each (capable of serving up to 20 container rows). This will allow the facility to handle 6,000-TEU-capacity vessels.

Source: *(48)*

A major reason for crane upgrades is to extend their reach in order to service new and ever-wider vessels. In the 1970s, cranes were typically capable of handling 11–12 rows of containers; but their design has evolved such that the Post-Panamax crane can handle up to

16 container rows on deck. However, the new generation of large containership rows holds 17 or more containers. Table 6.6 provides the maximum dimensions of cranes from various manufacturers in 1998. In this table, crane outreach refers to the distance from the centerline of the waterside crane rail to the centerline of the farthest waterside position of the trolley spreader (the moveable base of the crane). Crane backreach refers to the distance from the centerline of the landside crane rail to the centerline of the farthest landside position of the trolley spreader *(45).*

Table 6.6. A selection of maximum crane dimensions in 1998

Crane supplier	**Outreach**	**Number of rows served**	**Span**	**Backreach**
Ansaldo	151 ft	16–17	99 ft	69 ft
IHI	151 ft	16–17	80 ft	50 ft
IMPSA	158 ft	17–18	100 ft	50 ft
MAN/Takraf	175 ft	19–20	100 ft	73 ft
Mitsubishi	183 ft	20–21	101 ft	69 ft
ME&S	166 ft	18–19	101 ft	51 ft
Noell	172 ft	19–20	100 ft	83 ft
Reggiane	155 ft	17–18	99 ft	50 ft
Sumitomo H.I.	157 ft	17–18	101 ft	100 ft
Vulkan Kocks	160 ft	17–18	----	----

Source: *(57)*

Table 6.7 describes the world’s crane population at various time periods. In 1995, a majority of ports worldwide contained Panamax cranes (77 percent), while only a small percentage (three percent) possessed Beyond Post-Panamax cranes. From 1996 to 1998, key ports began adopting bigger and faster cranes, as shown in Table 6.7. In North America, this transitional shift is more evident, with Beyond Post-Panamax cranes now constituting 83 percent of the 1996–1998 order book *(45).*

Table 6.7. World gantry container crane fleet—existing and on order—1996–1998

Size	Ship handling	Operating in 1995	Deliveries* (1996–1998)	U.S./Canadian orders (1996–1998)
Panamax (<144-ft outreach)	13 rows served 106-ft beam <4,000 TEU	77%	30%	7
Post-Panamax (144–158-ft outreach)	16 rows served 132-ft beam 4,000-6,000 TEU	19%	23%	4
Beyond Post-Panamax (>158-ft outreach)	17+ rows served 140-ft+ beam 6,000+ TEU	3%	44%	55

* A total investment of $1.2 billion
Source: *(48)*

During the period from 1996 to 2001, based on crane orders as of April 1998, new Panamax cranes represented 32 percent of the market, Post-Panamax 21 percent, and Beyond Post-Panamax 47 percent. The total fleet composition, taking into account new cranes, is Panamax 63 percent, Post-Panamax 19 percent, and Beyond Post-Panamax 17 percent. Table 6.8 provides more details by year, including cranes ordered in 1998 for delivery in 2001.

Table 6.8. World fleet of operational and ordered quayside gantry container cranes 1996–2001

Year built/ordered	Panamax	Post-Panamax	Beyond Post-Panamax	Total
2001*	15	3	51	69
2000*	45	30	66	141
1999*	24	35	76	135
1998	55	37	68	160
1997	69	43	98	210
1996	71	41	59	171
Pre-1996	1,493	349	68	1,910
Total	1,772	538	486	2,796

*includes all orders at 4/98
Source: *(17)*

In an effort to accommodate mega-containerships, ports must acquire cranes that have adequate height, horizontal reach, power, and fast turnover rates. The ability of ports to load and off-load containers quickly is critical, and at key Asian ports like Singapore and Hong

Kong, containerships are able to be loaded/off-loaded at 30 to 40 lifts per hour for each crane *(45)*. At this turnover rate, a mega-containership like the Regina Maersk is able to be fully serviced (unloaded and loaded) in about two days. Cranes at U.S. ports, however, can service an average of only about 22 to 25 lifts per hour. At this turnover rate, the time required to service the same mega-containership is about three days. Ship owners like Maersk would like to spend a maximum of 24 hours per stop and ideally would prefer to limit port dwell time to 20 hours; so much work needs to be accomplished to meet this target.

On June 18, 1998, P&O/Nedlloyd's new mega-carrier, Southampton (a 6,690-TEU containership), was serviced at Singapore at a rate of 144 moves per hour, which was a new record for the carrier. The Port of Singapore Authority (PSA) reported that 2,416 containers were handled in 16.8 hours, though the fastest performance to date for PSA is 229 containers per hour, which occurred in July 1995 on the Mette Maersk (3,920 TEU capacity) *(58).*

Crane size does not necessarily translate into better performance. As a result of container growth, cranes are expected to move boxes at higher rates. Mega-containerships may undertake over 4,000 container exchanges in one port alone. At this rate, new crane designs are needed. Many things can be done to improve the physical size capabilities of cranes; however, speed (turnover rate) is the central issue *(57).*

Crane productivity involves positioning the trolley over the ship, lowering and raising the container, moving the trolley to the unloading point on the berth (truck chassis or rail), lowering, unloading, raising the trolley, and moving back to the next slot location on the ship. Speed is therefore of the essence and typical operating speeds for current crane designs, according to Vulkan Kocks *(57)*, include the following:

Hoisting/lowering full load	=	198 feet/minute
Hoisting/lowering empty spreader	=	446 feet/minute
Trolley travel speed	=	594 feet/minute

Operating speeds are also constrained by the performance of crane operators *(57)* and efforts are underway to raise their efficiencies. Research from Japan, Argentina, and Germany suggests that advanced hoisting and trolley technologies with a more passive operator role can raise speeds and therefore crane productivity *(57).*

Operating speeds have increased in tandem with crane size, and further speed increases will occur with the implementation of such technologies as anti-sway devices and part- or semi-automation of the operating cycle. In operating cycle automation, the crane will determine its optimum path and repeat the path in subsequent cycles. Other possible strategies that may be used to accelerate crane speed include separating the operator's cabin from the hoisting gear trolley and developing container-positioning systems. ABB of Sweden (control systems supplier) has recently introduced its Crane Positioning and Pendulum Control (CPC) and Automatic Crane Control System, which uses a Target Positioning Sensor to automatically pick-up and drop-off containers in the stack or on vehicles. This system uses laser scanners that enable accurate measurement of vehicle and container positions. The profiles of stacked containers on the ground and on the vessel are rapidly scanned by these lasers and matched with their correct destinations. ABB claims that its system removes the jerks and bumps from the crane operation and that the processing of information is accelerated, providing swifter and smoother operations and a reduction of the overall stress on both the crane and the operator *(57).*

Port operations serving containerships that must be quickly unloaded may be viewed as an hour glass with movement restricted by the handling gap at the crane/container interface. Larger and faster cranes help widen this gap, hence the continuing investment in crane renovation or new crane purchases in the sector. Since the literature argues that there will be relatively few mega-containerports, the number of Beyond Post-Panamax cranes that have been delivered or ordered is somewhat puzzling. Many ports purchasing these cranes may never receive a regular call from a mega-container vessel, which suggests the ports may never operate their new cranes at maximum potential *(17).* The answers probably lie in the efficiencies to be gained with new cranes (especially with the latest technologies), the potential to serve the largest ships, and the decreasing cost of these units, which were mostly manufactured in countries impacted by the 1996–1997 Asian crisis. In this latter regard, the economics for a large containerport are attractive. When crane life is figured into the purchase cost and productivity, the marginal cost per container using a Beyond Post-Panamax crane is small and outweighed by the ability of the crane to service all ship types.

Storage/Terminal Backland Requirements. Figure 6.1 provided a schematic of the apron layout for a containerport. In addition to the storage areas available on the apron, many port authorities use backland to store not only containers that have been unloaded from a ship and are waiting to be picked up by truck or rail, but also containers that have been brought in by truck or rail and are waiting to be loaded onto a ship. The amount of storage space necessary for containers varies depending on load sizes transferred to and from ships accessing the port, wharf activity (constant transferring of goods from ship to land or land to ship), and gate activity (hours of operation for truck and rail).

Several options exist to minimize the amount of storage space required at a port. One option is higher and/or denser stacking of containers to allow more units per land area. Typically, containers are stacked from three to five units high, though they can be stacked up to seven units high to optimize the number of containers per acre of storage area *(56).* Some ports stack containers as high as 12 units in response to severe land constraints. Another option is longer operating hours, allowing trucks, rail, and ships to transfer more containers in a day, thus increasing efficiency and minimizing the amount of time (and space) a container is stored in a yard. A third option is the application of Intelligent Transportation Systems (ITS) technologies capable of providing more efficient operations through such efforts as electronic tagging of containers for prompt processing, tracking, and transfer to and from the storage yard. A fourth option, on-dock rail, substantially reduces the need for truck drayage and allows direct loading/unloading of trains from the temporary storage apron, thereby eliminating the need for temporary container storage in the terminal backland.

According to Vickerman, the average storage requirements for a port servicing Post-Panamax ships are 50 acres per ship-berth. A Beyond Post-Panamax ship, however, will bring in approximately 50 percent more containers than Post-Panamax vessels; accordingly, approximately 75 acres per Beyond Post-Panamax berth may be appropriate. The numbers do not reflect the use of on-dock rail, which would lower storage requirements if fully implemented. Vickerman also cautions that these values are not necessarily fixed and that more research is needed to further estimate the storage area required for a typical Post-Panamax and Beyond Post-Panamax ship delivery *(45)*.

If a mega-containership makes a delivery that would otherwise be made using two or three ships over several days, more storage area is necessary to handle the increased amount of containers that are loaded/unloaded unless an effective on-dock rail system can be implemented. Even if the amount of containers is the same, more containers need to be stored to service a mega-containership transfer. The rate at which containers can be loaded onto rail or truck is less than the rate at which they are unloaded from the mega-containership, so it generally takes several days to transfer all containers to another mode for delivery. Figure 6.2 shows the difference in the transfer rate between a mega-containership, rail, and truck related to the number of days it would take to distribute a mega-containership load, assuming a 40/60 rail/truck split. The curves shown are only examples and would vary by port depending on share to rail, dwell times, and other factors.

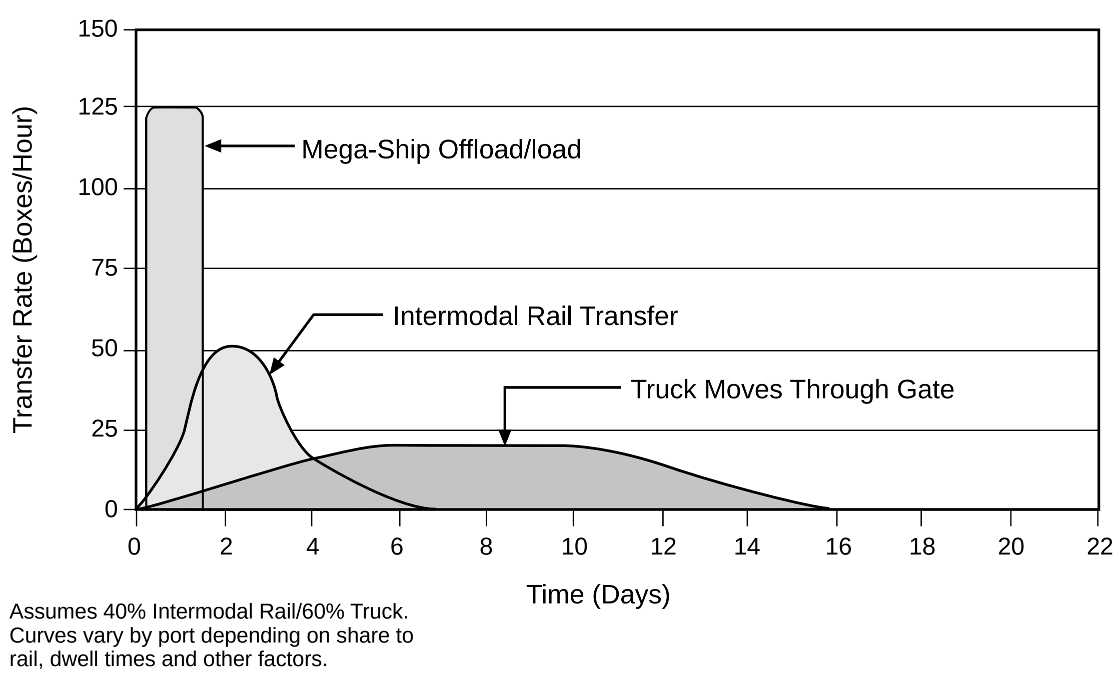

Figure 6.2. Mega-containership terminal peaking characteristics *(25)*

Terminal Staffing Requirements. A marine port container terminal is customarily staffed by permanent employees and by longshore labor. The number of employees varies depending on the number of ship calls and on the amount of cargo handled at that location. Staff personnel are usually grouped into teams with about 20 longshoremen, depending on such port characteristics as the type of container handling equipment available. A group is deployed at each container crane utilized to serve a ship.

The storage inventory and equipment staff consists of about 15 to 25 full-time employees for a 200,000-TEU-per-year terminal. A terminal of this size typically has a gate of eight to 12 lanes. Staff members include one union clerk per two lanes, one checker per two lanes, two to three on-site inventory and other clerical workers, three to five mechanics, and two to four full-time container yard equipment operators *(45).*

Finally, labor staff consist of nonunion management and clerical workers at the terminal; they are responsible for providing assistance and directing the employees. These members include a terminal manager, an administrative assistant, file clerks, secretaries, and guards. Staff costs constitute an important budget element in port operations, especially in North America with its strong unions and higher wages. A mega-containerport facility operating around the clock can generate a high wage bill for the port authority and can make offshore facilities or sites in countries with lower wage rates more competitive in the routing of global lines.

Landside Access

Intermodal Issues. A port needs to be easily accessible by both sea and land in order to operate efficiently. There are a number of access issues to be considered when providing efficient landside operation at a port. A 1993 Transportation Research Board report *(59)* identified the following landside access issues that are impediments to port operations:

- Congested truck routes,
- Numerous at-grade rail/highway crossings,
- Lack of land to develop adequate access,
- Low clearance for double-stacked trains, and

- Unavailability of on-dock rail.

Throughput. Throughput is defined as the number of TEUs that pass through a facility in a given unit of time, usually one year. Throughput is used to represent the size of the port and it can be related to the area of a terminal (in TEUs per acre) to demonstrate space utilization. However, relating this number to efficiency can be misleading owing to a range of factors that include:

- Level of transshipment,
- Storage density,
- Labor practices,
- Intermodal split, and
- Percentage of cargo unloaded/loaded at one call.

The level of transshipments is the factor that differentiates the seemingly highly efficient Asian ports from U.S. and European ports. Ports such as Hong Kong and Singapore have extremely high levels of transshipment. In transshipment, a box is unloaded from a ship, stored for a very short time, and then loaded back onto another, often smaller, ship to transport the cargo to its final destination. This container then counts as two when calculating throughput volumes. Obviously, this practice is more efficient than non-transshipment: unloading a box from a ship, storing the box, loading the box on a truck, having the truck leave the yard, having another truck enter the yard, unloading the box from the truck, storing the box, and finally placing the box on a second ship.

Another aspect of transshipment that improves throughput is the reduced amount of storage space needed. Because transshipment requires very short storage time (known as dwell time), a smaller area is required *(45).*

Container storage density is also impacted by high land values. In Asia, land containers are stacked higher in order to more effectively utilize scarce surface area. Such a practice requires a higher utilization of labor, and is not practical or necessary in the U.S. where containers are stored less compactly on wheeled chassis. Further, the labor in Hong

Kong and other Asian ports is utilized 24 hours per day, increasing the number of container transfers per day at the port. In the U.S., round-the-clock operations have not been adopted *(45).* Table 6.9 gives some examples of throughput for a variety of regional sites.

Table 6.9. Typical world throughputs

Port/geographic region	Throughput (TEUs/acre/year)
Asian average	8,834
European average	2,974
Rotterdam	4,400
U.S. average	2,144
U.S. West Coast	3,567
U.S. East Coast	1,281
Houston	3,200

Source: *(45)*

The intermodal split of a facility is also a key component of throughput. Loading cargo from ship to rail is more efficient than solely utilizing trucks. The use of rail greatly reduces dwell time and thus reduces the amount of storage required, a factor that makes U.S. West Coast ports more productive than U.S. East Coast ports. On the West Coast, modern intermodal terminals are used to quickly unload cargo from ship to rail. Further, the containers can be double-stacked on trains, allowing rail to gain greater economies of scale.

The two most important factors affecting transshipment in the Gulf of Mexico region are intermodal split and percentage unloaded. In Houston, most of the cargo unloaded is destined for locations in the Central Texas Triangle composed of Dallas-Fort Worth, San Antonio, and Houston itself. Such close locations are currently best served by truck; thus, there is insufficient current demand to fully utilize rail. Houston currently has a modern intermodal facility as well as the capability to send trains via a minibridge to the West Coast. However, increases in the demand for non-Texas cargo are needed before a greater intermodal split is feasible.

Further hindering throughput in the Texas Gulf is the percentage of containers that are loaded and unloaded. On the U.S. West Coast, an entire ship may be unloaded and loaded at one call. However, such expediency is not the case in the Gulf, as a smaller percentage of the containers are unloaded at a given port. Unloading an entire ship is a more efficient task than locating and unloading specific boxes of a large vessel, a practice that limits crane lifts per hour and, in turn, limits throughput.

Typical Modal Splits. Once a ship has been unloaded at a port, the modal split of the cargo becomes of primary importance. Modal split is defined as the share of cargo that moves by rail and the share that moves on highways or other modes. When planning a port, the estimated modal split becomes a crucial aspect in analyzing how the port will impact current infrastructure. A 7,000-TEU mega-containership, assuming a 75 percent rail/25 percent highway intermodal split, has the capability of filling more than nine double-stack unit trains with imported and exported goods *(45).*

Moving containers by rail is considerably more efficient than moving them by truck. In fact, the average unit rail costs can be 20–30 percent less (depending on length of haul and level of demand) than truck costs *(46).* Among U.S. ports, the modal split toward rail is much more predominant on the West Coast. The split at Long Beach, for example, is approximately 50/50 between rail and trucking, with the rail percentage expected to increase with the development of the Alameda Corridor which will link the ports with the intermodal rail yards. Moving east, the rail volumes decrease. A typical East Coast modal split consists of around 24 percent rail *(25).* The Gulf region is well known for having very low intermodal rail volumes; the Port of Houston, for example, has less than a 20 percent rail share.

Factors Affecting Modal Splits. The modal split at a given port is a complex issue that consists of many variables. The most important factors include rail demand, availability of a near-dock intermodal facility, and proper inland infrastructure.

The U.S. West Coast, in general, has intermodal infrastructure superior to that of the U.S. East Coast and has a much higher demand than the Gulf region. The West Coast has an advantage over the East Coast in terms of space and more modern infrastructure. In the West, double-stacked trains can be utilized without the constraints of low ceiling tunnels, which are common in the East. A further advantage lies in the West Coast's more advanced facilities, which can accommodate more rail-based cargo. In general, these basic advantages account for the variance in regional modal splits.

VZM/TranSystems identifies three key trends that will most affect future modal splits: (a) the growing importance of intermodal rail; (b) the continuing importance of truck access; and (c) the degree to which effective landside access can "decouple" port locations from the metropolitan areas they serve *(45).* Currently, the trend is to improve the quality of intermodal rail. Increasing rail utilization decreases the number of trucks over the road, which, in turn, reduces congestion and improves the environment. Further, loading a large number of containers onto a unit train at one time decreases the average dwell time and the necessary storage area at a facility. More ports are utilizing on-dock or on-terminal rail and are double-stacking containers onto rail cars. Regions implementing such improvements should attract more lines *(45).*

Changes in the rail industry should also facilitate a shift to rail. For example, the recent Class I rail mergers in particular should bring about an improved system. As mergers continue, the formulation of integrated transcontinental partnerships could be realized in the near future. Because all these factors indicate a rise in the percentage of containers handled by rail, guidelines for a future containerport should take these changes into account.

Rail Issues. Access by rail is a key component in maintaining efficient port operations. Such is the case at the ports of Los Angeles and Long Beach; drayage trucks move the containers between the port and rail facilities, a distance of between four and 25 miles. In 1990, about one million of the 2.2 million containers that went through the port had to be transferred between the port and rail lines by truck *(60).*

Throughout much of the western U.S., trains can be double-stacked, providing higher capacities and lower ton-mile costs. However, in much of the eastern U.S., trains cannot be double-stacked owing to limited clearance of overhead bridges and tunnels. If a port is located along rail lines that permit double-stacking, trains may not need to enter the port as frequently. On-dock or even near-dock rail facilities are critical factors for smooth and efficient transfer operations. Drayage costs can range from $88 to $330 per container per trip in 1998 dollars, depending on the distance *(56).* Rather than using trucks for drayage purposes between the ship and rail terminals, on-dock rail allows a container to be off-loaded from a ship, placed in temporary storage between the ship and rail line, then loaded directly onto the train, and vice versa. It has been suggested that rail lines be, at the maximum, 1,400 feet (424 m) from the ship *(25).* Difficulty with on-dock rail occurs when there is a need for more coordination between shipping lines and rail lines and, in some instances, when there is a lack of land area to provide on-dock facilities. A double-stack unit train operating with a two-person crew is able to haul about 300 containers or 200 trailers *(56, 60).*

Mergers. The Staggers Act of 1980 heralded the deregulation of the U.S. rail industry and laid the basis for a spate of mergers, which, between 1984 and 1997, saw the number of Class I, railroads decrease from 31 to six. Rail mergers and rail company consolidations may eventually create more streamlined operations to provide better service for shippers. By consolidating lines, there is less need for duplicate crews, rolling stock, and personnel for the handling of shipped goods. While these mergers may improve flow efficiency for the shippers, some users are concerned that there is no longer enough competition to keep the new rail conglomerates from raising rates as they acquire more of the rail lines servicing the shipper.

As the rail lines become more streamlined, another concern is the access to remote areas and the ability of the shippers to service these areas. As the rail lines merge, they are creating hubs and working with the trucking industry to improve service to key markets while remote areas that use rail to move bulk commodities from their areas suddenly find that there is no longer access to rail. One such reason for this elimination of service is the realization that rail is more profitable for long hauls than for short, especially in the intermodal area.

Rail Freight. Intermodal freight movements are increasing across the U.S., as major trucking companies like J.B. Hunt move longhaul trailers by rail. It is becoming apparent that rail is more efficient for trips over about 750 miles, and by adding double-stack service to long hauls, rail lines can increase their productivity *(61)*.

These double-stack trains are a factor in the intermodal movement of freight. The use of double-stacks improves the speed and movement of freight, which is a welcome feature for shippers who are looking for reliable intermodal movements of their goods. Difficulties with the use of double-stacks include inadequate tunnel clearance and "at-grade" crossings (which affects not only double-stack trains, but also regular train movements). As investments in rail infrastructure increase, some problems (e.g., rail crossings) are decreasing, though tunnel clearance remains a problem, especially in the east. Though recent restructuring—like the take-over of Conrail by CSX and Norfolk Southern—might accelerate programs to raise tunnel clearances, the high cost suggests that the programs will be incremental.

Truck Issues. Generally, a port located in a highly populated urban area both suffers from and creates traffic congestion, impeding efficient truck access and flow. This is critical to the port operations since all containers, including those transported by rail, make the final leg of their trip to port by truck. On-dock rail would reduce these volumes but is only planned at a few sites (like the Alameda Corridor), and is expensive to build. So trucks will continue to be the main mode at the port, draying intermodal containers to nearby rail terminals. Since the gates at most U.S. ports are only open for a limited time—typically five days per week for ten to 12 hours—trucks carrying containers will continue to be a major element in traffic around maritime ports. An evaluation of intermodal freight terminals found that 64 percent of 25 ports surveyed considered traffic on the terminal's access roads to be a major problem *(62)*. A number of these terminals did not have traffic signal controls, which caused long queues of trucks to form outside the terminal waiting to enter the premises.

An increase in total port container volume translates directly into an increase in landside traffic. For example, if a port has a throughput of 450,000–900,000 TEUs per year through the gate, this translates into approximately 1,000–2,100 truck trips on a typical day, given a 40 percent rail/60 percent highway intermodal split (assuming operation only on weekdays) *(26).* This may result in traffic congestion or, if congestion already exists, in heightened traffic congestion. Two solutions to this problem are to either increase highway capacity or reduce truck trips. A further solution is to keep gates open longer (some shippers would like to have gates open seven days per week, 24 hours per day) to smooth out the traffic over a longer period, perhaps avoiding contributing to peak urban demand.

Two ways to reduce the number of truck trips include introducing intermodal rail service or adding longer (and hence more productive) designs, termed long combination vehicles (LCVs), to truck operations. LCVs are typically designs that incorporate double or triple trailers. The most popular LCV advocated is a double 48-foot (termed "turnpike double"), which could carry around twice the number of containers hauled by current trucks *(63).* For example, a port having a throughput of 900,000 TEUs per year will produce around 2,076 truck trips per day. If LCVs are introduced, and the same number of LCVs are employed as conventional trucks, then the daily average truck trips will decrease to approximately 1,500 *(61).* However, LCVs create real problems in congested areas (because of their size) and may also accelerate pavement and bridge deck deterioration (due to higher axle and gross loads), requiring higher maintenance funding levels on their routes.

Impediments at Ports. There are many factors that may impair truck operations at ports. A questionnaire sent out by the American Association of Port Authorities (AAPA) in 1997 found that many ports suffered from infrastructure insufficiencies. The results of this questionnaire can be found in Table 6.10.

Table 6.10. Landside access impediments of 31 U.S. containerports (1997)

Impediment	**Number of responses**	**Percentage**
Road Access		
Interstate	10	32
State	12	39
Local	17	55
Bridges	14	45
Rail Access		
Bridges	11	35

Near-dock	15	58
On-dock	12	39
Truck Access		
Availability and location of street signs	10	32
Turning radii	15	48
Availability and location of turning lanes	12	39
Availability and location of lanes	11	35
Availability and location of multiple access routes	12	39
Availability of designated truck routes	12	39
Existing highway weight regulations	13	42
Highway and bridge load bearing capacity	14	45

Source: *(64)*

It is interesting to note that more than one-third of the ports experience major road access impediments and more than 40 percent of the ports experience highway weight-related impediments.

*Environmental Issues***.** The principal environmental concerns regarding the development of a port include:

- changes to freshwater bodies (owing to changes in salinity from dredging);
- dredging and disposal of material;
- loss of particular land areas (wetlands and coastal regions);
- increase in pollutants emitted from an increase in truck traffic and more trains running through the area;
- traffic congestion;
- light and noise pollution to adjacent neighborhoods; and
- pollution from vessel operations, including engines and ballast discharges.

Dredging a channel to allow ships with larger drafts to enter into a harbor has major environmental impacts on the water supply, marine life, and air quality. Widening or deepening a channel from the ocean increases the salinity of the water in the channel, which can potentially kill freshwater fish that reside within the area surrounding the ship channel. If a channel is to be dredged to allow larger ships to access the port, less dredging will be required if the port is located near the ocean. As a result, less saltwater enters into the freshwater area, and the salinity does not change as drastically. However, if the port is to be located far from the ocean, more dredging will occur for the ships to reach the port. As a result, more saltwater will flow into the freshwater basin, thus significantly increasing the salinity along the entire channel.

The disposal of dredged material is another environmental consideration. Disposing of the spoil into open water disrupts and often covers up animal life and reefs on the bottom of the waterbed. Since the mid-1980s, a close watch has been kept concerning how and where the spoil is disposed *(65, 66).* As previously noted, in the case of Texas City, the spoil eventually grew to be a landmass suitable for development. Spoil may also be used to construct wetlands if the disposal location of dredged material is carefully chosen and if it is determined that a wetland will positively impact the surrounding land.

Although dredged material may be used to develop a wetland, such development may be a result of the port's initial occupation of existing wetland. If development occurs over wetlands or other animal and plant life habitats, the developer must relocate or replace the lost habitat. Wetlands exist along coastal regions; and if a port is constructed or expanded along a coast, the port may take over land area that is a habitat for large numbers of animals and plant life. However, if a developer can replace the wetland using dredged spoil, the environmental impact will not be as devastating.

In addition to the environmental issues affecting animal and plant life, port developers must also address the potential harm or disturbance to human life. Construction or expansion of a port, especially to a mega-containership facility, will undoubtedly add to the numbers of trucks and trains that enter and exit the port to distribute the larger amount of goods brought in by ships, increasing the amount of pollutants emitted into the air from diesel trucks. The California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA) have found that there are at least 38 toxic chemical pollutants and cancer-causing pollutants in diesel exhaust. The EPA has introduced new regulations that will reduce the amount of allowable emissions from heavy vehicles. However, these regulations will not go into effect until the 2004 model year *(67).* Increased diesel fuel exhaust gases are only one concern regarding the increase in truck traffic in an area. The other concern is the added congestion to the road network surrounding the port. The increase in trains accessing the port will also lead to more congestion at at-grade intersections with roadways, more pollutants in the air, and more noise surrounding the port.

When neighborhoods are affected by port truck traffic, they become understandably concerned about these impacts and also about the noise and light pollution coming from the port during extended operation hours. If more containers are brought into the port by a mega-containership, crews will work longer hours to load and unload the ship within a smaller period of time, usually one to two days, resulting in a greater potential for disturbing residential areas.

Public involvement in the construction or expansion of a port is necessary to avoid future disputes. Although a port will undoubtedly affect the surrounding land, water, and air quality, steps can be taken to minimize the negative impacts. Harmful environmental and residential impacts can potentially be reduced by presenting and discussing alternatives with environmental agencies and by taking action to correct or minimize environmental concerns.

SUMMARY

As the era of mega-containership operations begins on the most important container trade routes in the world, U.S. ports compete for the new business associated with these large vessels. Future mega-containerport facilities will need to provide excellent inland infrastructure, as well as deep harbors, if they wish to accommodate the new generation of vessels. Table 6.11 summarizes the strengths and weaknesses of some U.S. gateways on the Atlantic and Pacific in terms of their infrastructure. While the points raised are, of themselves, inadequate for an inter-port comparison, they identify issues to be addressed in a full evaluation process.

Table 6.11. Evaluation of selected U.S. port infrastructure

U.S. port	Advantages	Disadvantages
Baltimore, Maryland	Large container terminal. Good rail connections. Accessible: north, from Chesapeake and Delaware Canal; and south, directly up Chesapeake Bay.	Docks are a day's travel up the bay. Hampton Roads offers keen competition.
Boston, Massachusetts	Channel has been deepened. Docks are an hour from the sea.	Midwest markets are often served by the St. Lawrence Seaway, while markets to the south are served by New York and northern New Jersey. This reduces the number of consumers depending on Boston.
Charleston, South Carolina	Deep channels. Modern container terminals. Uncluttered access to major interstate highway serving the South and Midwest.	Direct, modern rail links are lacking but planned.
Halifax, Nova Scotia	Deep channels. A day's sailing closer to Europe than other East Coast ports.	A day closer to Europe makes it a day further from key U.S. markets.
Hampton Roads, Virginia	Modern, large container terminal is close to the sea. Good rail connections. Deep channels.	Location. New York/New Jersey is the preferred North Atlantic load center.
Jacksonville, Florida	Deep channels. Modern terminals. Good rail and highway connections. Emphasizes trade with South America.	Strong competition from neighboring ports like Miami and Port Everglades.
Los Angeles/ Long Beach, California	Adequate harbor depth. Large, modern container terminals with sufficient backup land. On-dock and near-dock rail transfer yards. Extensive rail and highway infrastructure and frequent services to eastern U.S.	Congestion in the harbor area. High labor and port costs. Unpredictable, strike-prone labor force.
Miami, Florida	Short trip across Government Cut to the docks. Strong ties to Caribbean and South American ports and economies. Large cranes.	Limited warehouse space.
New York/ New Jersey	Large regional market. Natural load center. Good rail connections. Portway Intermodal Corridor Project.	Political rivalry over mega-terminal. Dredging issues not yet resolved. Drayage to rail terminals creates congestion.
Oakland, California	Modern container facilities with room to expand. On-dock and near-dock rail transfer yards. Good rail and highway connections.	Draft restrictions that prevent mega-containerships from entering the port. Most container services in the Pacific Southwest call Southern California first; Oakland does not get as much inbound intermodal cargo as LA/Long Beach.

U.S. port	Advantages	Disadvantages
Savannah, Georgia	Channels being deepened. Good rail and interstate connections.	Docks are located some 50 miles upriver from the sea.
Houston, Texas	Regional containerport. New rail loading facility. Established liner services. Interstate and rail access.	Barbors Cut at capacity. Channel at 40 feet.
Seattle/ Tacoma, Washington	Adequate harbor depth. Modern container terminals. Tacoma has plenty of room for expansion. On-dock and near-dock rail transfer yards. Pacific Northwest ports are at least one day closer to Asia by sea than California ports.	Roadway and rail bottlenecks in Washington State and the Cascade Mountains. Smaller population base makes Pacific Northwest services highly dependent on intermodal cargo destined for eastern U.S.

Source: *(37, 56)*

European-Gulf trade is highly sensitive to the improvement of intermodal links. It is possible that if rail intermodal services could improve between the East Coast and the Midwest to Southwest, the containerized traffic from Europe presently entering the country through the Gulf ports may shift toward ports on the East Coast. Such a traffic shift might alter container movements in the Gulf, since a large portion of the Gulf's containerized trade is with European ports.

However, it is also possible that as the intermodal links develop between the Gulf ports and the Midwest, specifically a north-south rail route, more containerized traffic will be drawn to the area, which would represent a continuation of the north-south development. In the future, significant amounts of cargo could travel from South America through Houston and on to Chicago via this north-south route. Finally, the accessibility to the Gulf of Mexico should be considered. It might be more feasible for shippers to have their cargo unloaded at a mega-containership hub just outside of the Gulf (e.g., the Caribbean) and then transshipped into the various ports within the Gulf region. All this is speculative and unlikely to be featured in short-term plans, but because the transport industry is in such a dynamic phase at the moment, and given that the momentum is with shippers and carriers *(68)*, changes to routes and loads may take place.

This chapter evaluated a substantial body of literature addressing the three major components of port infrastructure: maritime access, port operations, and landside access. Ports wishing to attract large containerships will have to undertake sizable investment programs in one or more of these areas. Since each is substantial, the more areas that need investment, the higher the cost that site faces if it wishes to become a mega-containership load center. The 1999 Sea-Land/Maersk contract with the Port of New York/New Jersey also shows that other financial incentives may have to be put on the table to induce liner service. Finally, most sites lack the rail interface (preferably on-dock) that can provide efficient (and cost-effective) moves. These issues combine to currently limit the attractiveness of Gulf sites, in particular, as potential load centers for mega-containership operations.

CHAPTER 7.
SUMMARY AND RECOMMENDATIONS

The literature review revealed a substantial body of work related to ship size, port management, and changes in international containerized trade. The summary below focuses on those elements that directly relate to the introduction of mega-containership operations in the U.S. Gulf. Elements that need to be addressed in any analysis include: (1) trends in world trade and in the way in which commodities are shipped across the world trading routes; (2) the changing world of the ship owner, particularly as it relates to strategic alliances and the demise of the conference system; (3) the operation of mega-containerships and the need for a port/vessel interface that enables maritime operations to benefit from the various scale economies produced by mega-containership operations; and (4) logistics and global container routes. The following sections detail some of the key findings and make recommendations concerning the focus of the subsequent reports associated with this research project.

WORLD TRADE AND COMMODITY ROUTE DENSITIES

Compelling evidence must be shown that there is a sufficient demand for containers on the particular routes served by the specific ports, because of the magnitude of the investment required for mega-containership operations from both the ship owner and the port operator. Another report from this project will therefore concentrate on examining current world trade levels and on identifying critical route densities over which mega-containership operations may be profitable. A United Nations document clearly identifies a process by which maritime forecasting could be utilized in such an activity *(69)*. This process, shown in Figure 7.1, begins with the routes and cargo classes that have been identified as being essential elements of this project.

The analysis of traffic records can identify seasonal impacts and provide data suitable for a variety of forecasting techniques that can predict future traffic levels, a critical element of mega-containership operations. When these future traffic levels are identified, it is then possible to look at the shipping technologies—which would include mega-containership operations—in order to see the impact of the different ranges of ship sizes and, therefore, costs on these cargo movements. Depending on the different combinations of liner schedules, vessel types, and alliance pricing policies, a variety of scenarios can be developed to test the range of cargo movements in the port area. All enterprises, especially those in the shipping port industry, attempt to develop forecasting procedures and strategies for investments in ships and port infrastructure that are based on the results of these analyses. This research project intends to undertake some form of trade analysis and trade forecasting, although it is recognized that the data needed are usually expensive to purchase and that their availability will depend on the cooperation of other entities and agencies.

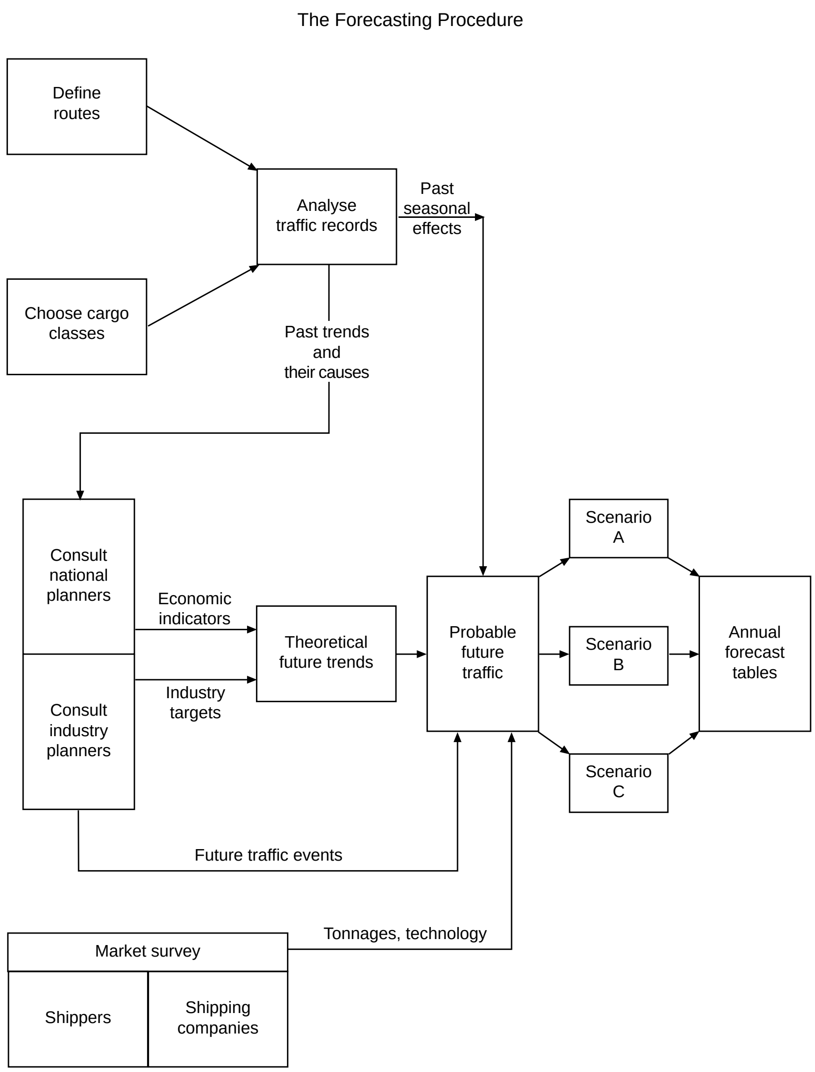

Figure 7.1. The forecasting procedure *(69)*

PORT PLANNING

The literature also indicates that all ports undertake some form of planning process, particularly when substantial investment programs are needed to develop new infrastructure. Figure 7.2 shows a generic port planning process (using the stages defined in Table 7.1). The process consists of two basic stages *(69*). The first stage consists of developing a first-stage analysis of the particular condition being examined. This condition could include expansion of existing conventional container operations, the development of break bulk facilities, widening a shipping channel, purchasing navigational equipment, and providing mega-containership operations. The first stage is an essential screening process that attempts to ensure that the basic case for the condition is sound. Once accomplished, this stage can then be followed by a more detailed and costly process that begins with more substantial evaluation of costs, labor impacts, operational issues, environmental considerations, engineering strategies, and sequencing of investment elements so that a draft proposal for both local and federal approval can be reached. In some cases, the issues evaluated must be configured in other, more complex ways to pass scrutiny if the proposal is to be funded by a bond issuance. The researchers intend to evaluate those port-planning documents in the public domain that relate to Gulf operations to identify key characteristics that could be part of the load center evaluation process to be developed in this project.

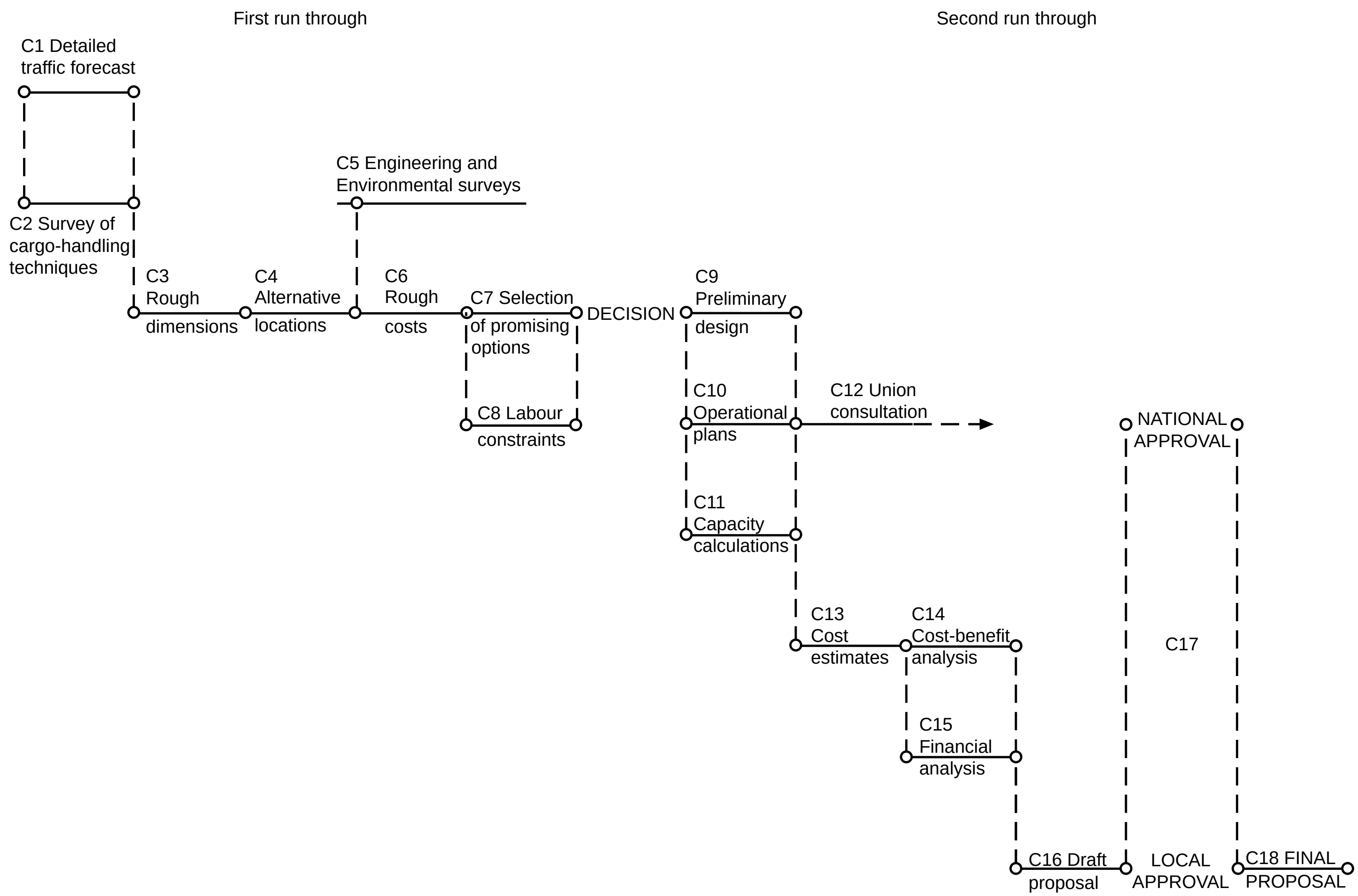

Figure 7.2. The port planning sequence (69)

Table 7.1. Procedure for port project planning

Task C1. Detailed traffic forecast Revise master plan forecast and detailed figures for the economic life of the investment proposed. Task C2. Survey of cargo-handling techniques For each class of traffic that has been forecast, examine alternative port-handling techniques and their impact on future productivity. Task C3. Rough dimensions Group traffic classes with similar handling characteristics and, for each berth group or terminal, find approximate level of additional facilities needed and make rough estimate of their dimensions. Task C4. Alternative locations For berth groups and terminals concerned, propose alternative water and land areas in locations that will not interfere with traffic in adjoining zones and that will provide safe berthing. Task C5. Engineering surveys For each location, carry out engineering studies to quantify the main work required and adjust site locations as necessary to avoid excessive costs. Although engineering surveys should be carried out after Task C4 and before Task C6, in practice they may need to continue the whole period, providing more accurate results as the survey proceeds. Environmental surveys are also undertaken and feedback to Engineering. Task C6. Rough costs Estimate cost of constructing and equipping each facility under consideration. Task C7. Selection of promising options Eliminate less attractive alternative solutions, discuss conclusions with decision authority, and obtain agreement on a short list of alternatives to be further studied. Task C8. Labor constraints Consider labor questions and manning problems that may arise with respect to each alternative technology in parallel with Task C7.	Task C9. Preliminary design For each alternative retained, design layout of all facilities in sufficient detail to discover access, operating, or storage problems. Task C10. Operational planning Prepare plans showing equipment and operation of new facilities and productivity targets. Task C11. Capacity calculations Calculate alternative levels of facilities needed to accommodate feasible range of capacities and services. Task C12. Union consultation Initiate consultation with trade unions on proposed cargo-handling techniques. Task C13. Cost estimates Refine cost estimates for all works, equipment, and services to produce basis for economic and financial analysis. Task C14. Cost-benefit analysis Analyze economic case for each alternative. Task C15. Financial analysis Analyze financial viability of each option and review available methods of achieving sound financing. Task C16. Draft proposal Consolidate all analyses and compare advantages and disadvantages of each option in a draft report. Task C17. National and local approval Discuss draft report with local and national authorities and obtain agreement on recommended solution. Task C18. Final proposal Formalize agreed solutions in a report with supporting analyses.

Source: *(69)*

CHANNEL CHARACTERISTICS

For port operations in the Gulf, large ships pose additional financial costs over and above those related to berth, storage, and landside access issues. The Post-Panamax ships, particularly those defined as mega-containerships, require a draft of between 45 and 50 feet. As part of the planning process identified in Figure 7.2, a channel design process needs to be undertaken. A generic channel design process, shown in Figure 7.3, captures most of the key elements to be included. The process starts with the channel dimensions and alignment relating to the size of the ship being proposed. Also to be considered are the environmental issues and constraints that may form critical elements in the preliminary design stage. The preliminary design develops a simulation study relating to width, depth, and alignment and, in some cases, develops a physical model. Typically, there follows a real-time simulation study of the channel in order to develop the final waterway design. Inherent in the process is the estimation of cost required to place the waterway design into operation. As indicated in the previous section, it is expected that channel considerations will exert an impact on the development of any load center in the Gulf; accordingly, channel considerations will be a critical feature of this research project.

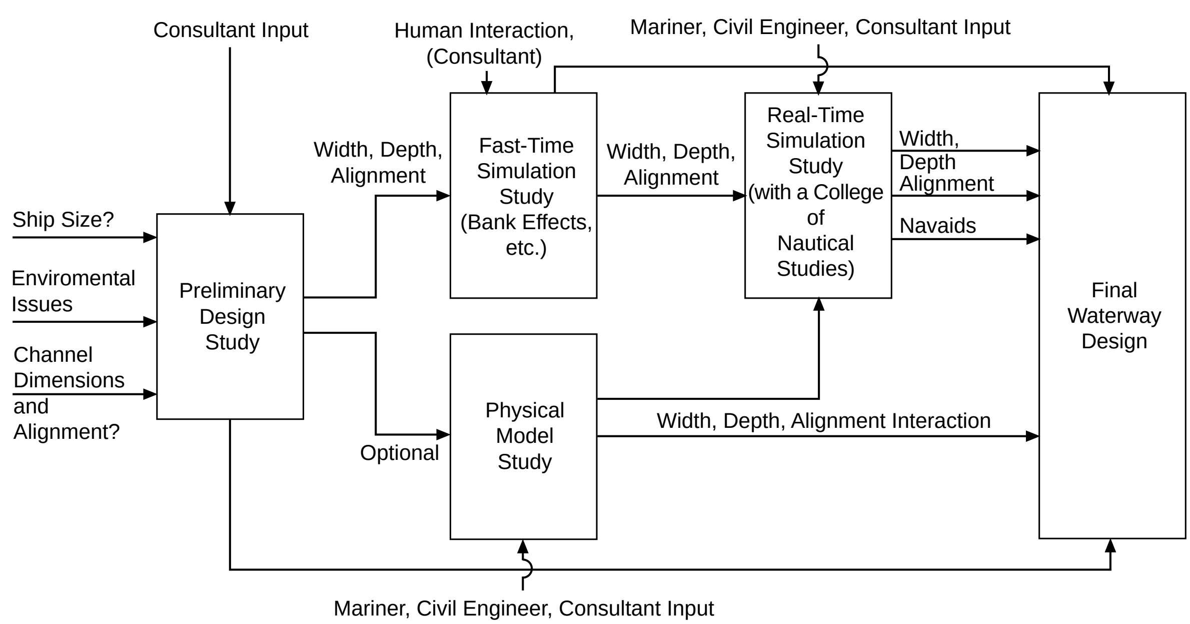

Figure 7.3. Generic channel design process *(14)*

CONTAINERPORT OPERATIONS

The port can be viewed as a system that serves a variety of scheduled vessels of different sizes and types that carry a variety of cargoes. Containers require special treatment, particularly given their different rates of movement between the various modes. Large ships must be serviced and unloaded as quickly as possible, causing large storage areas to rapidly fill to capacity. These storage areas then must be managed in such a way that by an interaction of labor, equipment, and modes, the containers are moved in an efficient and effective manner to their eventual destinations. The complexity of container terminal planning is a result not only of the interaction of the various components of terminal operations, but also of institutional factors like federal and state laws that impact terminal operations *(69).* Again, the research team will investigate planning documents associated with container operations in the Gulf to identify the key characteristics that indicate the potential for developing both a load center for mega-containership operations and an evaluation process for incorporating containerports into statewide transportation planning.

GLOBAL LOGISTICS

Marine containerports, whether large or small, are one link in the container-moving global transportation system. Containers travel long distances; those that move partly by sea do so through a variety of modes and intermodal terminals. It is the interaction of the full range of modes and terminals that gives rise to the ultimate efficiency and cost associated with the provision of that service. Because maritime operations are but one part (perhaps the major part) of the container transportation system, it is therefore important to develop an evaluation process that recognizes the importance of ships as well as their ports of call. In recent years, the growth of logistics management has focused on a full-system analysis—an analysis termed *supply chain management.* The results of effective management are a reduction in overall cost and risk, together with long-term benefits derived through committed relationships *(70).*

The issues of port infrastructure and land access, both critical elements of a state transportation plan, focus on the supply side of the economic equation of supply and demand. Logistics takes these issues into account when used to determine the best routes for containerized trade; both supply and demand work together to establish the success of any marine container terminal.

IMPLICATIONS FOR RESEARCH PROJECT REPORTS

Project 0-1833 was initially undertaken because TxDOT staff wished to evaluate the impacts of very large containerships in the Gulf, especially problems with landside connections to the port chosen to service these vessels. The belief was largely based on three factors:

1. International demand for container movements was forecast to remain strong, at nearly double-digit annual growth through 2010, while that of container traffic in the Gulf was predicted at even higher rates *(24)*.

2. The number of ships calling on U.S. ports was thought likely to decrease, but the use of larger and more automated containerships would increase the amount of cargo handled per ship. Earlier studies reported that a small number of east, west, and Gulf Coast seaports would dominate the U.S. container business and thus gain "mega-containerport" load center status *(48)*.

3. The likelihood of a load center in the Gulf, possibly located in Texas, was significant for TxDOT planners, particularly those working on the revised statewide transportation plan. Load centers were known to create substantial volumes of traffic on the land side, and the ability to identify which site was the prime candidate for such a center would be an important evaluation tool for TxDOT's planning process.

In the first year of this project, based in part on these factors, the prime focus was the selection of a mega-containership load center site in Texas and the identification of associated landside access issues that would need to be addressed by both the local authorities (e.g., an MPO) and TxDOT. The literature survey reported in this document presented information that necessitated a new focus. The main categories of the findings are as follows:

1. Literature on ship design, port operations, and network analysis allows researchers to quantify many of the broad effects associated with a substantially changed world maritime industry and the growth in logistics and freight traffic operations.

2. Shipping companies have undergone changes in recent years, including a dramatic change in a key market segment (Asia), changes in the regulatory nature of the industry (1998 OSRA), and a number of alliances, takeovers, and mergers that have concentrated power in fewer companies. Many of these companies have ordered larger ships, but there are currently fewer mega-containerships on order than had been predicted in the mid- to late-1990s, and their usage is currently restricted to high-density routes that are few in number. Larger ships have economies of scale when at sea since cost per TEU transported declines as the ship size increases. Once in port, the same vessels display cost diseconomies—the cost per TEU rises as the ship size increases. In order to control the total costs of operating a large containership, each operator tries to shorten the time in port and maximize the time at sea *(71)*. This relatively straightforward (and obvious) economic response also results in fewer ports being included in the routing of these ships. At present, no mega-containerships are routed on the North Atlantic-U.S. East Coast and Gulf network.

3. Economies of containership size, combined with the costs of the ships in port, have driven carriers to adopt different network structures. However, the use of large containerships is predicated on the amount of containers waiting at each port, and the volumes across the North Atlantic do not seem sufficiently large at this time to warrant the regular operation of these ships. Also, it does not seem likely that a small number of East and Gulf Coast seaports will attain the status of load centers in the planning horizon used by TxDOT. Already, the numbers of U.S. Atlantic and Gulf ports handling significant numbers of containers are small. Four ports—New York/New Jersey, Hampton Roads, Charleston, and Jacksonville—handle around two-thirds of the total containers coming into the U.S. Atlantic and Gulf port system. The Port of New York/New Jersey, currently handling over four million TEUs per year, is clearly a load center, and there appear to be no other strong candidates at this time. The volumes in the Gulf are substantially below those volumes normally associated with mega-containership operations among world ports, markets, and networks.

4. While at this time it seems unlikely that mega-containerships will be placed into regular service in the Gulf of Mexico, more work should be undertaken to examine container demand, trends in the industry, and the growth of key alliances. The literature revealed that potential load centers at both Freeport (Bahamas) and Panama City (Panama) are being seriously evaluated by the

industry. This makes sense given the density of routes in the Caribbean area, including those going through the Panama Canal. In order to examine different routes and load center sites, the literature review strongly suggests a closer examination of shipping costs, port operations, and demand for a variety of commodities. Such an examination should be done in the context of a supply chain analysis that recognizes the long links in the international trade transportation flow between origin and destination.

5. The literature review suggests that TxDOT should not simply be interested in the selection of a load center in the Gulf of Mexico. Rather, results of the research project should provide TxDOT with a mega-containership load center selection matrix and a containerport evaluation process to be used for statewide planning purposes. When larger ships are allocated onto routes that affect Gulf flows, there may be a series of new hub-and-spoke services from the mega-containership load center that may offer new opportunities for a variety of Texas ports and not just those currently handling containers. Therefore, a system evaluation should be undertaken which captures much of the supply chain now being used by shippers and logistics companies.

6. The literature discloses a highly dynamic maritime sector. It is likely that routes, schedules, and port selection will be under constant review as companies seek higher margins and a better return on investment. The best way to assist TxDOT in its planning during this dynamic phase would be to develop generic processes and models that can be recalibrated as conditions change.

These findings were made known to the Project Monitoring Committee when the first draft of this document was completed in mid-1999. Subsequently, the Committee and the Project Director agreed to expand the scope of the research project to include both a mega-containership selection process and a containerport evaluation process.

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APPENDIX A

ANNOTATED BIBLIOGRAPHY

ANNOTATED BIBLIOGRAPHY

Alderton, P. M., *The Quantification of Port Time*, London, City of London Polytechnic, 1987.

This discussion paper forms one of a series of papers produced through the Transport Studies Workshop of the (then) City of London Polytechnic, and examines the problems of producing a general model that will generate reasonable estimates for all ships going to all ports.

Anderson, K. M., and **C. M. Walton**, "Evaluating Intermodal Freight Terminals: A Framework for Government Participation," Center For Transportation Research, August 1998.

Valuable information concerning both intermodal networks and ports throughout the U.S. A method for rating the intermodal freight terminals as candidates for government funded access improvements is proposed in this report. It also presents an overview of the intermodal freight transportation industry. Government intermodal freight planning and participation, including examples of government-sponsored intermodal projects, are presented. An intermodal freight planning procedure is then proposed. A terminal capacity analysis is performed as required for a terminal prioritization process. Finally, three prioritization strategies are proposed and illustrated using data collected from Texas. The system is designed to rank priority by facility for a given network, utilizing facility operational and physical attributes.

Ansary, H. J., "North American Ports and the Internationalization of World Market," *Intermodal Freight Terminal of the Future, Transportation Research Circular No. 459*, Washington D.C., Transportation Research Board, July 1996.

A discussion of information regarding ports in Canada, as well as the breakdown of container traffic by percentage within North America by region in 1993. The impacts on ports and the competition between ports as they try to provide increasing service are considered, indicating that ports need (1) to be flexible in responding to changing conditions, (2) to take a proactive approach to marketing, and (3) to focus on the needs of shippers and carriers. It is a well-written article.

Bennathan, E., and **A. A. Walters**, "Shipping Conferences: An Economic Analysis," *Journal of Maritime Law and Commerce 4(l),* Jefferson Law Book Company, 2100 Huntingdon Avenue, Baltimore, Maryland, October 1972.

An examination of the likelihood of rationalization in shipping conferences, combining the legal elements of the conference system with an economic analysis using an array of micro-economic techniques, including marginal cost pricing.

Bennathan, E., and **A. A Walters**, *Port Pricing and Investment Policy for Developing Countries,* Oxford University Press for the World Bank, Washington, D.C., 1979.

An analysis of pricing policies for port services and the use of prices to control the distribution of benefits; it recommends pricing and investment policies designed to increase the economic wellbeing of developing countries. By offering the first sustained application of the principles of economics to the pricing policies of ports, the authors promote the concept of cost-based port tariffs and marginal cost-based congestion fees.

Beth, H. L. (ed.), *Liner Shipping in the Eighties: Report on the International Symposium held at Bremen, October 24th–26th*, 1979, Bremen, Institute of Shipping Economics, 1980.

A collection of papers presented at the International Symposium held at Bremen, October 24–26, 1979, on worldwide shipping policies and problems and liner shipping. Opening statements set the scene for developments of liner shipping and impact of economic developments. Discussions led by chairmen follow each paper.

Beth, H. L., and **B. Volk**, *Shipping Markets in 1980 and Seaborne Trade Forecasts,* Bremen, Institute of Shipping Economics, 1981.

Part of a series looking at world shipping. The development of the demand side of the shipping market and its interrelation with economic development in general is considered.

Bess, H. D., and **M. T**. **Farris**, *U.S. Maritime Policy: History and Prospects,* New York, Praeger Publishers, 1981.

A discussion of maritime transportation, the history of maritime policy, and early policy decisions and events at the beginning of the 20th Century. Also included are analyses of the Merchant Marine Act 1936, maritime policy in the 1970s and technological changes, pricing problems, antitrust, and the Federal Maritime Commission.

Bird, J. H., "Seaport Development: Some Questions of Scale," In: B. S. Hoyle and D. Hilling (eds.) *Seaport Systems and Spatial Change: Technology, Industry and Development Strategies*, Chichester and New York (et al.), John Wiley & Sons, 1984.

Contains information concerning developmental complications of seaports, the development of seaport studies, problems of seaports on spatial and temporal scales, problems faced by organizations in connection with the future development of seaports, and seaports in the future.

Blackburn, J., "Texas Coastal Activism and Litigation," Galveston Bay Conservation and Preservation Association, October 20, 1998.

Presented are environmental issues associated with development along the Texas Gulf Coast. Several of these concerns regarded the expansion of the Port of Houston, Galveston, Bayport, and Corpus Christi.

Branch, A. E., *Dictionary of Commercial Terms and Abbreviations,* London, Witherby & Co., 1984.

A dictionary of commercial terms and abbreviations covering the entire spectrum of the business sector, embracing terms in accountancy, advertising, banking, commerce, computers, economics, insurance, international trade, law, marketing, personnel management, real estate, selling, statistics, tourism, and transport.

Branch, A. E., *Dictionary of Shipping: International Trade Terms and Abbreviations,* 3rd ed. London, Witherby & Co., 1986.

Presents the correct and effective use of shipping, international trade terms, and abbreviations. The third edition covers international marketing, international banking, cargo handling, shipping, ports, documentation, chartering, and terms found in Far Eastern markets. Also included is information on international trade and shipping organizations, world currencies, and ports.

Branch, A. E., *Elements of Shipping, 6th ed.*, London and New York, Chapman and Hall, 1989.

Contains elements of the shipping industry, including chartering, ship types, types of cargo and their stowage in cargo-handling equipment, international organizations, processing export consignment, containerization, ship operation, and crewing. Also included are economic, operating, commercial, political and technical aspects. Bibliographical references are included.

Branch, A. E., *Elements of Shipping, 6th ed.*, London and New York, Chapman and Hall, 1989.

Covers the elements of shipping, including the ship, ship design and construction, cargo, required manpower for operating a ship, liner conferences, bills of lading, containerization, shipping companies, and passenger fares and freight fares. Included are bibliographical references.

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A Greek-English/English-Greek translation for those who use/operate cargo ships, both tramp and liner. Areas covered include voyage/time charters, documentation including bills of lading, ship types and their gear, ports and equipment and facilities, cargo and packing, and geographical and weather features.

Brodie, P. R., *Illustrated Dictionary of Cargo Handling*, London, Lloyd's of London Press, 1991.

Focuses on the visual aspects of cargo handling and shipping. Included are definitions, descriptions, and illustrations of the many forms of cargo-handling equipment, vessel types, technical sections of merchant ships, containers, ports and facilities, and equipment.

Brooks, M., "Issues in North American Container Port Competitiveness," *Journal of the Transportation Research Forum, Vol. 32, No. 2*, Reston, Virginia, 1992.

Identifies and addresses a range of issues that will impact port usage in the 1990s. The issues are grouped into four sections: port operating differences, inequalities in industrial support for ports, rail regulatory differences, and fiscal differences. A number of research deficiencies are identified and a research agenda prepared for Canadian ports.

Bross, S. R., *Ocean Shipping,* Cambridge (Maryland), Cornell Maritime Press, 1956.

Provides a general overview of ocean shipping. The publication is practical guide to the various problems involved in the carriage of goods by water, including impact of improvements in design and operating efficiency of ships, trade routes, marine insurance, claims, accounting, international relations, and military sea transportation service.

Buckley, J. J., and **L. C. Kendall**, *The Business of Shipping, 6th ed.*, Centreville, Maryland, Cornell Maritime Press, 1994.

The text covers almost all aspects of ocean shipping, including information about liner services and tramp shipping, terminal operations and management, labor issues, conferences, and freight economic issues. The beginning of containerized shipping is covered, and a glossary of terms is included. It is very well written and useful.

Buxton, I. L., A. Zachariades, and **T. E. Svensen**, *Ship Speed and Economics,* Newcastle, School of Marine Technology, University of Newcastle upon Tyne, United Kingdom, 1983.

Presented are notes from a short-course held during January 11 through 13, 1983, including fleets and freight market, ship types and machinery, calculating optimal speed, economic factors affecting optimal speed, technical and other factors affecting optimal speed, estimating optimal speed, speed and performance in service, and liners and new ships.

Calvert, J., and **J. McConville**, *The Shipping Industry Statistical Sources*, London, City of London Polytechnic, 1983.

Provides access to the wealth of statistical information available on the shipping industry. The major areas of the shipping industry are covered. Subject headings are subdivided into books, journals, and annuals. Each entry gives publication details and lists of statistics contained therein.

Casson, M., *The Quality of Shipping Services: An Economic Appraisal of Strategies for the European Liner Shipping Industry*, Reading, University of Reading, Department of Economics, Whiteknights, Reading, Berkshire, United Kingdom, 1986.

Presents the impact of threats to European shipping firms from new sources of foreign competition, the valuation of quality in the market for shipping services, and impacts of the "quality revolution" on the shipping industry. Production quality is distinguished from transaction quality. An efficient supply of production quality and dealing with "system effects" is discussed.

Cargo Systems International, *Containerisation into the 1980's: The Market for Specials,* Worcester Park, Surrey: Cargo Systems, Research/Consultancy Division, 1980.

The historical development of the world container fleet and accompanying world container production volumes is charted, with particular reference to the evolving requirement for special containers—refrigerated/insulated units, tank containers, open tops and other special containers, as well as dry freight units in the medium-term period to 1985.

Chadwin, M. L., **J. A. Pope**, and **W. K. Talley**, *Ocean Container Transportation: An Operational Perspective*, Taylor & Francis, New York, 1990.

Discusses the process by which a container is moved throughout a terminal, focusing on optimization and describes in detail the equipment used to maneuver, stack, and transport the containers. Time and motion studies of on-terminal container handling, economic impact studies of port activities, design of a model to allocate the costs associated with container terminal operations, the impact of road and rail infrastructure on the marine terminals are some of the topics covered.

Chadwin, M. L., and **W. K. Talley**, "Vessel and Port Technologies at the Turn of the Century," *Transportation Research Record 1333*, Transportation Research Board, National Academy of Sciences, Washington D.C., 1992.

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 with a wide adoption throughout world ports of techniques currently in place in only the most advanced countries/ports. A range of predictions is made, from a slowing down in containerized traffic, larger ships dominating major trade routes and growth in computer systems moving information between ports.

Chapman, S. E., *A Global Analysis of Ship Ownership and Ship Management*, Colchester, Lloyd's of London Press, 1989.

An industry survey summarizing an analysis of 340 responses to a Lloyd's *Ship Manager and Shipping News International* questionnaire sent to senior executives in the shipping

industry in 1989. Size, location, trades and markets in which ship owning and ship management companies operate are characterized.

Chappel, D., "Provision of Optimal Cargo Handling Facilities at a Berth," *Maritime Policy and Management* 17(2), Taylor & Francis, London, United Kingdom, April–June 1990.

Focuses on optimal cargo-handling rates and considers (a) under what circumstances optimal rate is actually provided, and (b) how optimal rate is affected as regards prebooked time slots at berth, containerized cargoes, and long queues.

Chrzanowski, I. H., *An Introduction to Shipping Economics*, London, Fairplay Publications, 1985.

A concise analysis of all sectors of the shipping industry from their historical perspective, including the influence of freight markets, cost structures, pricing, role of the shipping industry in the national economic context; shipping policy, and gradations from protectionism to liberalism.

Couper, A. D., *The Geography of Sea Transport*, London, Hutchinson & Co., 1972.

Includes discussions of the impact of technological change in sea transport on trade links, shipping routes, and economic activities; the role of sea transport in ancient and medieval worlds and the influence of merchant shipping on British economic growth in the 19th Century; and trends in world ship owning, shipbuilding, and ship types against a background of supply and demand.

Couper, A. D., (ed.), (Series editor: Robert Gardiner), *The Shipping Revolution: The Modern Merchant Ship*, London, Conway Maritime Press, 1992.

The third in Conway's *History of the Ship* series, this volume begins with an overview of world shipping and the shipping revolution against a background of changing operational environment in the period from the 1960s. Included are developments in design and functions of modern ships, how new offshore industries support vessels, shipbuilding, propulsion, navigation, equipment, and ownership of vessels.

Cuny, P. J. (ed.), *Lloyd's Maritime Directory*, Colchester, Essex, Lloyd's of London Press, c1998.

Details are given of over 5,500 ship owners and managers, and 35,000 vessels worldwide based on data held at Lloyd's—the preeminent maritime insurance agency and repository of maritime information. Included is a ship owners/managers section listing countries and companies. Indices are available to allow access by country, company, or vessel. Nearly 400 port authorities throughout the world are listed, together with 4,000 tug and salvage vessels.

Davies, J. E., "An Analysis of Cost and Supply Conditions in the Liner Shipping Industry," *Journal of Industrial Economics* 31(4), Oxford, Blackwell Publishing, England, June 1983.

The nature of costs and supply conditions incurred by companies engaged in the provision of scheduled cargo minor services are examined. The analysis concludes that the liner conference system, despite being over a century old, still has a valuable role to play in the servicing of world trade—a role that is likely to remain for many years to come.

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Methods used to estimate the capacity of a port are questioned. The possible use of operations research techniques for port planning within a framework of conventional economic benefit-cost analysis is discussed.

Dowd, T. J., and **T. M Leschine**, "Container Terminal Productivity: A Perspective," *Maritime Policy and Management* 17(2), London, Taylor & Francis, United Kingdom, April-June 1990.

Problems and prospects of using quantitative measurements for container terminal productivity to estimate or compare productivity of terminals at ports are presented.

Drewry Shipping Consultants, *The Advance of Deep-Sea, Fully Cellular Container Shipping*, London, H. P. Drewry Shipping Consultants, 1978.

Part of a series covering the world's bulk shipping, the development of deep-sea, fully-cellular container shipping, characteristics and deployment of the deep-sea, fully-cellular fleet, and future prospects.

Drewry Shipping Consultants, *Ship Costs: Their Structure and Significance*, London, Drewry Shipping Consultants, 1990.

Part of the *Seaborne Trade and Transport* series covering the world's bulk shipping: the cost of shipping, ship acquisition costs, operating costs, voyage costs, external cost influences, and future prospects.

Drewry Shipping Consultants, *Traffic and Competition Oil Round-the-World Container Routes*, London, Drewry Shipping Consultants, 1986.

Part of a series covering the world's bulk shipping: containerization and conferences, container fleet development, deep-sea liner trades, and the impact of round-the-world services.

El Noshokaty, S. M., *Optimum Ship Selection of Ports, Routes, and Cargoes*, doctoral dissertation, University of Wales Institute of Science and Technology, Cardiff, United Kingdom, 1988.

The problem of ship selection of ports, routes, and cargoes is solved by three mixed 0-1 fractional models. The first model is deterministic, the second is two-stage stochastic, and the third is chance-constrained stochastic. A computer program is developed to solve the mixed 0-1 problem.

Evans, J. J., "The Elasticity of Supply of Sea Transport," *Maritime Policy and Management* 15(4), London, Taylor & Francis, United Kingdom, 1988.

The theory of short-run supply function of tramp shipping is examined, concluding that elasticity of supply is constant at all levels of output from lay-up point to maximum design speed.

Frankel, E. G., *Structural Adjustment and Integration of Ocean Shipping: 2nd Chua Chor Teck Annual Memorial Lecture*, London, Chua Chor Teck Memorial Fund Trustee Committee, 1988.

A memorial lecture given Wednesday, January 13, 1988. The changing conditions in ocean shipping, technological developments, economic impact changes in shipping, structural changes in shipping, future prospects and developments, and the new environment and impact on shipping are reviewed.

Frankel, E. G., *The World Shipping Industry,* London and New York, Croom Helm, 1987.

A review of the expanding role of developing countries in shipping and an evaluation of the contribution of shipping to development, changes in the institutional and environmental framework of shipping, social impact, and challenges, opportunities and problems of the shipping industry.

Garrod, P., and **W. Milklius**, “The Optimal Ship Size: A Comment,” *Journal of Transport Economics and Policy* XIX(l), London School of Economics, University of Bath, January 1985.

Extends the analysis of Jansson and Shneerson, “The optimal ship size,” *Journal of Transport Economics and Policy* XVI (3), September 1982. The focus is on faster loading, unloading rates, greater optimal ship size, and significant effect on users.

Gilman, S., “A Review of Ships’ Costs,” *Maritime Policy and Management* 12(l), London, Taylor & Francis, 1985.

An examination of the methodology, definitions and practices regarding ships’ costs, issues arising from cost relationships, parametric studies, and network costs.

Gilman, S., “The Choice of Ship Size on Deep-Sea General Cargo Routes,” *Maritime Studies and Management* 3(2), Bristol, Scientechnica Ltd., England, October 1975.

Ship size is determined by a set of interactions among handling performance, route length, traffic flow, itinerary, requirements for frequent and regular service, port costs, and general system organization. It identifies major influences and prospects for further growth.

Gilman, S., *Competitive Dynamics of Container Shipping,* Aldershot, Hants, Gower Publishing Company, 1983.

Proceeding from basic analysis of the operating characteristics of container systems through a consideration of market and conference function, to a study of a number of container routes. Covered are economies of scale, logistics, and ship selection on various routes, as well as developments and issues in regulatory policy.

Gilman, S., "Extrapolation and Models in the Prediction of Developments in the Marine Transport Industry," *Maritime Studies and Management* 3(2), Bristol, Scientechnica Ltd., England, October 1975.

An editorial beginning to a journal, suggesting that both statistical and intuitive extrapolation provide a poor basis for prediction of maritime industry development.

Gilman, S., *Ship Choice in the Container Age*, Liverpool, Marine Transport Centre, University of Liverpool, 1980.

An examination of containership costs. Included are: new costs and various components of fuel consumption; flexible ships (basic concept, access, design of cargo spaces, operational performance); transport geography; size, speed and deployment of containerships; and the port sector and handling performance.

Gilman, S., and **G. F. Williams**, "The Economics of Multi-Port Itineraries for Large Container Ships," *Journal of Transport Economics and Policy* X(2), London, London School of Economics, May 1976.

Developments on major European container routes and the effects on new ports and established port hinterlands are examined. The relationships between marine and inland sector costs that have exerted particularly important influence are measured.

Goodwin, E. M., and **J. F. Kemp**, *Marine Statistics: Theory and Practice,* London, Stanford Maritime, 1979.

An introduction to statistical methods for those concerned with ship operations. The development of automatic and semi-automatic equipment and the technological developments creating an increased need for a statistical approach to problems are discussed. Evidence is taken from a numerical record of certain entities and quantifies particular features of the record for use in a management context.

Goss, R. O. (ed.), *Advances in Maritime Economics,* Cambridge, Cambridge University Press, 1977.

Includes eight studies of the different aspects of maritime economics. Emphasis is on the economic efficiency of sea transport systems. Topics include flag discrimination, taxation, ship size/delays and cost effects, economics of congestion, and application of cost-benefit analysis to safety of life at sea. Included are a substantial introduction, and comparison and extension of some of the arguments.

Goss, R. O., "Ships' Costs: A Review Article," *Maritime Policy and Management* 10(2), London, Taylor & Francis, April–June 1983.

A review of available cost data on ships' capital and operating costs, suggesting that there is a need for agreement on methods and sources of raw data to be used, and reviews progress in this area.

Goss, R. O., and others, *The Cost of Ships' Time,* London, Her Majesty's Stationery Office, 1974.

Presents a method of evaluating the cost of ships' time that could be used to evaluate predictable delays or time savings to ships. Methods, results, and delays to cargo and containers are discussed.

Graham, M. G., and **D. O. Hughes**, *Containerization in the Eighties,* London, Lloyd's of London Press, 1985.

An historical account of the industry since the advent of containerization, including problems affecting the future, recent developments in 1980s, what is important to container services, and the future impact of UN Liner Code and UN Multimodal Convention.

Gubbins, E. J., *The Shipping Industry: The Technology and Economics of Specialization* (Volume 5 in Transportation Studies Series), London, Gordon and Breach Science Publishers, 1986.

A comprehensive introduction to the shipping industry, showing how technological advances in shipping design have led to improved efficiency and transportation of more sophisticated cargoes, promoting international trade. Included is an analysis of the complex interplay between technological developments, economic pressures, and political focus.

Gwilliam, K. M., *Current Issues in Maritime Economics,* Dordrecht, Kluwer Academic Publishers, The Netherlands, 1993.

A selection of 11 papers presented at an international conference in Rotterdam in June 1991. The papers address three major areas of interest: (1) the changing international context; (2) the relationship between market structure and the workability of competition; and (3) decision processes of firms in the shipping world.

Gwilliam, K. M., "Maritime Economics in Transition," in K. M. Gwilliam (ed.), *Current Issues in Maritime Economics,* Dordrecht, Kluwer Academic Publishers, The Netherlands, 1993.

An editorial introduction to a collection of papers from a conference at Erasmus University in Rotterdam, June 1991, for the retirement of Professor H. J. Molenaar. The introductory paper juxtaposes the issues as identified by Molenaar in his valedictory observations and the opinions on them offered by the conference contributors.

Hattori, K., *Tonnage Demand: Supply Trends and Outlook of Scrapped Tonnage,* Tokyo, Japan Maritime Research Institute, 1984.

Outlined are trends at the time of tonnage demand and supply and the scrapping situation in that connection, to be followed by attempts to predict future tendencies in long-term perspective.

Heaver, T. D., "The Treatment of Ships' Operating Costs," *Maritime Policy and Management* 12(l), London, Taylor & Francis, 1985.

Growth of world trade has seen a great increase in specialization of ships by type and size. Effects of this development have been diverse and fundamental.

Holguin-Veras, J., and **C. M. Walton**, "On the Application of Combined Models: A Case Study on the Simulation of Container Operations," *Journal of the Transportation Research Forum, Vol. 37, No. 1,* Reston, Virginia, 1998.

Two different simulations of service times for the loading and unloading of containers are analyzed. The first approach, termed combined, expresses service times as a function of two components: systematic and random. The second approach relies on empirical service time distributions to simulate service times. Results indicate that the combined model, though requiring a lengthier estimation process and more input data, provided a more accurate depiction of service times.

Holloway, R., "The Problem of the Ports," *Lloyds Bank Review* 99, London, January 1971.

This article suggests that the sense of crisis in the port industry and in labor is due to the scope and speed of technological change. The ports have to cope with three technological revolutions at once: (1) port-cargo handling; (2) ship size; and (3) the competition for other means of transport.

Hoyle, B. S., and **D. Hilling** (eds.), *Seaport Systems and Spatial Change: Technology, Industry and Development Strategies,* Chichester and New York (et al.), John Wiley & Sons, 1984.

A collection of papers concerned with the dynamic relationships between seaport systems and the process of spatial change, with special reference to the technologies, industrial development patterns, and regional planning strategies that affect these relationships.

Hughes, C. N., *Shipping: A Techno-Economic Approach*, London, Lloyd's of London Press, 1989.

Considered are purely technical as well as commercial viewpoints of decision-making in shipping. Issues covered include shipbuilding considerations and ship types—bulkers, passenger vessels, oil and chemical tankers, and gas carriers; main propulsion systems; auxiliary power generation; registry, manning, and classification; operational technoeconomics, and onboard systems.

Imakita, J., *A Techno-Economic Analysis of the Port Transport System,* Farnborough, Hants, Saxon House, 1978.

A comprehensive analysis of the technical operations of seaports. Covered are the main operations of a port, including ship guidance into berthing areas, cargo handling, warehousing, and inland transport links, followed by the resulting aggregate system used to find optimum patterns for rates of operation, employment of labor, equipment, and investment strategies.

Institute of Civil Engineers Conference Proceedings, *Port Engineering and Operation,* Thomas Telford, London, 1985.

Included are several papers with a focus on ship size and port issues. The themes cover developments in ship design, the practice and philosophy of port operation, and port planning and design.

James, A. P., J. M. Howard, Jr., J. P. Basilloto, and **H. Harbottle**, *Megaports and Load Centers of the Future with the Port of Houston as the Baseline Port,* Texas Transportation Institute, SWUTC/98/467404-1, Texas A&M University System, College Station, Texas, September 1997.

A discussion of improvements in the containership industry, including the introduction of megaships, and the impacts and needs of the current port infrastructure. The Port of Houston is used as a base port and covers the needs of ports servicing larger vessels, such as the need for faster turnaround within a containerport and more efficient container handling. Argued is the issue that ports that do not meet the needs of the larger ships will turn toward servicing market niches that feed the megaports.

Jansson, J. O., and **D. Shneerson**, "The Effect of Capacity Costs and Demand Elasticities on the Structure of Liner Freight Rates," *Logistics and Transportation Review* 22(l), Berkeley, California, Vancouver, Faculty of Commerce and Business Administration, University of British Columbia, March 1986.

Jansson, J. O., and **D. Shneerson**, "The Optimal Ship Size," *Journal of Transport Economics and Policy* XVI(3), London, London School of Economics, September 1982.

Presents a model for determining the optimal size of a ship to minimize total costs (at sea and in port) per ton of cargo. The model shows how optimal size varies as a result of changes in route characteristics and factor prices.

Jansson, J. O., and **D. Shneerson**, *Port Economics,* Cambridge (Massachusetts) and London, MIT Press, 1982.

Economic principles to salient issues of seaports are applied. The historical development of port organization is covered, including technology; production measures, short- and long-term cost functions, pricing, and investment. Also included is empirical testing of theory against port data.

Kendall, P. M. H., "A Theory of Optimum Ship Size," *Journal of Transport Economics and Policy* VI (2), London, London School of Economics, May 1972.

A discussion of the optimum ship size theory developed, macroeconomics of some aspects of shipping practices for dry bulk cargo, and the conceptual development of a model for optimum ship size, along with its applicability.

Kraman, M. A. (ed.), *PORTS '98*, American Society of Civil Engineers, Virginia, 1998.

Paper topics are varied and include such subjects as international terminals, port planning, terminal planning, container terminals, marine terminals, intermodal links, innovative project delivery, geotechnical engineering and foundations, port seismic guidelines, waterfront structures, cranes and shiploading systems, pile inspection and maintenance, transportation links, marine fendering, small craft harbors and recreational piers, composite technology, vessel moorings, environmental issues, ferry terminals, coastal engineering, dredging, breakwaters, military facilities, navigation, and waterways and locks.

Lambert, M., (ed.), *Containerisation International Year Book*, London, National Magazine Company, England.

A guide to port facilities, terminals, and container traffic statistics. The directory contains a register of over 4,800 container-carrying vessels.

Lopez, N. J., *Best Chartering and Shipping Terms*, 11th rev. ed., London, Barker & Howard, 1992.

A classic reference and a practical guide for shipping professionals, including changing circumstances in the shipping industry, consideration of bills of lading legislation, sea waybills, calculation of laytime with new decision, INCOTERMS 1990, intermodalism and electronic data interchange.

Lyndon B. Johnson School of Public Affairs, *The Texas Seaport and Inland Waterway System*, The University of Texas at Austin, Policy Research Project Report 114, 1995.

Information is provided regarding the waterways in Texas, including the Gulf Intracoastal Waterway, the Mexican seaport and inland waterway system, the railway system access and highway landside access to Texas ports, and legislative action affecting Texas ports. Profiles of all Texas ports are included.

Lyndon B. Johnson School of Public Affairs, *Port-Related State Programs and Federal Legislative Issues*, The University of Texas at Austin, Policy Research Project Report 117, 1996.

Covers the state's involvement in ports and waterways, and includes individual state profiles of many states. Also included is information on the current debate (as of 1995) regarding the Ocean Shipping Reform Act, and a discussion of the Jones Act and the Harbor Maintenance Trust Fund.

Lyndon B. Johnson School of Public Affairs, *Multimodal/Intermodal Transportation in the United States, Western Europe, and Latin America: Governmental Policies, Plans, and Programs*, The University of Texas at Austin, Policy Research Project Report 130, 1998.

The changing global economy and trade, the U.S. public sector involvement in transportation, and the intermodal programs of several states and countries (i.e., Minnesota, Oregon, Florida, Pennsylvania, Virginia, Washington, Wisconsin, France, Germany, the United Kingdom, Argentina, Brazil and Mexico) are covered. Trade issues relating to MERCOSUR, NAFTA, and the European Union are included.

Marti, B. E., "Shift-Share Analysis and Port Geography: A New England Example," *Maritime Policy and Management* 9(4), London, Taylor & Francis, 1982.

Demonstrates the validity of relative shift technique in aiding port geographer/planners in decision making. New England's port facilities are examined, applying the technique to Boston's port.

Marx, D., *International Shipping Cartels: A Study of Industrial Self-Regulation by Shipping Conferences*, Princeton, Princeton University Press, 1953

The origins and fundamental economic constraints faced by shippers are discussed. The age of the text limits its applicability to modern business practices. However, valuable background information on the development and perceived necessity for international trade agreements is well presented. Conference operations and agreements and information about tramp-liner competition and rationalization are covered.

Miller, E. W., and **R. M. Miller**, *Transportation-Water: Waterways, Shipping and Ports, A Bibliography,* U.S.A., Vance Bibliographies, 1987.

Provides 500 references including articles, government documents, and other publications. Shipping is discussed as it relates to operations, economic aspects, regulations, and docks. Also discussed are commodities transported by water (e.g., coal, petroleum, minerals, grain) and ports located in major geographical areas of the U.S.

Muller, G., *Intermodal Freight Transportation* (4th ed.), Eno Transportation Foundation, Inc., Washington D.C., 1999.

This superb book is a must for anyone wishing to gain a complete picture of the current intermodal freight market—both domestic and international—and its growth in the 1990s. Chapters focus on defining intermodal transportation, its development in the U.S., the container revolution, government deregulation, various modes, the military issues, documentation, intermodal freight facilitation, terminals, containers, information technology, and competition. The book also contains useful appendices on national freight policy and intermodality in the European Union.

Murphy, P. R., J. M. Daley, and **D. R. Dalenburg**, “Port Selection Criteria: An Application of a Transportation Research Framework,” *Logistics and Transportation Review* 28(3), Berkeley, California, Vancouver, Faculty of Commerce and Business Administration, University of British Columbia, September 1992.

This paper develops a framework for classifying existing transportation choice research by using two dimensions: the decision(s) being researched and the respondent’s role(s) in the decision process. Following a discussion of this framework, the paper then presents the results of an empirical study involving a single decision (international water port selection) evaluated by multiple participants (larger and smaller shippers, international water carriers, international water ports, international freight forwarders) in global trade. Both univariate and multivariate analyses indicate that port selection factors are evaluated differently by various participants in international commerce. The paper concludes by discussing possible implications of these divergent views.

Nagatsuka, S., *Trends of the World Shipping and Shipbuilding in 1991 and Prospects for the Same in the Near Future*, Tokyo, Japan Maritime Research Institute, 1992.

Part of a series related to maritime affairs, the report covers trends and future prospects of major industries demanding shipping services, trends and prospects of shipping and shipbuilding, and trends in Japanese shipping and shipbuilding. The previous titles are updated.

Nersesian, R. L., *Ships and Shipping: A Comprehensive Guide,* Tulsa, Pennwell Publishing Company, Oklahoma, 1981.

A view is given of all facets of the shipping industry with the aim of exploring all areas of shipping rather than narrow specialties. An entire commercial transaction is covered step by step, from inception to signing the contract, and a solid background of the shipping business is presented.

Nettle, S., *Port Operations and Shipping: A Guide to Ports and Related Aspects of the Shipping Industry,* London, Lloyd's of London Press, 1988.

The basic principles of both the ports and the shipping industry are explained, emphasizing the interrelationship of the two industries and their importance to national economies, as well as their vulnerability to changes in world economic and political patterns.

Organisation for Economic Cooperation and Development (OECD), *Maritime Transport,* Paris, OECD, 1990.

An annual report, this publication provides comprehensive coverage of international developments in maritime transport, with particular reference to national shipping policies and longer-term trends in international shipping and trade. A statistical annex of up-to-date data on sea-borne trade, the movement of bulk commodities, world fleet, and freight markets is included.

Oum, T. H., **"**Derived Demand for Freight Transport and Intermodal Competition in Canada," *Journal of Transport Economics and Policy* XIII(2), London, London School of Economics, May 1979.

A demand model is formulated for intercity freight transport as intermediate input to production and distribution sectors of economy, estimating price elasticities, elasticities of substitution between, *inter alia*, waterway freight transport, excluding ocean shipping.

Packard, W. V., *Sea Trading, Vol. 1: The Ships*, London, Fairplay Publications, 1984.

A description of the shipping industry including a detailed account of the vessels used in all modern sea trading, their terminology, designs and operational constraints, speed consumption and operation loadlines, drafts and deadweights, machinery, capacities, classification, flag registration.

Payer, H. G., *Ocean Megaships and RoRo Feeders: Containerships of the Future*, New York, Maritime Activity Reports, Inc., June 1997.

This study was part of a research project entitled, "Container Transport Systems of the Future '94," sponsored by the German Federal Ministry of Education, Science, Research and Technology. For each of 40 basic ship designs between 5,000 and 8,000 TEUs, the team examined nine round trip alternatives, a total of 360 combinations. Each was analyzed with respect to the cost of sea transport as a function of total distance, number of ports visited, ship size, and ship speed. The optimal ship design, powered by a 68 MW diesel engine, was one with around an 8,000-TEU capacity and a 24-knot speed.

Pearson, R., *Container Ships and Shipping*, London, Fairplay Publications, 1988.

Covers a mixture of the commercial and technical aspects of the shipping industry, adopting a traditional structure and consisting of a broad tripartite discussion of the basic elements of demand, supply, and disequilibrium. Methodological techniques that can be applied in containerization are illustrated, and case studies are given to show the symbiotic relationship between commercial and technical aspects.

Pearson, R., and **J. Fossey**, *World Deep-Sea Container Shipping: A Geographical, Economic and Statistical Analysis,* Aldershot, Hants, Gower Publishing Co., England, 1983.

Changes in deep-sea container shipping are described. A statistical commentary, it discusses container transport geography; containerline operating economics, and structure of container-carrying fleets.

Perakis, A. N., "A Second Look at Fleet Development," *Maritime Policy and Management* 12(3), London, Taylor & Francis, July-September 1985.

The problem of fleet operating costs and annual cargo capacity characteristics is considered, and finds artificial constraint on dealing with this problem imposed by "A simple approach to fleet deployment," H. Benford, *Maritime Policy and Management*, 8(2), and seeks to formulate the problem correctly.

Per Bruun, D., *Port Engineering* (2 volumes), Gulf Publishing Company, Books Division, Texas, 1989.

Each volume is a comprehensive reference on port and coastal engineering. Volume 1 reflects the latest progress in port economics and navigation, harbor hydraulics, breakwater engineering, modeling techniques, marine structures and foundations, terminal construction, berthing, mooring and fendering principles, and cargo handling. Volume 2 covers harbor transportation systems, including fishery and small craft harbors; site selection and environmental, hydraulic, and navigational studies; analytical approaches to solving sedimentation problems; and the latest developments in dredging operations and equipment design.

Pope, J. A., and **E. M. Cross**, "The Optimal Load Size for Ocean Shippers," *Logistics and Transportation Review* 24(4), Berkeley, California, Vancouver, Faculty of Commerce and Business Administration, University of British Columbia, December 1988.

Describes a model for computing optimal load size and port call schedule. The model considers the cost of carrying inventory, the shipping cost, and the port entry cost. The optimal load size is determined using differential calculus. The port call schedule is determined by using the results of the optimal load size calculations to construct a spreadsheet model. The end product is a decision support system to aid shipping decisions. An example is presented for bulk products from South America to the U.S. East Coast.

Pope, J. A., and **W. K. Talley**, "Inventory Costs and Optimal Ship Size," *Logistics and Transportation Review* 24(2), Berkeley, California, Vancouver, Faculty of Commerce and Business Administration, University of British Columbia, June 1988.

An investigation of the effect of changes in inventory costs and ship costs on optimal ship size. Two widely used inventory management models are used. It is demonstrated that optimal ship size is highly sensitive to: (1) the inventory management model selected; (2) the treatment of stockouts and safety stock; and (3) the inventory management cost structure that prevails.

Robinson, A. E., *Inland Ports and Supply Chain Management*, paper presented at the International Business Association, Eighth Annual Conference, Cancun, Mexico, May 1999.

Inland ports are a further integrating mechanism within the supply chain management approaches to value creation. By enhancing multiple alliances, inland ports become economic growth modes. Inland ports facilitate the shortening of the supply chain, thereby

reducing costs. Costs are further reduced by making information transparent and reducing the risk of uncertainty in channel behavior. Inland ports are now starting to emerge and alter channels of distribution, and examples include Columbus, Ohio and Kelly Air Force Base in San Antonio, Texas.

Robinson, R., “Size of Vessels and Turnaround Time: Further Evidence from the Port of Hong Kong,” *Journal of Transport Economics and Policy* XII(2), London, London School of Economics, May 1978.

Using recent U.S. import statistics, this paper assesses the relative importance of tariffs and transport charges on LTK exports to the U.S., showing that the incidence of transport costs on exports from LJK to the U.S. is greater than that of tariffs.

Schönknecht, R., and others, *Ships and Shipping of Tomorrow,* 1st American edition, Centreville, Cornell Maritime Press, Maryland, 1983.

Developments in ships and shipping are discussed, scientifically examining development possibilities, and giving advantages and drawbacks to solutions that are technologically and economically practicable. Developments described are illustrated in multicolor drawings.

Simon, S., “More on the Law of Shipping Containers,” *Journal of Maritime Law and Commerce* 6(4), Baltimore, Jefferson Law Book Company, Maryland, July 1975.

Examined are steamship companies’ conversion of cargo operations from traditional break-bulk methods to the containerization concept, and the consequent litigation concerning the status of carriers’ freight containers in connection with the package limitation section of COGSA. A discussion is included of landmark U.S. cases, *Shinko Boeki v. United States Lines 1974* and *Cameco Inc. v. United States Lines 1974*.

Stopford, M., *Maritime Economics*, London, Harper Collins Academic, 1988.

An introduction of the economics of the global shipping industry, describing the cyclical mechanism of supply and demand for sea transport and explaining how the shipping market is organized. Also discussed are the economics of liner and bulk shipping conferences, unitization, bulk transport, shipbuilding, scrapping, and maritime forecasting.

Sychrava, L., and **Bush, M.**, *Forecasting Ship Demand,* London, Seatrade, 1971.

The EEC global forecasts for demand for ships are examined. Forecasting approach and modifications are discussed, and the effect of some of the modifications on the revised forecast for 1975 is illustrated.

Talley, W. K., **"**Optimal Containership Size," *Maritime Policy and Management* 17(3), London, Taylor & Francis, 1990.

The impact of ship size is addressed by comparing average cost per container movement incurred by a containership per voyage leg on a given route under three scenarios. The rationale for conclusions is presented.

United Nations Conference on Trade and Development Secretariat, *Major Issues in World Shipping: a) Merchant Fleet Development; b) Structure of World Shipping,* Geneva, United Nations, 1986.

A consolidated report in response to requests of Conference and Committee at the 10th and 11th sessions. The imbalances between supply and demand in world shipping, and developments and issues in world bulk and liner shipping are considered.

United Nations Conference on Trade and Development Secretariat, *Port Development: A Handbook for Planners in Developing Countries,* 2nd rev. ed., New York, United Nations, 1985.

Provides guidance in the formulation of national port development policy and preparing realistic programs for extension and improvement of individual ports. General principles of port planning, procedures to be applied for establishing a program of work, traffic forecasting, and productivity are included, as well as a discussion of methods of planning various port facilities.

United Nations Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 1997,* UNCTAD, New York and Geneva, 1997.

This annual publication identifies the main developments in world maritime transport and provides relevant statistical data. Emphasis is given to the development of the merchant marines in developing countries, as compared with other groups of countries, and to correlation between development of global trade and activities of overall maritime transport.

U.S. Department of Transportation, *Intermodal Freight: An Industry Overview*, Washington D.C., March 1994.

All aspects of intermodalism are considered, from a description of the budding industry to impediments for future applications. Many contributors are included, and subjects covered include the Alameda Corridor, break-even points for rail and truck cost-impact of varying drayage costs, and intermodal volumes and growth.

U.S. Department of Transportation, *A Report to Congress on the Status of the Public Ports of the United States 1996/1997,* Washington D.C., 1998.

Basic data related to the port and maritime industry. Discussed are the U.S. public port industry's economic activities, and the critical issues covering facilities, financial issues, and dredging. In the latter part, intermodal issues are also included.

U.S. Department of Transportation, *Impact of Changes in Ship Design on Transportation Infrastructure and Operations*, Washington D.C., February 1998.

Questions are addressed about the growth of worldwide-containerized demand and the impact this growth will have on the U.S. transportation system. Current advances in containership technology, port infrastructure inadequacies, and infrastructure needs to accommodate these ships are summarized. A short analysis of each region of the U.S. in included.

VZM/TranSystems, *Maritime Planning Guidebook,* San Francisco, California, April, 1998.

The basic concepts underlying the design and planning of port facilities used by VZM/TranSystems are defined, including on-dock requirements, seaside access, rail access, and other aspects required in port planning. Also given are basic concepts in the changing world of containerships, as well as the logistics and infrastructure requirements for planning a mega-containerport.

Veldman, S., "The Optimum Size of Ship and the Impact of User Costs: An Application to Container Shipping," in K. M. Gwillian (ed.), *Current Issues in Maritime Economics,* Dordrecht, Kluwer Academic Publishers, the Netherlands, 1993.

An illustration of how user costs can be incorporated into the assessment of a liner shipping service's optimum ship size. A model is developed to show shipping costs of a liner shipping service as a function of ship size and uses the model to consider questions concerning optimal ship size for a given route.

Vickerman, Zachary, Miller, *Texas Deep Water Container (Mega) Port: Final Report Phase 2: Conceptual Development Study for Shoal Point*, Texas City, Texas, Vickerman-Zachary-Miller, San Francisco, August 1998.

Based on an engineering consultant's study of the possible development of a containerport at Shoal Point, this report contains conceptual layouts of megaship accommodations and container facilities. Eight conceptual development alternatives for a port at Texas City are identified, and the deepening the Texas City Channel to accommodate these vessels is proposed. Also considered are the possible impacts of new terminal development on existing Port of Texas City infrastructure. Also included is a summary of the market assessment that was performed in phase one, as well as a conceptual construction schedule.

Watson, D. G. M., *Practical Ship Design*, Elsevier Ocean Engineering Book Series Volume 1, Oxford, England, 1998.

A distillation of the knowledge acquired after a lifetime of ship design of both merchant and naval ships including cargo and passenger ships, tugs, dredgers, and service craft. Covered are concept design, detail design, the effect of regulations, preparation of specifications, and matters of cost and economics. Structural design and hydrodynamic design issues are also included, making this an excellent book on the issues related to increasing containership size.

Winston, C., "A Multinominal Probit Prediction of the Demand for Domestic Ocean Container Service," *Journal of Transport Economics and Policy* 15(3), London, London School of Economics, September 1981.

An attempt to demonstrate the usefulness and limitations of the prediction capability of statistical choice models in analyzing actual instances of a new alternative—the ocean container service.