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DISCUSSION PAPER

Report No.: 5204

Bulk Shipping and Terminal Logistics

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July 1984

Ports, Shipping and Aviation Unit
Transportation Department
The World Bank

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July 1984

ABSTRACT

This paper is intended as a guide to sea port planners in the preliminary assessment of projects involving bulk terminals. An overview of the bulk trades and bulk shipping provides the framework for assessing the market for bulk terminal services. Siting considerations are addressed taking into account the inland transport network, and the relative merits of various transport modes for bulk movements. Terminal equipment and facility layouts are discussed with regard to operational characteristics, and some indication of relative costs are provided. Mathematical models useful in evaluating preliminary design options are presented for various aspects of terminal design such as berth congestion and storage capacity calculations.

ACKNOWLEDGEMENTS

This paper was written as part of a research effort into the design of bulk terminals within the Ports Unit of the Transportation Department of the World Bank. The views expressed in the paper are those of the authors and should not be attributed to the World Bank. Helpful comments on the paper were provided by Ezra Bennathan (Economic Advisor), Clell G. Harral (Highway Advisor), and Liviu L. Alston (Railway Advisor) of the Transportation Department, and Richard Scheiner (Port Engineer) of the Western Africa Projects Department.

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BULK SHIPPING

AND

TERMINAL LOGISTICS

PREFACE

Bulk terminals are transportation facilities where vehicles (i.e., ships, barges, rail cars, trucks, etc.) are accommodated and where particular functions necessary to the transportation process are performed. Terminals are required at the ends of a transport chain and at intermediate points. Intermediate facilities are involved with the transshipment of goods between intra-and inter-modal transport. The functions of a bulk terminal include the following:

1. Cargo loading and unloading
2. Cargo consolidation and deconsolidation - this is often beneficial because of economies of scale in ocean transportation, feeder transportation, and/or terminal operation.
3. Storage - this means temporary or long-term facilities, as a service to port users or to effect transport economies
4. Classification of cargo
5. Intrasystem or intersystem cargo transfer
6. Vehicle marshalling and cargo stowage
   - (a) Cargo stowing on a ship or other transport vehicle is accomplished usually by using loading equipment, such as shiploaders (i.e., grabs, buckets, chutes, etc.) which must be compatible with the vehicle or ship cargo space.
   - (b) Securing, tie-down, or stowage on or in the transport
7. Vehicle maintenance, servicing, and/or modification
8. Physical form change of cargo
   - (a) Cargo conversion, such as slurrying, bagging, baling, etc., of dry bulk cargo may be done for reasons not associated with the loading function.
   - (b) It may be performed also to facilitate cargo handling or transfer operations.

9. Packaging of cargo

10. Safeguarding of cargo

11. Cargo and vehicle information management and documentation.

Each of these functions needs to be considered in the design of bulk terminal systems.

An analysis of the terminal costs associated with the loading function must include time costs incurred by both cargo and vehicles. Bulk cargo loading involves delays in vehicle time and resultant costs to the vessel owner. Therefore, ship, truck, rail-car, etc., turn-around time costs and cargo inventory holding costs must be included in determining terminal operating costs. Similarly, cargo conversion costs, if accomplished as an integral part of the overall transportation process, must be included as part of the terminal costs.

Various descriptive models of the terminal classification and cost processes can be developed and used. It is necessary, here, to recognize that terminals are networks of operational links which often are random in nature with regard to the time factor and the sequence of operations used by cargo in its flow through the terminal.

Section 1 provides an overview of the bulk trades and discusses the major commodities moving in the trade. Section 2 describes techniques for projecting trade and traffic levels. The economics of bulk shipping is discussed in Section 3. Inland transport for bulk commodities and bulk terminal siting are the topics of Section 4 and 5. Equipment options, facility layout, and terminal cost estimation are dealt with in Sections 6, 7 and 8. Mathematical techniques useful in bulk terminal analysis are presented in Appendices A through E.

This report is a sequel to the report entitled, "Container Logistics and Terminal Design." It presents the results of a study of bulk terminal systems and their essential design considerations. The issues involved in design, from project identification to traffic forecasting, siting, capacity determination, equipment selection, cost determination et al., are discussed to provide an up-to-date basis for decision-making in bulk terminal project development.

The study was performed under the direction of Mr. E.G. Frankel, Port, Shipping and Aviation Advisor of the International Bank for Reconstruction and Development. Other members of the study team were Mr. John Cooper (Consultant), Mr. Yoo Whan Chang (Consultant), and Dr. George Tharakan (Consultant). Information was received from many sources, all of whom are identified and acknowledged at the appropriate places in the text.

I. OVERVIEW

I.1 Description of the Bulk Trades

World maritime trade in 1982 amounted to 3.21 billion metric tons. This figure is down from the highest trade level, 3.77 billion metric tons, achieved in 1977. The transportation of petroleum accounted for about one-half of the tonnage in worldwide maritime trade. Major dry bulk commodities, including iron ore, coal and grain, accounted for another one-quarter of the tonnage shipped. The remaining quarter came from the transportation of general cargo items.

Traditionally, shipping has been split into two separate markets - liner shipping and bulk shipping. The liner market provides small consignment services to many different shippers, as well as full ship loads shipped on "liner terms"; consignments may vary in size and each consignment must have a separate bill of lading. Liner operations ship goods for anyone on request. A single shipload of goods may represent as many as five hundred different consignments. This requires coordination among many shippers, freight forwarders and other parties, who can be reached only with a regularly published schedule and standardized commercial arrangements. The shipper may be unable or unwilling to arrange any part of the goods transportation (including inland movements), so liner operations frequently offer door-to-door service. Most liner operations provide container1/ services, but also provide noncontainer capacity for commodities which cannot physically fit in a container.

1/ Containers are usually 8 x 8 x 40 or 8 x 8 x 20 foot boxes into which goods are loaded at the shipment point. The containers can be transported door-to-door, which includes the ocean leg, without the goods being removed from the container. This system has many advantages, notably in the reduction of stevedoring costs.

In bulk shipping, one load is shipped usually under a single bill of lading. Multiple consignments do occur occasionally, but may not always be possible. In the United States, for example, there is a law requiring ship operators who issue more than three bills of lading per sailing to register as common carriers. There is, however, considerable overlap between liner and bulk commodities, simply because the principal differentiating factor is consignment size. Goods such as timber, plywood, steel, grain, cement, and fertilizer are commonly shipped in either market sector. These so-called "neobulk" commodities could be described as bulk substances, but often move in consignment sizes so small that many, many shipments would be needed to fill a vessel.

Shipment size of bulk traffic is large and can be controlled by the shipper. Considerations of economies of scale play a major role in the design of bulk logistics systems.2/ Because of the control possible, shippers can obtain large savings by carefully integrating shipping activity with other operational aspects. Oil, steel, grain and aluminum companies, for example, use linear programming models to help manage their logistics planning functions. From these models it is possible to note how economies of scale in ship capacity can be traded off against inventory holding costs and storage capacity at the producing, loading, unloading or distribution centers.

2/ Economies of scale do not play such a large role in the liner trades. The largest decrease in unit costs occurs in goods that are shipped in full container lots (about 10 tons). After this, while economies of scale still exist, seldom are they passed on, except with large volume shippers with sufficient power to negotiate a rate reduction for a specific commodity, as the rate charged per full container does not depend on how many are shipped.

The greatest market penetration of bulk trades is in the "primary" commodities (Table I.1.1). However, the market share in these commodities varies widely, with some being shipped in small shipment sizes as, for example, hides, fibers (wool and cotton) and beverages (coffee, cocoa and tea), which remain major liner cargoes. One reason they are shipped as liner cargo is that their packaging is not compatible with the bulk cargo handling processes available. Cotton bales, for instance, are more expensive to load on a ship than containers filled with cotton bales, and hogsheads of tobacco are not strong enough to be stacked to fill a hold without the structural support of a container. Sometimes, bulk commodities are shipped on liner ships because they are consigned to different destinations and cannot be handled economically in bulk. Occasionally large volume manufactured products, such as paper and automobiles, are shipped as bulk cargoes.

The development of the modern, small-sized bulk carrier has increased the number of commodities shipped in a bulk mode. Improvements in commercial warehousing and distribution systems also have facilitated this trend; bulk ocean shipments can often be divided into retail-sized quantities at the warehouse. Fertilizer and rice are good examples, with bulk shipments commonly ranging from 3,000 to 8,000 tons.

There are five major bulk commodities carried in maritime commerce--iron ore, coal, bauxite, phosphate rock and grains. Tables I.1.2 and I.1.3 give historic shipment levels and an estimate of the transport requirements for major bulk commodities. Figures I.1.1-3 show the trade patterns for the three major bulk commodities. The remaining commodities are termed minor bulks; these include sugar, sulfur, steel scrap, timber and fertilizer.

Table I.1.1 Trade in Primary Commodities (Average 1978-1980)
(in millions of U.S. dollars)

Commodity	Total Value	Developing Country Share
Bananas	1167	1079
Bauxite	768	648
Beef	7577	1243
Cocoa	3139	2969
Coffee	11983	11063
Copper	8991	5529
Fibers	10551	4059
Fish Meal	990	488
Ground Nut & veg. oils	3676	2710
Hides	3307	407
Iron Ore	6265	2702
Lead	1709	480
Maize	9879	1334
Manganese Ore	410	319
Petroleum	245234	212294
Phosphate Rock	1847	1206
Rice	4193	1811
Rubber	3821	3762
Sugar	10614	3672
Tea	1817	1394
Timber	18458	5515
Tin	2659	2157
Tobacco	3806	1706
Wheat	12789	782
Zinc	2001	473

Source: Commodity Trade and Price Trends
The World Bank 1982/83 edition.

Table I.1.2 Annual World Exports of Eight Major Bulk Commodities
(in millions of tons)

Commodity	1970	1977	1979	Growth rate [1960(1)-1978(9)]
Iron ore	321.7	357.3	390.7	2.1%
Coal	102.0	136.8	155.5	3.8%
Bauxite	27.2	33.9	-	5.4%
Phosphate rock	38.5	48.5	-	5.5%
Wheat	50.1	66.8	72.4	3.3%
Corn	28.9	55.1	74.7	8.3%
Coarse grains	48.2	81.2	103.2	7.2%
Rice	8.8	10.8	11.9	9.8%

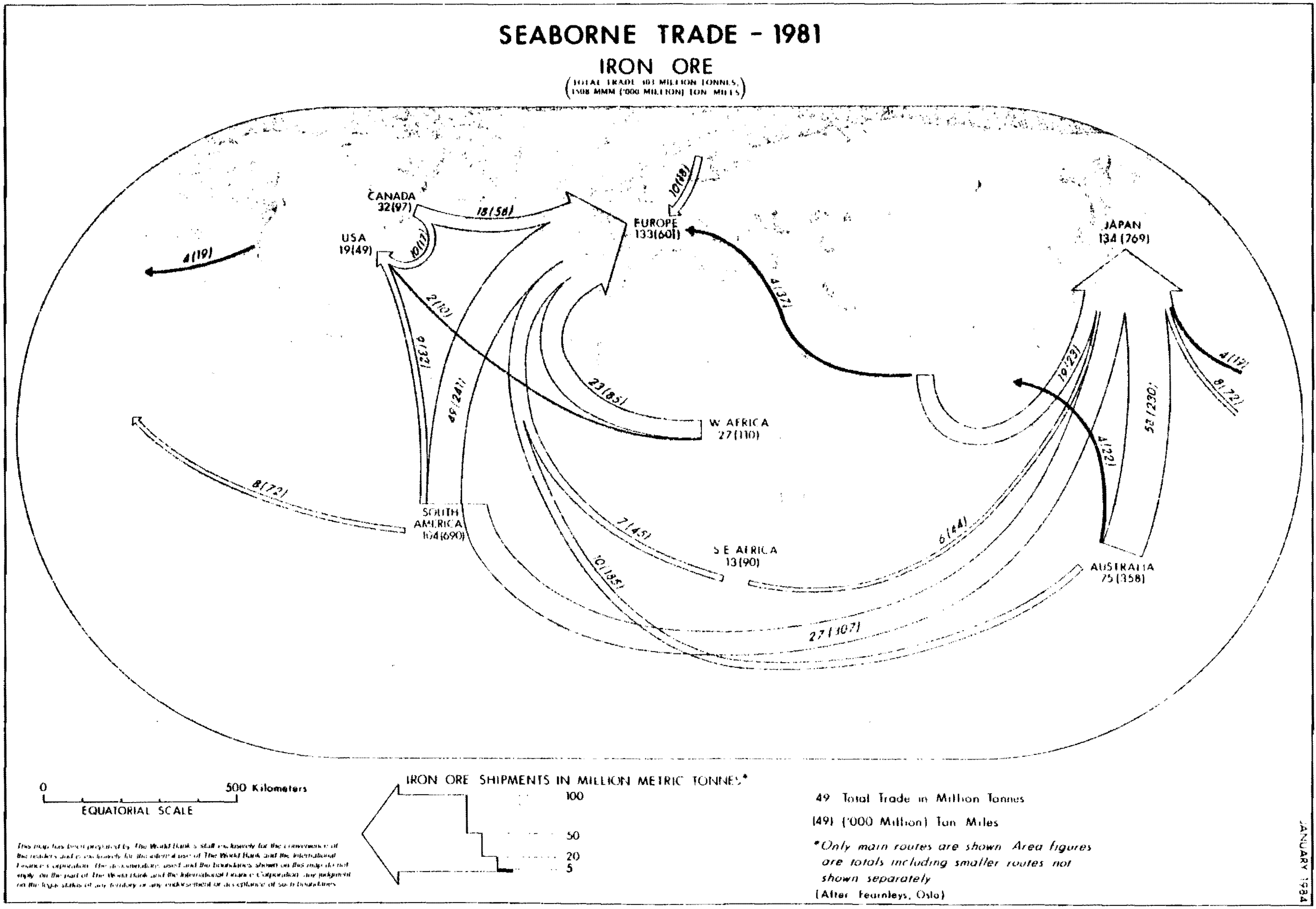
Source: World Bank Commodity Handbooks, Except Coal
Coal-Coal Trade Transportation and Handling, CS Publications,
Surrey, U.K. 1981.

Table I.1.3 Total World Transport Requirements for Eight Major Bulks
(1977)

Commodity	Distance (n.m.)	Ton-miles ($x\ 10^6$)	Mean ship size (dwt)	Number of Voyages	No. ships in trade
Iron ore	5,000	1,786	100,000	3752	390
Coal	4,700	-	-	-	-
Bauxite	3,750	127	60,000	2118	158
Phosphate	3,500	169	15,000	11320	183
Wheat	5,300	383	28,000	2590	294
Corn	5,300	395	28,000	2670	303
C. grains	5,300	547	28,000	3960	418
Rice	5,300	63	28,000	1190	135

Source: World Bank staff estimates

FIGURE I.1.1



SEABORNE TRADE - 1981

IRON ORE

(TOTAL TRADE 303 MILLION TONNES,
1508 MMM ('000 MILLION) TON MILES)

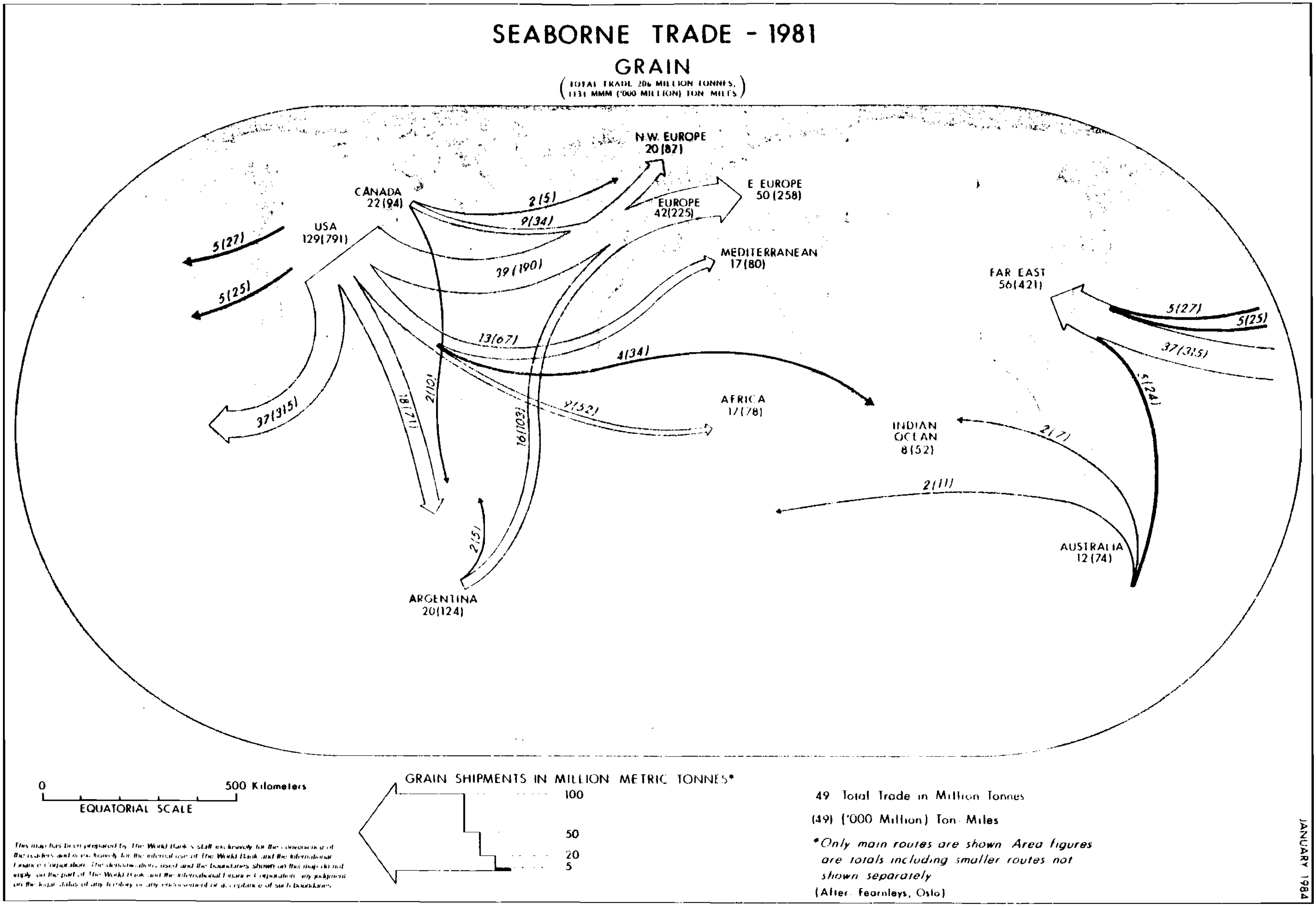
49 Total Trade in Million Tonnes

(49) ('000 Million) Ton Miles

*Only main routes are shown. Area figures are totals including smaller routes not shown separately

(After Fearnleys, Oslo)

FIGURE I.1.2



SEABORNE TRADE - 1981

GRAIN

(TOTAL TRADE 206 MILLION TONNES,
1131 MMM ('000 MILLION) TON MILES)

49 Total Trade in Million Tonnes

(49) ('000 Million) Ton Miles

*Only main routes are shown. Area figures are totals including smaller routes not shown separately

(After Fearnleys, Oslo)

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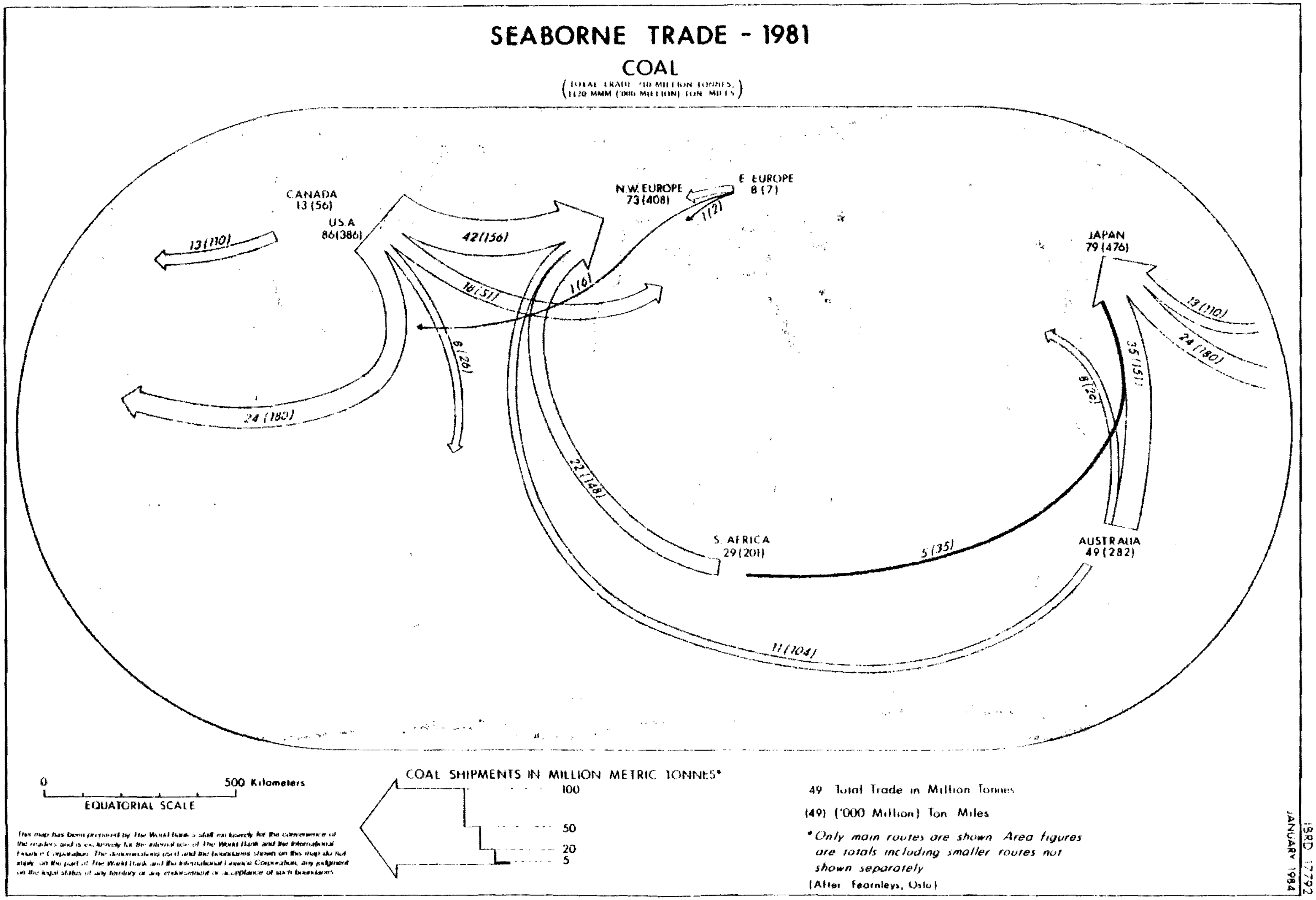
FIGURE I.1.3



SEABORNE TRADE - 1981

COAL

(TOTAL TRADE 210 MILLION TONNES,
1120 MMM ('000 MILLION) TON MILES)

COAL SHIPMENTS IN MILLION METRIC TONNES*

49 Total Trade in Million Tonnes

(49) ('000 Million) Ton Miles

*Only main routes are shown. Area figures are totals including smaller routes not shown separately

(After Fearnleys, Oslo)

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Bulk commodities are usually basic or intermediate goods that require additional processing after transport in order to be useful. Grain, for example, requires storage, milling and packaging. Thus, bulk shipping is part of a much larger industrial process. The exact shipping service required depends on the industrial process itself, and on the size and location of processing facilities. For bauxite or nickel, the type of shipping required depends mostly on the relative cost of electricity, since this cost determines where processing plants will be. Depending on the location of processing plants, the movement of "aluminum" from mine to market could be done in a number of ways as shown in Table I.1.4.

Table I.1.4 Possible Ways to Ship "Aluminum" from Mine to Consuming Market Area

Product	Value/ton (1978 $)	Tons/ton of final Product	Cubic feet per ton
Bauxite	$ 30.00	4.5	25
Alumina	$ 140.00	2.25	28
Aluminum ingots	$1,130.00	1.01	--
Plates & shapes	--	1.00	250

Source: The Outlook for Bauxite/Alumina Trade and Shipping, H.P. Drewry, London, 1984.

Commonly bulk shipping is tightly integrated into the industrial process. In the steel industry, ore carriers may load cargo at only one mine and unload it at only one steel mill. Such stable trading patterns occur when the demand for a commodity is stable and its supply is from a small number of sources. In this case, with careful optimization of a bulk logistics system, large economies can be realized.

Where demand is not steady or the source of material supply is not well determined, a large investment in dedicated facilities and ships cannot be justified because of the likelihood of low utilization. To serve such a market, a large sector of general purpose bulk carriage has evolved making it possible for one vessel to carry many different cargoes in its life, the cargoes which are carried depend on the vessel's position and the contracts available. Many grain trades operate this way. Much shipping capacity is then procured on a voyage (or spot) basis. Table I.1.5 gives the percentages of cargo carried by short-term contracts in each of the major bulk trades.

Table I.1.5 Percentage of Commodity Flows Moving in Voyage Chartered Ships

Commodity	Percentage Carried On Voyage Charter Basis
Iron ore	3%
Coal	4%
Bauxite	2%
Phosphate rock	3%
Grain	34%

Source: Dry Bulk Charter Market and Trends, H.P. Drewry, London, 1983.

Where economies of scale exist in maritime transport, it is important to pay strict attention to the details of bulk logistics and, more important, to increase the degree of organization and integration. The transportation of kaolin (China clay) from the United States to Japan offers an excellent example. Such clay is used to coat high quality papers. Until recently kaolin was transported as a slurry from the mine to a small processing plant where it was dried and bagged. The bags then were loaded on pallets into a general cargo ship and taken to Japan. In Japan the dry kaolin would be converted back to a slurry and pumped into storage ponds at the paper mill.

Today slurry-carrying ships can be substituted for dry-bulk carriers and much of the intermediate processing is, as a result, eliminated. The kaolin example also illustrates how bulk trading operations need not be of immense scale. Only two vessels are required to carry the total export of kaolin slurry. The savings are indicated in Table I.1.6.

Table I.1.6 Savings in Kaolin Transport Using Slurry Carriers

Step Eliminated	Approximate Savings per Ton*
1. Drying slurry prior to bagging	$50.00-energy cost
2. Bagging	$15.00-cost of bags $ 5.00-cost of bagging
3. Loading ship	$60.00-stevedoring
4. Unloading ship	$60.00-stevedoring
5. Bag slitting and reslurrification	$ 8.00-cost of operation
Total savings	$198.00/ton

* Assuming typical U.S. and Japanese costs

Source: World Bank staff estimates, 1983

I.2 Bulk Trades of Developing Countries

Bulk trades mainly provide the following functions in the world economy:

1) Raw materials are moved from point of origin to point of need permitting optimal location of industrial sites.

2) Fuel supplies are moved from areas of surplus to deficit areas (both crude and product movements).

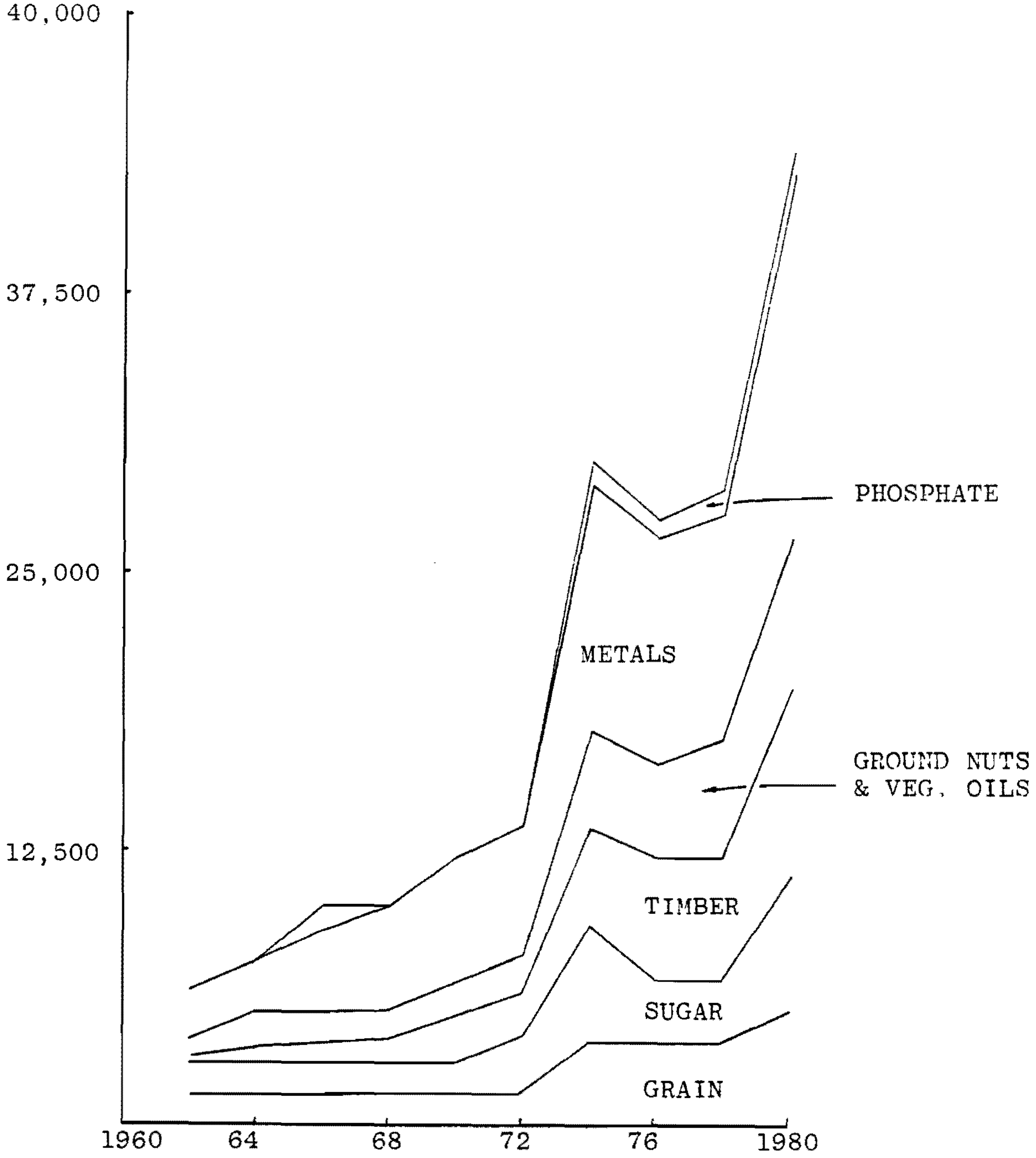
3) Food supplies are similarly moved from surplus to deficit areas.

In these trades, inexpensive bulk shipping allows movement of low value goods in large volumes.

Shifting raw materials accounts for about half of the bulk trade in developing countries. Fuel transported in dry bulk is mainly coal, most of which is supplied by developing countries. Although this trade is still small, the growth of developing countries' coal trades is potentially high. Columbia, Venezuela, Chile, Brazil, Botswana and Zimbabwe all have significant coal reserves and could emerge as big coal suppliers. Korea, for example, is increasing steel production capacity and is also relying on coal-fired plants for power generation instead of oil.

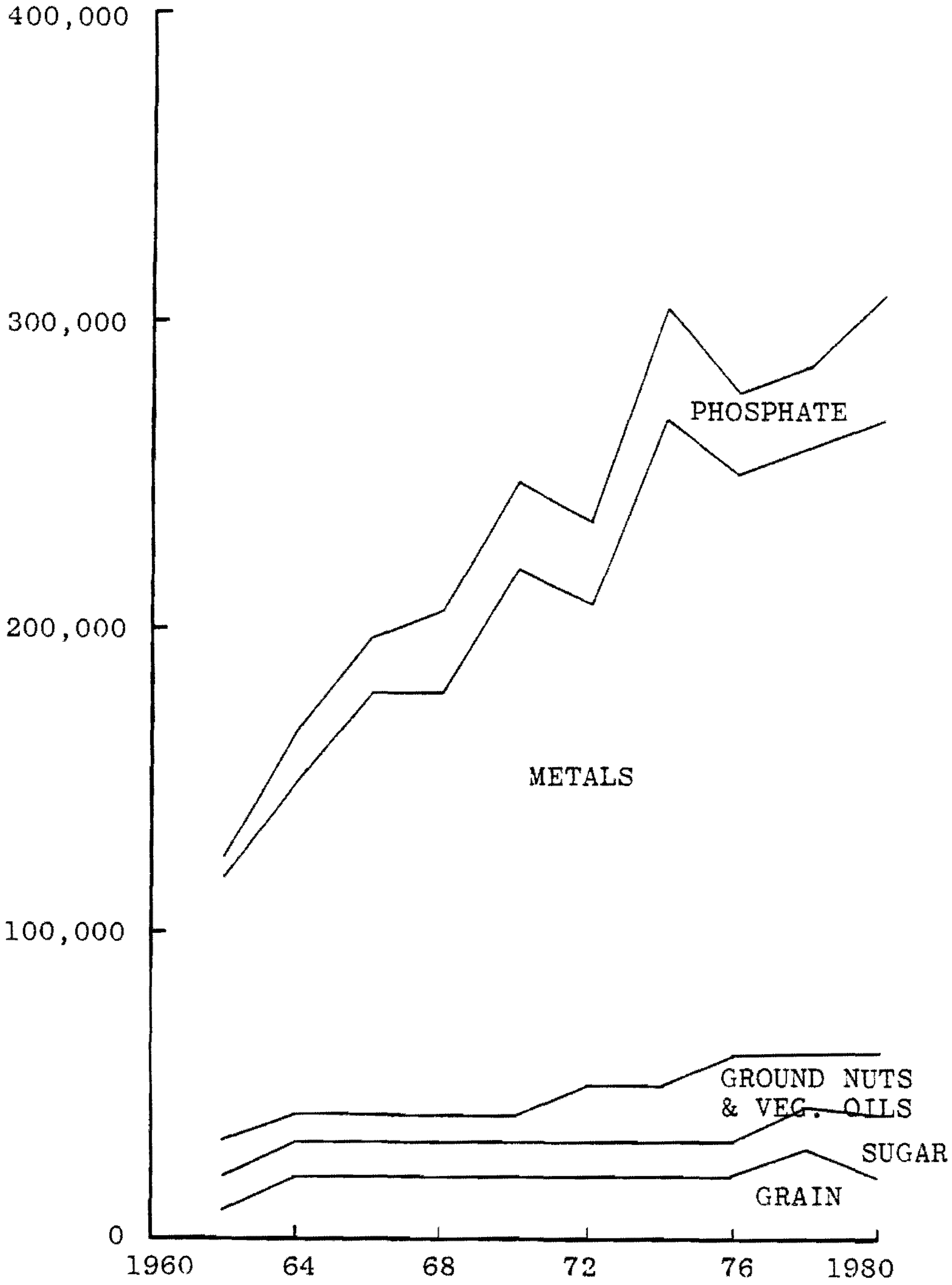
Approximately a third of bulk traffic is in food, it might be noted, principally, grains, sugar and oil seeds. Only a few developing countries are bulk exporters of food. These include Argentina (grain), Burma and Thailand (rice), and Brazil (sugar). In any event, both the import and export bulk trades of developing countries have been expanding rapidly. Figures I.2.1-2 indicate the total value and weight of major bulk exports of developing countries. The major growth has been in "Metals" which includes ores. Though agricultural commodities not shipped in bulk (i.e. coffee, tea, cotton, etc.) together with non primary goods, represent 85 percent of developing country exports by value, the concentration of metals, timber and

FIGURE I.2.1 VALUE OF SELECTED BULK EXPORTS OF DEVELOPING COUNTRIES (Million USD)



Source: Commodity Trade and Price Trends.
The World Bank, Wa82/83 editD.C. 1982/83 edition

FIGURE I.2.2 WEIGHT OF SELECTED BULK EXPORTS OF DEVELOPING COUNTRIES (1000's tons)



Source: Commodity Trade and Price Trends. The World Bank, Washington, D.C. 1982/83 edition.

grains in certain countries make these commodities especially important to the economies of those nations.

Figure I.2.3 (from World Bank data) presents the total weight of the major bulk imports to developing countries. The principal commodity carried and also the one with the highest growth rate is grain. Because imported grain is used as a means to compensate for shortfalls in the domestic crop, the amount of grain which a particular country imports can fluctuate with domestic harvests. As a result, while world grain shipments may present a pattern of steady growth, a given nation's grain imports can vary considerably from year to year (see Table I.2.1).

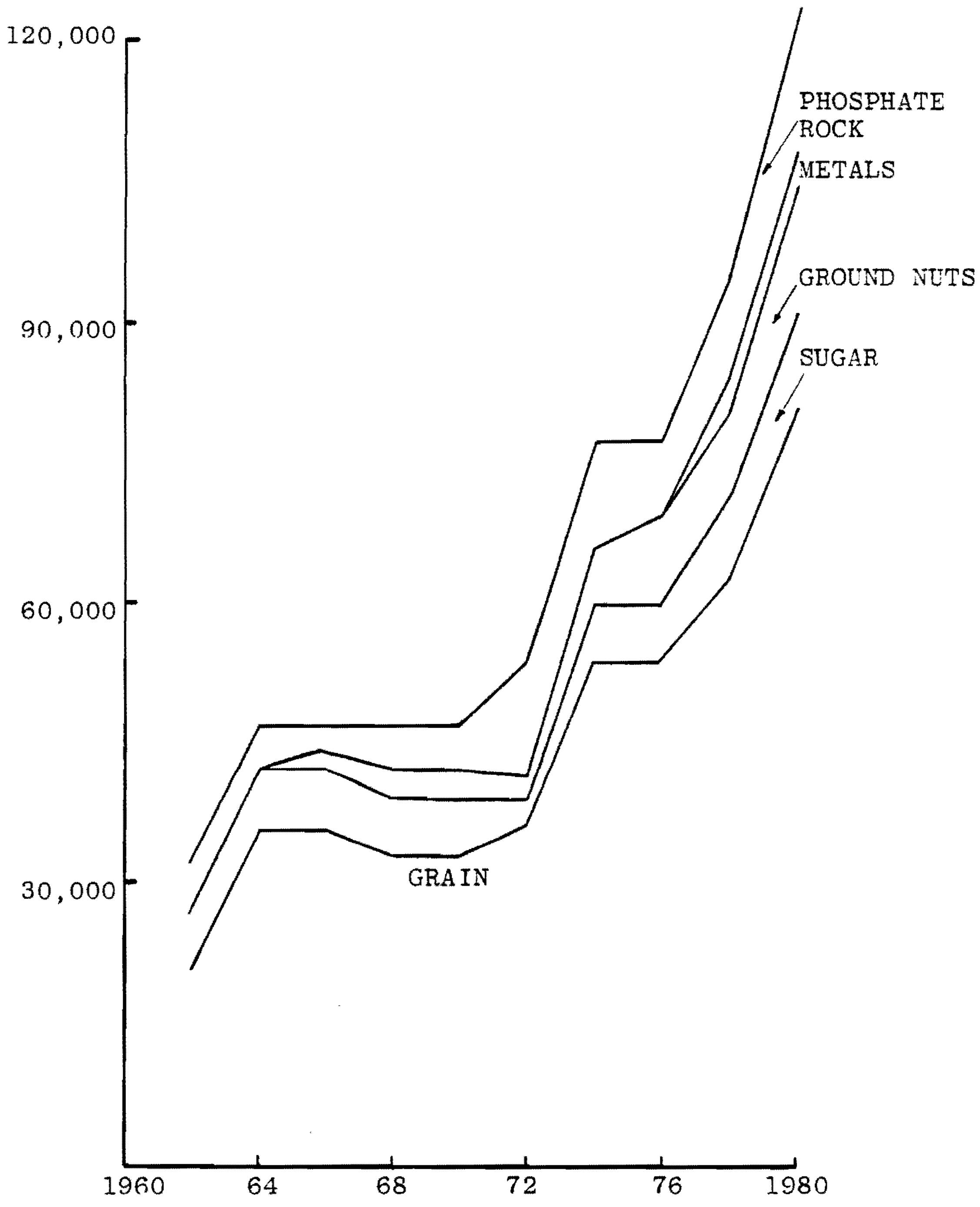
Table I.2.1 Wheat Imports of Major Developing Countries
(in thousands of tons)

Importing Nations	1961	1965	1970	1976	1977	1979
India	3,090	6,572	3,586	6,289	852	300
Brazil	1,881	1,876	1,969	3,428	2,624	3,654
Egypt	661	1,230	850	1,930	3,346	3,608
Korea	336	476	1,178	1,787	1,989	1,695
Pakistan	1,079	1,515	228	1,185	497	2,236
Bangladesh	252	241	1,061	1,049	623	1,123
S. Europe	3,248	2,273	2,073	1,723	1,603	2,081
China	2,889	5,626	5,583	2,598	7,577	8,951
Other	4,211	5,137	7,400	13,370	15,255	18,818
Developing Countries (Total)	17,647	24,946	23,928	33,359	34,369	42,466
World (Total)	38,511	49,927	48.785	65,675	64,236	76,039

Source: Grains Handbook, The World Bank, Washington, D.C. 1982.

Some countries, particularly India, import less grain today than in 1961 because the performance of the agricultural sector improved. One notable fact emerging from an analysis of the table is that the grain trade is growing more diverse--with the older principal importers buying a

FIGURE I.2.3 WEIGHT OF PRINCIPAL BULK IMPORTS OF DEVELOPING COUNTRIES (1000's tons)



Source: Commodity Trade and Price Trends.
The World Bank, Washington, D.C. 1982/83 edition.

smaller proportion of the grain moving in international trade. In 1966, 11 percent of the world's grain trade was shipped to "other developing countries" while, in 1979, the percentage reached 25 percent. The conclusion is inevitable that grain today is being shipped to more diverse destinations. The ability of the trade to support these "other developing countries" by the use of large vessels must be carefully assessed.

I.3 Interests of Developing Countries in the Bulk Trades

Developing countries have two primary interests in owning and operating bulk shipping. The first is profits and foreign exchange earned from transportation. The second is the impact of domestic control.

Foreign exchange earnings from bulk shipping operations are the difference between the cost in foreign exchange of using foreign tonnage versus domestic tonnage. These are estimated in Table I.3.1

Table I.3.1 Illustrative Foreign Exchange Savings from the Operation of a 60,000-ton Bulk Carrier Built Overseas (in USD/YR)

Cost Component	Payments to Others	Developing Country Expenses
Wages 1/		571,000
Subsistence 1/		90,000
Stores 1/		91,000
M&R 2/	457,000	
Insurance 2/		422,000
Port & Canal	508,000	
Fuel & Lubes	3,086,000	
Capital	3,683,000	
Subtotal	7,734,000	1,174,000
Profit (10%)		900,000
Totals	7,734,000	2,074,000
Percentage	79%	

1/ Sometimes as much as 40% of wages, and substantial portions of subsistence and stores are paid for in foreign exchange.

2/ This assumes no domestic repair capability and a self-sufficient insurance industry.

Source: World Bank staff estimates, 1983.

for a 60,000-ton bulk carrier acquired overseas and operated by a developing country. The 10 percent profit on gross expenses is an arbitrary figure. As many shipping operations are currently losing money, this is optimistic.

Most crew expenditures will be in local currency, although it is common to pay at least 40 percent in foreign exchange. Most vessel operating expenses, such as fuel, maintenance (spare parts and shipyard fees), port and canal tolls, and capital costs, will be paid in foreign currency. The money spent on marine insurance could go either way. If a country does not have a marine insurance industry, the insurance costs are foreign exchange expenditures. If a country does have a marine insurance industry, foreign exchange risk would still remain since the place where a given vessel is to be repaired cannot be predetermined.

In any case, the maximum savings in foreign exchange is established at about 20 percent. Minimum savings would result if profits were zero and marine insurance was counted as a foreign exchange expense. Were this the case, foreign exchange savings would only be about 10 percent. Table I.3.1 should be considered an optimistic assessment.

The theoretical price of bulk shipping (basically a free enterprise) is the marginal cost of the least efficient ship employed in the trade. Earnings from ship operation are the difference between the total cost of the ship operation and revenues, which are earned at the marginal cost price set by the market. It is not possible to determine if a developing country will make earnings without considering market activity and determining what the marginal ship's costs are. This is a consideration given further attention in the section on ship procurement.

Flags of convenience allow extremely low cost ship operations because of liberal certification, crewing, and tax policies. No country can have a cost advantage over flags of convenience, such as those of Panama and Liberia, unless capital and insurance costs are less. The remainder of the cost factors--spare parts, crew, and port charges, will be no more for the vessel registered under a flag of convenience than for one that is registered domestically. Insurance costs depend on the loss history. For established maritime nations, such as India, insurance rates would be comparable to world rates. In any case, a developing country's cost of insurance (or risk) is no lower than current world rates.

Subsidized ship financing is available for developing countries that wish to purchase newly-constructed ships. Such subsidized financing is usually about 3 points below the going OECD ship financing interest rates with terms 50 percent longer and loans of up to 90 percent of a ship's cost. An initial two-year holiday on principal repayment makes secondary financing possible, so little or no cash is required. To the extent that this financing is available, it offers developing countries a large competitive edge in ship acquisition financing.3/

There are many who maintain that soft-term financing offered by developed countries for new ship sales to developing countries is largely the result of a lack of shipbuilding orders in developed country shipyards. No good reason exists to subsidize ship sales to developing countries in this manner were the demand for ships higher and the yards working at close to full capacity.

Developing countries have major interests in ensuring that a bulk logistics system plan, before it is undertaken, is in accordance with their development goals. A country can improve its economic position, either by improving the continuous stream of real income resulting from trade,

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3/This is becoming less so as developed countries cut back support for the shipbuilding industry.

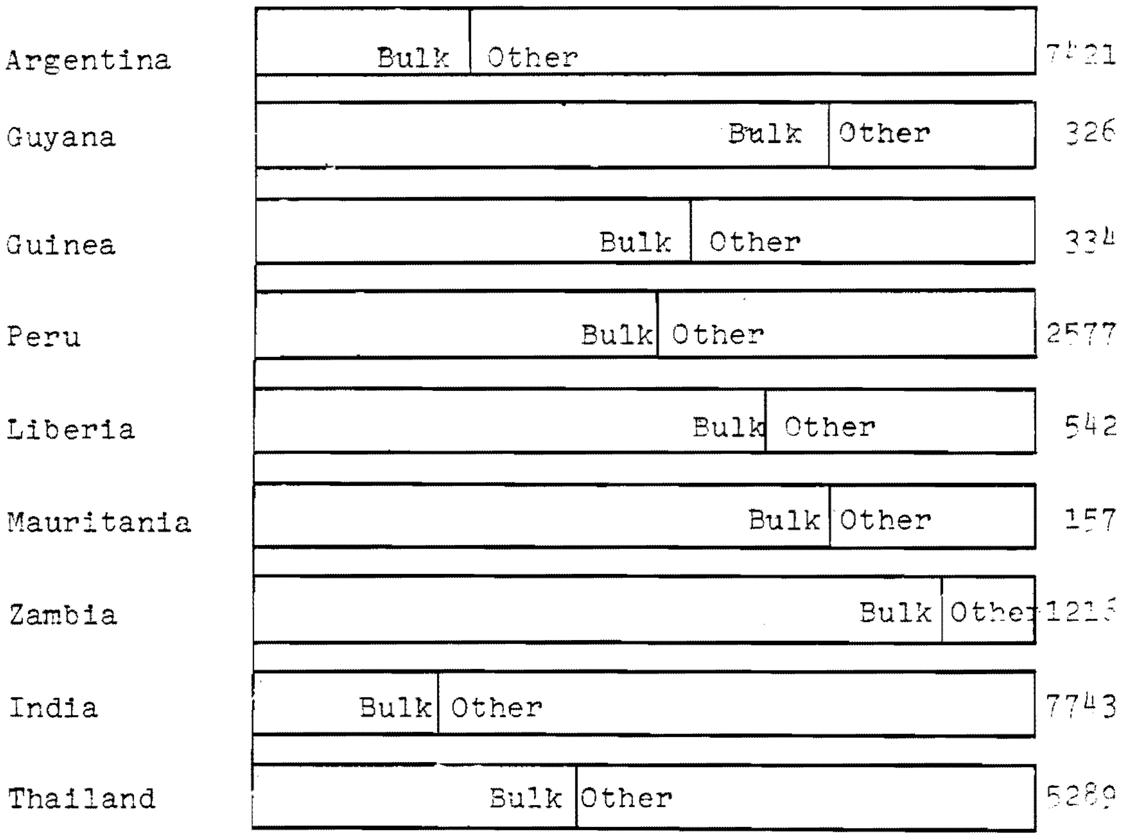
or by reducing the continuous real expenses. Investments in bulk shipping can achieve both to some degree. However, such investments should be made in areas where the country has the greatest comparative advantage, and this may or may not include bulk shipping.

All these factors influence a country's bulk commerce in various ways. When countries with large raw material resources do not possess a comparative advantage in processing, the expansion of bulk export facilities may be the best way to increase income from those resources. This is the case with bauxite, since aluminum smelting is localized in those areas of the world where electricity is inexpensive. Improvements in bulk export logistics can provide increased income which can then be invested in areas where a greater return is available.

Otherwise, when the country with raw materials has the comparative advantage in its processing, exporting raw materials would subtract from the potential income. The type of shipping capacity provided must then be of a different technical nature.

Developing countries as a group are not heavily dependent on bulk exports for foreign exchange earnings. However, some specific countries are. Figure I.3.1 compares the distribution of bulk versus other exports by value of nine developing countries involved in bulk trades. In addition, Chile, Bolivia, Jamaica, Burma, Fiji, and others are in a similar position. As shown in Table I.3.2, bulk exports can account for between 60 percent of per capita income (Liberia) and 3 percent (Argentina). Even for a large country, such as Argentina, for which bulk export earnings are not vital from a welfare standpoint, bulk exports account for 20 percent of its international trade.

FIGURE I.3.1 DISTRIBUTION OF EXPORTS BY VALUE
(Millions of USD)



Source: Commodity Trade and Price Trends
The World Bank, Washington, D.C.,
1982/83 Edition.

Table I.3.2 <u>Comparison of Bulk Exports to Indicators of Country Welfare</u>
(1980 figure)

Country	Population (million)	Total Value of Exports (million USD)	% Bulk	Value Bulk (million USD)	Per Capita Bulk Value (USD)	Per Capita Income (USD)
Argentina	25.7	7,421	19.8	1,469	57	1900
Guyana	.8	326	79.8	260	332	620
Guinea	4.5	334	58.3	194	43	150
Peru	16.9	2,577	47.7	1,228	73	700
Liberia	1.8	542	72.6	393	218	360
Mauritania	1.3	157	79.8	125	97	220
Zambia	5.1	1,206	89.5	1,079	212	390
Thailand	43.0	5,289	32.8	1,734	40	358

Source: Per Capita Income Figures from <u>The World in Figures</u>, The Economist, London, 3rd Edition, 1981.

When countries are heavily involved in bulk exports, the logistics system can be highly developed and technically efficient. Frequently, limitations in the port facilities at the other end of the trade limits the volume and size of shipments. Improvements in the bulk logistics system regarding that end of the process are outside the area of the developing country's control.

One way to improve control over the bulk exports is to deliver the cargo CIF at the port of discharge instead of FOB at the mine's shipment facility. Transportation costs can represent between 30% and almost 100% of the value of bulk commodities. Hence, careful planning in the acquisition of shipping capacity is necessary. As time charter rates are now well below cost in many trades, substituting time charters for a portion of the present shipping requirements presents a possible improvement over acquisition of new tonnage.

A country that has a competitive advantage in processing may find that bulk facilities are not always suitable for exports of semi-finished materials. There are a number of reasons for this. Total volume of the finished products may exceed that of the raw material, thereby vastly increasing transportation costs, loading process may be different, and the ship itself may need to visit more ports for discharge as it becomes part of a distribution channel for the product. This happens to be the case when a country substitutes the export of plywood, for instance, for the export of logs. A tendency exists to substitute liner vessels (including container ships) for bulk carriers to ship the product. There is a large difference between the cost of using liner and bulk ships. Experience shows that the former can sometimes consume much of the industrialization project's proceeds. A more economical course of action is to perform intermediate distribution where possible with dedicated bulk vessels. This has been done successfully with plywood in ocean-going barges.

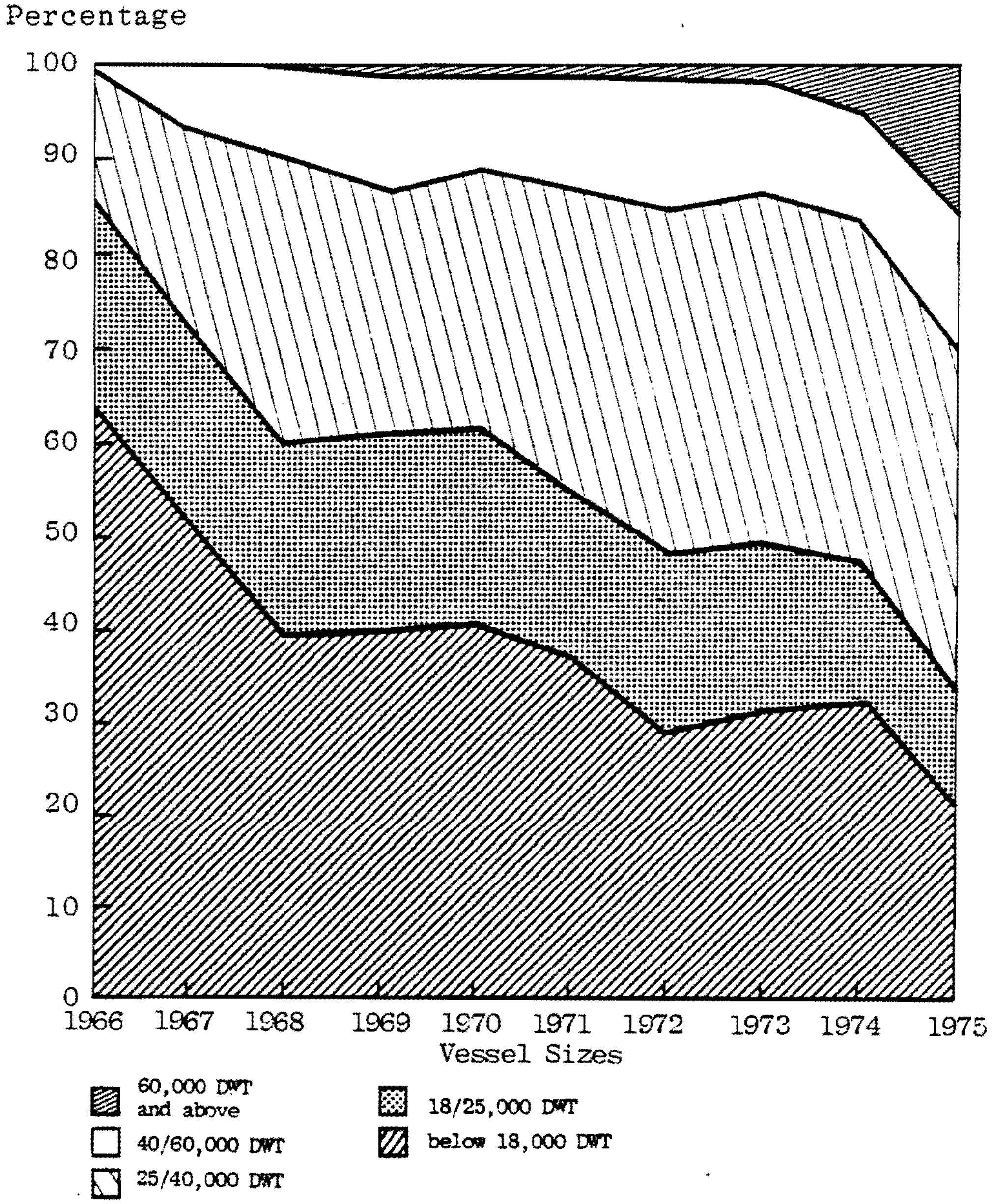
One area of weakness in developing countries' bulk logistics is in the importation rather than in the exportation of goods. Many opportunities exist throughout the world to reduce the cost of food and raw material imports by improving bulk logistics systems.

Grain is a trade where large improvements are possible. There are efficient grain discharge facilities in some developing regions, but the typical port facility is inadequate because of slow discharge rates. Port time could be easily reduced and at reasonably low cost. A recurring problem occurs when the grain facility is just too small to handle the quantity of grain aboard the ship. Even when a slow discharge process is being used, the ship often must wait for the grain ashore to be moved to other locations before unloading continues. Grain can be carried most cheaply in the largest of ships, and the volume of the trade occasionally justifies such shipments. Figure I.3.2 shows the breakdown of vessel sizes used in the grain trade. Significantly, water depths available at many ports used for grain imports are insufficient to allow the ship to enter. Ships must often be lightered with overall operations usually poorly organized. Little thought is given to investment in equipment truly suited to the job. The bulk discharge rates in offshore lightering operations is often as low as 2-3,000 tons a day or even less. With proper equipment, rates of 10-20,000 tons per day can be reached. However, when designing grain import facilities the variability in grain imports must be considered before large investments are undertaken.

I.4 The Role of Ports and Harbors in the Bulk Trades

Adequate ports and terminals are crucial to the efficient organization of bulk logistics operations. When terminals are inadequate, only labor-intensive handling techniques are possible (which frequently involve long delays due to periodic cessation of cargo handling when storage ashore is lacking). When vessels are handled without modern port facilities, the most frequent cause of inefficiency is a lack of resources. A shortage of cargo storage ashore, in particular, makes optimal planning and organization of the cargo handling operation impossible. In fact, historic long delays in bulk operations are due practically to a lack of planning and over-estimation of the port resources available. Even at primitive harbor facilities the large expenses of queues cannot be averted if cargo is not removed faster

FIGURE I.3.2 VESSEL SIZES EMPLOYED IN THE GRAIN TRADE



Source: Port Development, UNCTAD Secretariat
United Nations, New York, 1978.

than it is discharged.

Modern harbor facilities with large-scale, fixed ship loaders and unloaders are at least ten times more productive than undeveloped sites. While loading and unloading methods vary, one common method is to fill bags in the hold of the ship and then discharge them using the ship's gear. This is, of course, an expensive operation considering ship turnaround and berth occupancy costs.

Generally cargo handling gear mounted on bulk carriers is much less efficient than shore-based gear. Cargo gear mounted on a ship gets in the way of fixed ship loaders and unloaders. Consequently it is hardly desirable on a vessel which is frequently handled at modern facilities. Modern high capacity self-unloading ships, however, are an exception. Unfortunately most of the large bulk carriers are not fitted with any cargo handling equipment. Trades where modern equipment is not available must be conducted in small, more expensive vessels even though the draft in the harbor allows the use of a larger vessel. This can be very inefficient indeed.

The scale of bulk facilities must be roughly that of the ship itself. Except for proper organization of existing facilities and an increase of storage ashore, there is not an "entry level" facility in the bulk trades. Small facilities are feasible in container trades because mobile cranes make efficient, small-scale operations possible even with the largest container ships.

Due to the scale of these bulk facilities, their cost is largely a fixed investment. Unit costs are higher if the facility is underutilized. The location and demand for bulk facilities is very important. In situations where the utilization of bulk facilities is not certain such facilities present a risky investment and that risk should be carefully evaluated. This means distribution systems development for bulk cargo must be integrated with large-scale port investments.

I.5 Bulk Shipping

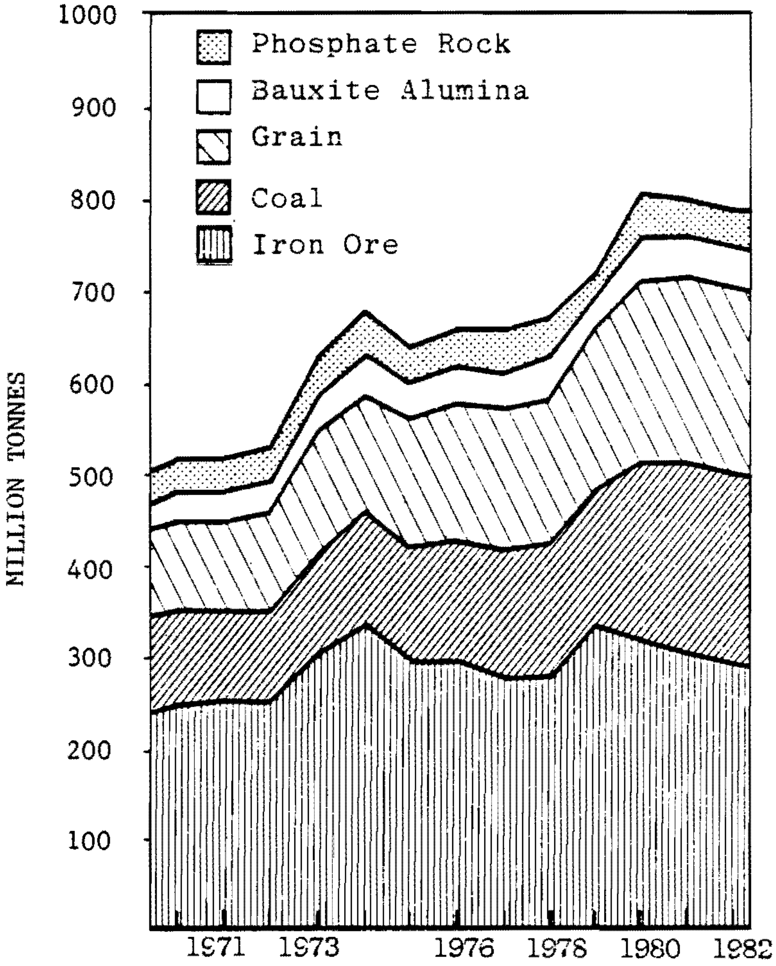
Total bulk shipping trade in international commerce grew from a level of 512 million tons in 1970 to over 801 million tons in 1980 indicating an average annual growth rate of 4.3%. Since 1970 the major bulk trades have passed through two major cycles with sharp increases in volumes between 1972-74 and, again, between 1978-80. The only major commodity which remained nearly static in volume and, therefore, declined proportionally (between 1970-82) was iron ore as indicated in Figure I.5.1. Coal and grain trades have had the largest and most consistent growth. Generally it is assumed that the volumes of major bulk commodities traded are functions of the following:

a) Political Stability
b) World Economic Growth Rates
c) Relative Energy Demand
d) Confidence in the World Economy
e) Degree of Freedom of International Trade

As a result of its dependence on these conditions bulk trades are usually fragile and subject to major changes in the volume and direction of trade. Past long-term bulk trading relationships no longer define world bulk trades. Now most bulk commodity importers are continuously seeking more attractive sources of supply with lower delivered costs, which, in most cases, include significant ocean transportation costs.

FIGURE I.5.1

MAJOR BULK COMMODITY TRADES



Considering the medium range future of major bulk trades, total volume of world trade in iron ore is expected to grow from 304 million tons in 1981 to 356 million tons in 1990 for an increase of nearly 16.5% over a 10 year period. The coal trade is expected to grow from 204 million tons in 1981 to 322 million tons in 1990 for an increase of nearly 55%. Grain, bauxite/aluminum and phosphate rock are all expected to grow only marginally by about 20% over the same period with total world dry/bulk shipping trade growing from about 800 million tons in 1981 to 1,040 million tons in 1990 - a growth of under 30% over the ten year period.

Table I.5.1 Bulk Carrier Fleet Development
(in thousands of dwt)

Vessels over 10000 dwt Figures in number of ships and '000 dwt

Year	Mth.	Tankers		Combined Carrier		Bulk Carrier		Total	
		No	dwt	No	dwt	No	dwt	No	dwt
1973	1.7	3223	201419	327	33023	2672	84358	6222	318800
1974	1.1	3293	215574	355	37415	2781	89393	6429	342382
	1.7	3383	234162	373	40221	2868	93132	6624	367515
1975	1.1	3406	254327	386	42081	2992	97812	6784	394220
	1.7	3398	272879	392	43443	3094	101873	6884	418195
1976	1.1	3439	290891	398	44208	3197	105749	7034	440848
	1.7	3398	306627	405	45445	3311	110212	7114	462284
1977	1.1	3384	320531	414	46808	3454	116586	7252	483925
	1.7	3339	327339	419	47545	3662	123735	7420	498619
1978	1.1	3301	331940	419	48273	3826	129629	7546	509842
	1.7	3184	329886	417	48722	3930	133516	7531	512124
1979	1.1	3129	329657	418	48589	3960	134931	7507	513377
	1.7	3096	327603	415	48779	4017	136856	7528	513238
1980	1.1	3071	326836	410	48179	4020	137657	7501	512672
	1.7	3079	326785	411	48376	4056	138875	7546	514036
1981	1.1	3081	324706	401	47266	4116	142058	7598	514030
	1.7	3085	322387	404	47393	4198	147234	7687	517014
1982	1.1	3084	320158	385	45250	4316	154713	7785	520121
	1.7	3011	310689	380	45078	4438	161796	7829	517563
1983	1.1	2944	300923	362	43145	4545	169231	7851	513299
	1.7	2861	289768	363	43248	4630	174331	7854	507347

Source: World Bulk Fleet, Fearnleys, Oslo, August 1983.

To discuss bulk shipping capacity or supply in relation to bulk shipping demand, ton-mile demand is of especial interest. Total ton-mile demand increased from 10.6 billion in 1970 to 16.78 billion in 1980, but fell shortly after to only 14.19 billion ton-miles in 1982.

Ton-miles of crude oil and product movement remained almost constant between 1970 and 1982. Over the same period, however, ton-mile demand of coal and grain more than doubled.

The world bulk fleet (both tankers and dry bulk carriers) increased from 6,222 vessels in 1973 to 7,854 vessels in 1983, or 26%, while total carrying capacity increased by 58% over the same 10 year period as noted in Table I.5.1. However, it should be noted that the fleet capacity increased to 510 million tons (dwt) by 1978 and has since remained at a fairly constant size. Tanker capacity has declined by over 40 million dwt since 1978 while dry bulk carrier capacity increased by about 40 million dwt over the same 1978-83 period.

According to the size of the dry bulk carriers the largest increase is noted in the 60-80,000 dwt class. In 1965 only seven ships with a combined capacity of less than 500,000 dwt were available in this size class. This has now grown to over 430 vessels with a capacity of 28.7 million dwt. There is a similar, though more recent increase in the number of 100-150,000 dwt bulk carriers of which there are now 188 with a total capacity of 23.4 million dwt. The largest component of the fleet, however, remains the handy-sized 25-40,000 dwt carrier with 1,727 vessels with a carrying capacity of 53.6 million dwt or 43% of the total. The average age of bulk carriers is 9.3 years with carriers of sizes less than 40,000 dwt having an average age of 10.98 years and larger carriers having an average age of 7.9 years.

Considering ownership of the bulk fleet, it is noted that 57% of the world bulk fleet by number and 56.2% by dwt is registered under the flags of Liberia, Greece, Japan and Panama; 28% of world bulk carrier capacity is registered under the flags of Liberia and Panama. Japan has only 8.3% of the bulk carriers under its flag, but controls over 11.5% of bulk carrier deadweight, as the average size of Japanese-registered bulkers is significantly larger than the world average size.

Considering tonnage on order in 1983, 396 out of 562 bulk carriers were ordered from yards in Japan (344) and Korea (52). The average size of bulker on order in 1983 was 43,263 dwt.

With regard to future fleet developments, it is expected that total bulk carrier fleet capacity will increase from 174.3 million dwt in 1983 to 190 million dwt in 1986, 210 million dwt by 1990 and 252 million dwt by 1995. An increase in the number and fleet capacity of vessels of 25-40,000 dwt is expected over that period with a lesser increase in the 60-80,000 dwt class.

Important considerations in organizing bulk shipping which must be studied before decisions are made on ship acquisition, chartering and various aspects of bulk shipping operations can be summarized as follows:

1. Strength of Demand for Transportation
    * **Political and strategic considerations**
    * **Seasonal consideration**
    * **Demand for shipping of other commodities**
    * **Demand for shipping of same commodity in other regions**

- Long-term changes in production, consumption and method of distribution of commodities

2. <u>Supply of Vessels</u>

   - World order book
   - Utilization of the current fleet
   - Long-term changes in the composition of the world fleet

3. <u>Ship Market Conditions</u>

   - Current spot and term charter rates
   - Aggregate of past market behavior
   - Volume of market activity
   - Volume of scrapping and laid-up vessels

4. <u>Expectations and Forecasts</u>

   - Forecasts of market level, operating costs and shipbuilding prices
   - Availability of backhaul arrangements

5. <u>Nature of Commodity Using Transportation</u>

   - Type, grade and quality
   - Value per ton
   - Seasonal or nonseasonal

6. <u>Control over Commodity Source</u>

   - Degree of outright control
   - Ability to schedule production and shipment

7. <u>Control over Commodity Use</u>

   - Nature of use (continuous or intermittent)
   - Ability to schedule use
   - Volume of turnover
   - Size of consignment acceptable

8. <u>Availability of Alternate Forms of Transport</u>

9. Cost Related Variables

10. Impact of Transportation Costs on Specific Parties

    * Percent of transportation cost of total operating expenses
    * Percent of transportation costs in raw materials costs

11. Expected Cost of Product Shortages

    * Cost of slowdown or shutdown
    * Loss of sales or goodwill
    * Probability of shortage under various arrangements

12. Costs of Raw Material Shortage

    * Cost of physical shortage
    * Cost emergency procurement
    * Inventory holding cost
    * Risk of spoilage or obsolescence

II. FORECASTING IN THE BULK TRADES

II.1 General Comments

Forecasting is the evaluation of future prospects based on past experiences and expectations for future occurrences. While producing a "perfect" forecast is desirable, many well-designed, useful forecasts have been "wrong" because their basic assumptions were later found to be incorrect. Examples are changes in the price of oil, the closing and opening of the Suez Canal, and the sizes of grain harvests.

Frequently the accuracy of a forecast is immaterial, as the goal is to make the best possible decision with the information available. A useful by-product of forecasting is the research performed in areas where information is lacking. It is not uncommon to find that the increased understanding which results from this research is more valuable than the forecast itself.

A common assumption in forecasting is that the best indicators of the future are the present and the immediate past. While in many cases this is a sound assumption, this need not be true in every case. Often "trends" can be started by improvements in statistical collection procedures. In developing countries this is frequently the case when automated data processing is implemented for the first time.

It is also possible that a goal of a project is to change the structural organization of a particular sector or industry. Examples of this are investments in export-oriented industry, transshipment ports or implementation of large industrial projects well beyond the historical scale of past development. In situations such as these history has little place in the "forecast" and a more market-research-oriented approach should be attempted.

Five fundamental issues always arise when establishing the basis for a forecast. These include the following:

1. How much should the present and immediate past count in predicting the future?
2. How accurately does available information describe current and past situations?
3. What mechanisms are at work undermining the relationship between the past and the future?
4. What specific plans exist to alter the structural variables affecting the forecasted quantity?
5. What are the uncertainties present in the basic assumptions?

The treatment of uncertainty is important. For much maritime information, such as charter rates, the random portion of the quantity is so large that, **even** if correctly estimated, the trend portion may have little utility in planning. Here, establishing upper and lower bounds on the variable may provide sufficient planning information. Monte Carlo simulation can also be of assistance; the IBRD Staff occasional paper number 11, "Risk Analysis and Project Appraisal," by Louis Pouliquen, provides a lucid treatment of this approach.

In cases of poor project performance, many problems have their origin in inadequate forecasts. A frequent occurrence is for forecasts to overestimate the revenues of a project. A World Bank study found that the most important reasons for this were the following:

* Slower than expected growth of the basic economy or particular sector
* Incorrect assumptions based on too static a view of the relationship between transportation requirement and production
* Insufficient allowance for competition from other modes
* Poor operating performance of the operating authority

Another factor causing an overestimation of the returns from projects is that, once sufficient resources are available for a large scale project, the goal of the forecasting effort becomes more a matter of justifying the project than of evaluating it. Such forecasts are not unbiased assessments of the future.

Still another difficulty with forecasts is that, generally, they have both an engineering and an economic purpose. From an engineering standpoint the maximum or potential use will probably establish design criteria for the facility. This is because the savings from constructing facilities too undersized to meet maximum demand may be outweighed by the costs of congested facilities.

From an economic standpoint the forecast must predict the average revenues generated by the project and hence determine its economic viability. This requires an estimate of the expected market size of the project and its risk. For some projects the market size cannot be determined by the present situation. It is the <u>rate of market share growth</u> of the project which determines its basic viability. Here, market research plays a crucial role in project evaluation.

To prepare such a market share forecast a marketing plan must be prepared to estimate the volume of revenue generated by the facility. This should include measures which should be undertaken to market the services of the facility and which should consider the design elements that will expedite the marketing effort. When a dedicated marine facility such as an ore or coal terminal is under consideration, the marketing plan should be for the commodity itself as well as the transportation demand derived from it.

A final problem affecting forecast accuracy is the late completion of the project or, even worse, of a single vital element of the project when everything else is on time.

II.2 Predicting Potential Volumes

The potential volume of cargo to flow in a bulk logistics system is important because it helps to set the optimal design capacity for the system and places an upper limit on the revenue generated from the use of the facility. Potential volumes are generally determined from forces exogenous to the bulk logistics project. These can be the countries' Gross National Product, population growth, or developmental projects. The exception to this is the cost of transportation of the commodity which, of course, exerts a substantial effect on the situation.

Efforts to forecast cargo flows tend to fall into three categories: trend extrapolation, model building, and policy (or opinion) capture. There are many technical methods available for each group. These are fully summarized in Table II.2.1.

Trend extrapolation, pattern identification and probabilistic forecasting are all based on series of historical data that are analyzed in various statistical ways to arrive at forecasts of the future. In general, these techniques are the most commonly used and are the most comprehensible of forecasting methods.

The second group includes dynamic models, cross-impact analysis, KSIM, input-output analysis and policy capture. These methods are based on models or simulations of the phenomena to be forecasted. Because they demonstrate the interactions of the separate elements of a system as well as their combined overall effect, they are called structural models. These models are helpful in attaining a broad perspective and better grasp of the totality of a problem, in foreseeing effects that might otherwise be overlooked and in anticipating public reaction to alternative problem solutions.

Table II.2.1 Elements of Bulk Logistics Forecasting

Technique	Input	Output	Span	Example
Trend Extrapolation	historical data	array of time series forecast	(No specific span)	population estimates
Pattern Identification	historical data	array of time series forecast	short medium	commodity demand
Probabilistic Forecasting	historical data	various sets of probability matrices decision tree, etc.	(No specific span)	risk analysis
Dynamic Model	historical data	results of various alternative growth and decline of the system variables	long	water resource planning
Cross Impact Analysis	events and their effects	table showing interaction among items	(No specific span)	estimates of impacts on the project from occurrence of lower population rate
KSIM	variable and its value	numerical forecasts	long	impacts on deep water ports from new policy
Input-Output Analysis	sectors and amount of transaction	input-output table showing interrelationship among sectors	short medium	estimates of output increased by additional demand
Policy Capture	preference of participants	graphics illustrating weights and functions	(No specific span)	measurement of the relative preference of individuals for competing issues
Scenario	data and information base	formal documents (definition, assumption, data, findings, etc.)	long	scenarios for future growth pattern
Expert Opinion Method	opinions of experts	varies	(No specific span)	future of American water resource
Alternative Futures	historical data	varies	medium long	alternative future of inland waterway traffic
Values Forecasting	survey data	document (generalization and prediction about behavior)	(No specific span)	forecasts of changes in peoples' lifestyles

Source: Handbook of Forecasting Techniques,
Stanford Research Institute, 1975

The last group includes scenario, expert opinion method, alternative futures, and values forecasting. This kind of forecasting tends to be more global, more qualitative, and "softer" than more conventional approaches. In general, these are the least developed of the forecasting techniques.

Policy capture methods are based on the presumption that policies and plans tend to come true and that determining what they are and what their goals are provides a sound base for a forecast. A variant of this is the expert opinion method. This method assumes that experts in the field can base their opinions on extensive knowledge of the field and hence make good forecasts.

Modelling can be extremely productive because it encourages thinking about the causes of events. This can be invaluable, especially if it can be communicated outside the model which is being created. One way to do this would be to provide a complete statement of the model's assumptions in simple language. Models frequently rule out relationships. One might suppose, for example, that orders for new ships are related to the average age of the fleet. The idea being here is that new ships are ordered to replace worn out ones. All attempts to model the shipbuilding market have shown that this is not the case; rather, new orders are closely related to current revenues.

II.3 Market Share Estimates

A product's market share is the percentage of the total market serviced by that product. Major markets are generally defined by the type of product (such as fuel oil) and submarkets by areas of differing elasticity of demand. Thus, the ship fuel market and the home heating oil market are different submarkets because of the different elasticity of demand for the product, even though the product itself is the same. Depending on the circumstances, a bulk logistics system's market share may be based on the total market or on a submarket. In discussions of market share it is important that the market under consideration be rigorously defined because of a possible confusion of market share growth with a total expansion of the market.

Confusion between growth of market share and expansion of demand is common, especially in Marine Transportation. For example, people who view the container trades as a self-contained market would tend to see good prospects for expansion based on the historic rapid increase in container traffic. While those people who view the fundamental market as general cargo would see that the volume of general cargo in international trade is growing slowly. Also they would note immediately that the limits of expansion of the container trades were being rapidly approached despite the high growth rate. Failure to see this point clearly has caused much overinvestment in ships of nearly every type and in the shipyards where they are built.

Market shares change for a variety of reasons. A major reason is that of diverted demand. Examples of diverted demand are the substitution of container vessels for general cargo ships and the penetration of bulk carriers into the grain trades, again at the expense of general cargo ships. In many cases, this diverted demand results from dramatic technical innovation of ship type presenting vastly different requirements for port capacity. In the case of the introduction of the container ship, VLCC, and large bulk carrier, older port facilities became unusable and totally new ones were required. Estimating the rate at which this technical progress occurs is of some importance in making the proper decision about the timing of the building of new port facilities and ensuring that surplus facilities are not built because of an over-estimate of the demand for the new facility.

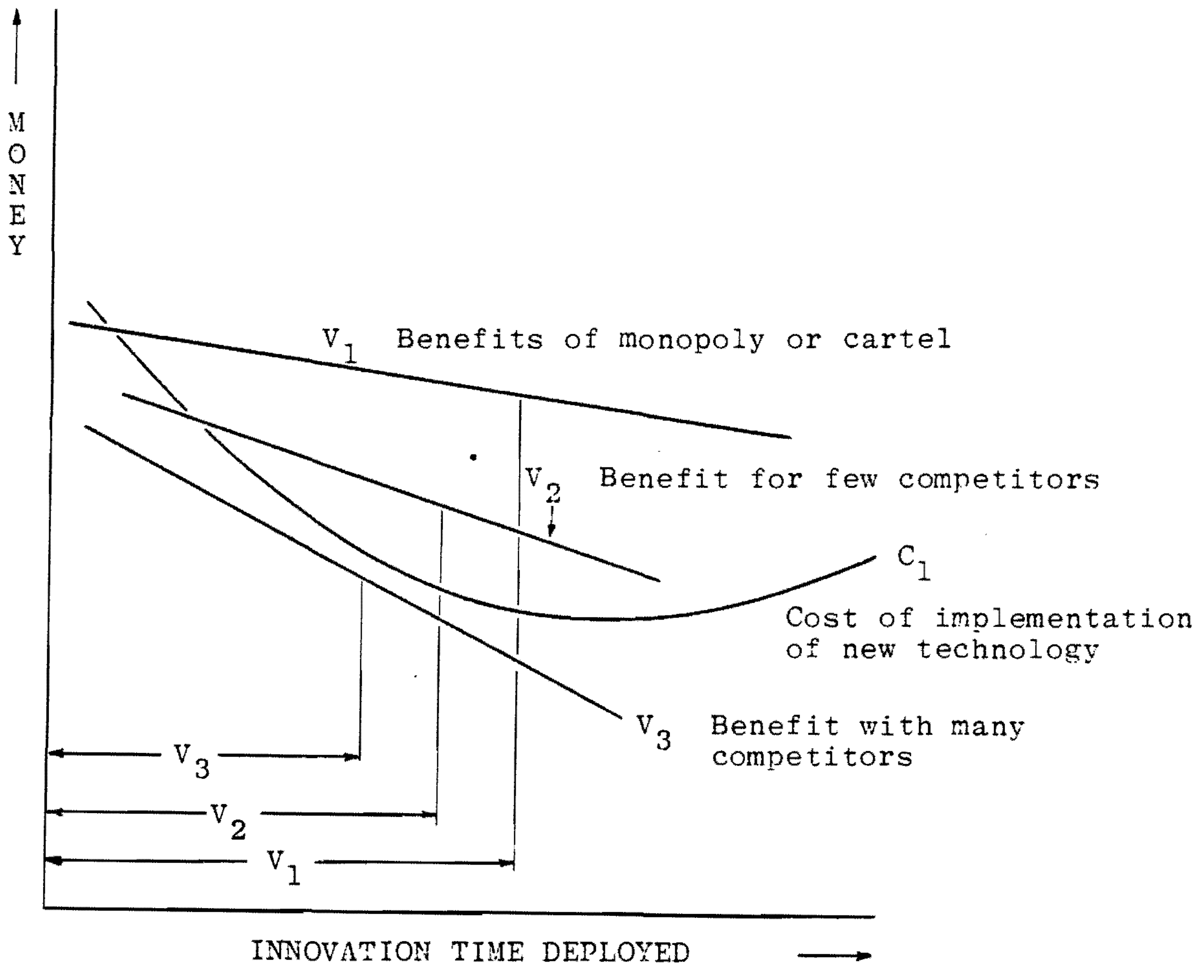
One of the factors which differentiates bulk shipping from liner shipping is that technical innovation occurs at a faster rate than in the liner trades. For instance, it required fifteen years for containers to become commonplace after proving the concept in the trades between the United States and Hawaii and Puerto Rico. By way of contrast, the concept of the slurry carriage of ore was deployed in less than five years and the expansion of maximum tanker sizes from 50,000 tons to 250,000 tons in less than seven years.

The reasons for this are not entirely clear, but it is likely that the structure of the market for the services of these ships plays a major role. The liner trades are highly cartelized while the bulk trades more closely resemble a free market. This distinction is not always clear-cut as trades in many bulk commodities such as grain and gypsum are highly concentrated (even though the sources of the ships themselves may not be).

Consider Figure II.3.1. Here the cost of installing new technology is given by a cost curve as a function of time. The cost of earlier implementation is higher because of increased technical risk, crash programs, the cost of scrapping obsolete equipment, etc. The cost far in the future rises primarily beause of the cost of maintaining a capability in unused technology.

Assuming that investment decisions are made to maximize the surplus of revenues over cost, the timing of the deployment of the technology depends primarily on the benefits. Three benefits curves are postulated.

FIGURE II.3.1 COSTS AND BENEFITS FROM NEW TECHNOLOGICAL INNOVATION



The top V_1 is the base and represents gains accruing to a monopoly or tightly controlled cartel. The time when the new technology is deployed is the point where the difference between the two curves is at its greatest. The curve is downward sloping because of the increased time available to reap benefits if the technology is deployed earlier and possibly because of the improved competitive position of the firm.

When more firms are involved in the trade, the benefits curves will be shifted down because of the decreased market share and will have a steeper slope because earlier deployment increased a firm's market share at the expense of its competitors. This benefits curve is denoted V_2. Note that with an increase in the number of firms technical innovation occurs earlier. As the number of firms increases, the combined shifts will result in a benefits curve V_3 for which the introduction of new technology results in losses. In this case firms will abandon the trade if the losses are large enough or deploy the new technology even earlier to minimize losses.

It is likely that the liner industry is represented by curve V_1, the bulk shipping industry by either curve V_2 or V_3, and the tanker sector by curve V_3. From this standpoint it is probable that innovation in the bulk shipping industry will begin earlier and be completed more rapidly than in the liner sector.

This indicates that basing forecasts on the historic rate of adoption of a new idea in the bulk trades is risky. The actual popularity of the idea may be misjudged by the short-term rate at which it is deployed. In other words, one should be cautious about adopting it too quickly. This note of caution applies especially to decisions regarding the dredging of ports for extremely large ships.

II.4 Bulk Logistics Forecasting

The goals of bulk logistics forecasting can be divided into sector planning, bulk shipping planning, and bulk port planning as follows:

A. Sector Planning

(a) Provide estimate of commodity sales or purchases

(b) Provide estimate of income or expense projections

(c) Provide basis for investment in industrial facilities

(d) Provide estimate of transportation requirements by mode

B. Bulk Shipping Planning

(a) Provide projection of shipping requirements

(b) Determine vessel types and sizes required

(c) Provide information to plan procurement of vessel

- Purchase new
- Purchase used
- Time charter
- Spot charter
- Contract of affreightment

(d) Estimate cost of providing marine transport

C. Bulk Port Planning

(a) Depth and geometry of dredging

(b) Determine areas in port devoted to specific activities

(c) Determine number and type of berths required

(d) Determine number, type and size of cargo handling equipment procured

(e) Determine port interface and support requirements (e.g., generating capacity installed in the port)

(f) Determine the market serviced by the port

Demand mechanisms in the bulk trades fall into three general categories:

- Normal - determined by existing mechanisms and growth rates
- Diverted - determined by competition
- Generated - determined by industrial development

These three mechanisms produce different growth patterns. Normal growth assumes that general demographic factors such as GNP or population are good indicators of traffic and cargo flow. This could apply to automobiles, building materials, etc. Normal growth assumes that trade growth is independent of investments in the logistics systems.

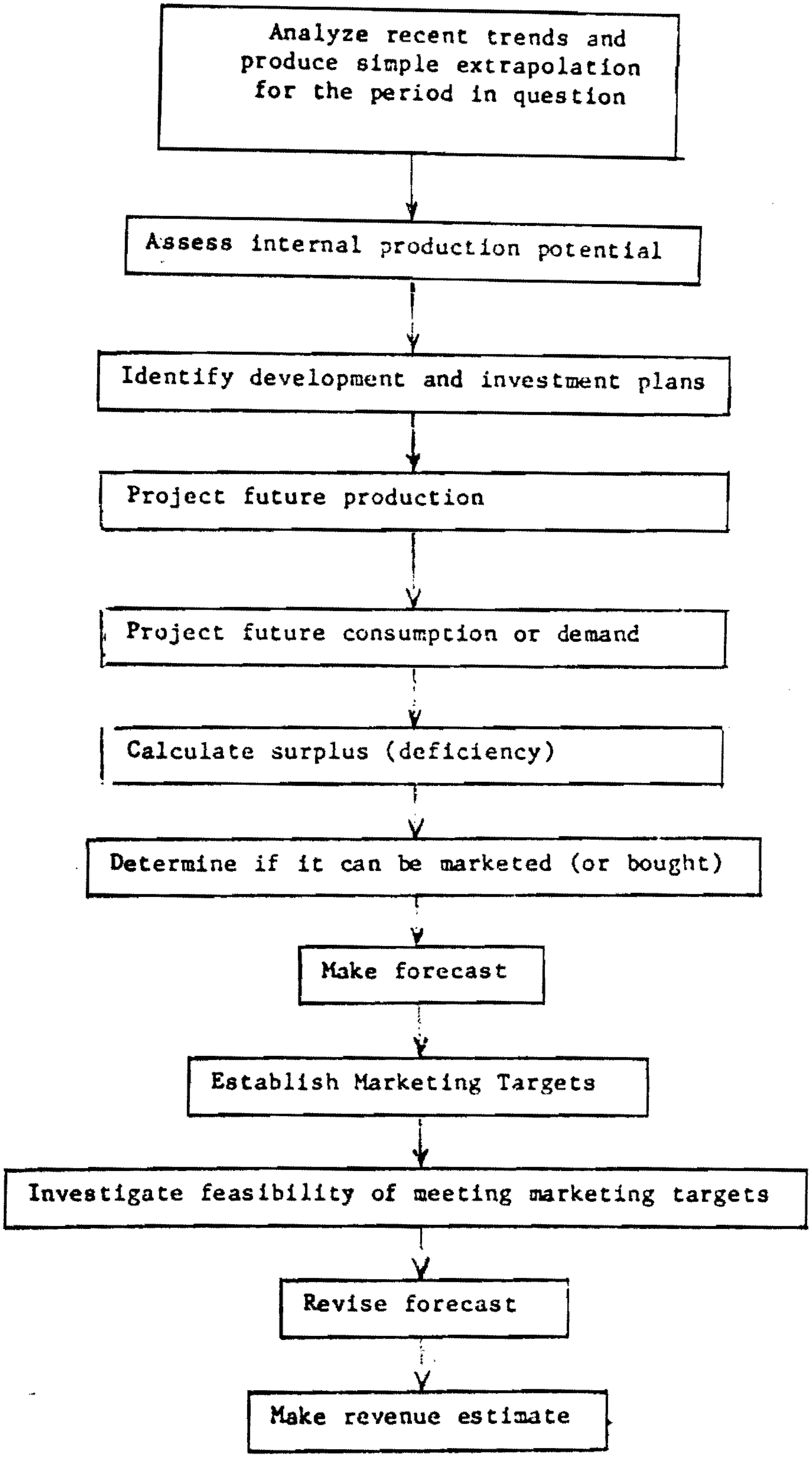
Figure II.4.1 offers a general method to prepare a forecast for a bulk port facility. The goal of this procedure is to determine, first, what the potential market for the bulk trade is. Then, to evaluate the actual commercial prospects of servicing the trade and, finally, to use this information to estimate actual sales.

In step one a naive forecast is made using the general techniques described in the section on predicting potential volumes. In step two the existing production capacity is inventorized and evaluated. A similar exercise is performed in step three for planned industrial development.

Projections are then made for future consumption and production and subsequently checked for plausibility by determining if sales or purchases of the difference are possible on the target markets. This, then, is used to make a raw forecast which is used as a base for the marketing analysis. Marketing targets, next, are established and a formal marketing plan is developed to ensure that the marketing targets are reasonable. This marketing plan is translated into a revenue estimate which can be used for economic project evaluation. The projected maximum flow achieved when marketing efforts no longer yield increases in sales is used as a basis for the engineering design of the facility.

In essence the method consists of extrapolating past data and

Figure II-4.1 Elements of Bulk Logistics Forecasting



checking the plausibility of the extrapolation. There are a number of methodologies that produce valid extrapolations when the problem meets certain assumptions. Not all of them give the same answer, so the selection of the method used is highly important.

Figure II.4.2 is a schematic representation of the process used in developing fleet projections for bulk shipping.

II.5 Bulk Traffic Forecasting in Ports

In any port analysis determining the actual as well as the potential port hinterland is essential. Port hinterland or area of influence studies are therefore required to determine the geographic area dependent on such port facilities. Part of a hinterland study is the evaluation of developments of socio-economic activities likely to affect the demand for port commerce (and, in turn, be affected by it).

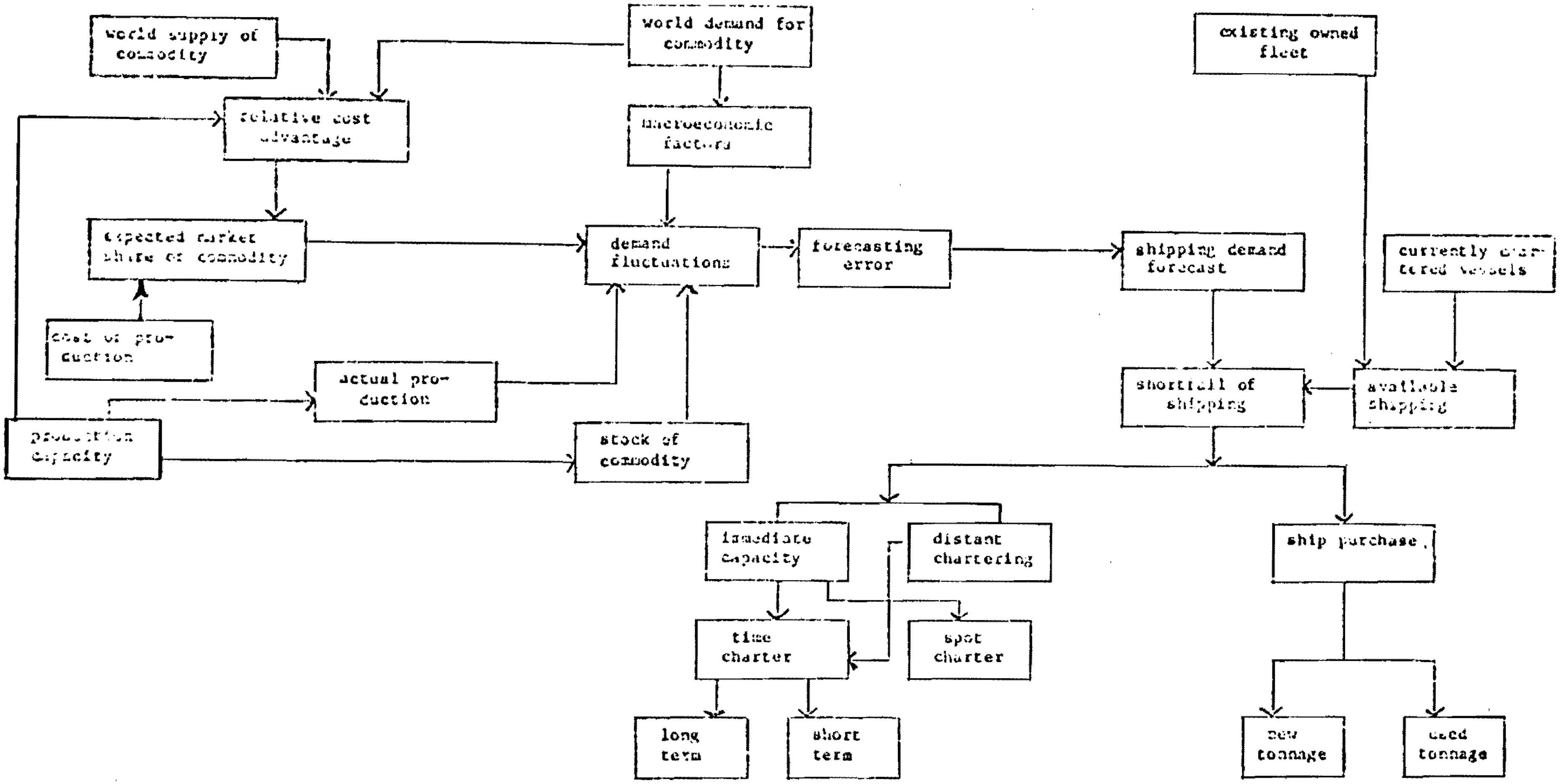
Port tributary or hinterland area determination is often performed on the basis of factor such as the following:

- Equal Transport Cost
- Equal Distance
- Equal Time
- Interport Analysis
- Competitive Factors

The required data for such an analysis usually consists of the following:

- Origin - Destination Records
- Imports and Exports
- Transport Costs/Time/Special Requirements
- Port Costs (Direct - Indirect)
- Competing Ports

FIGURE II.4.2 FORECASTING DRY BULK SHIPPING DECISION MODEL REQUIREMENTS



- Entrepot Trade
- Port Hinterland Changes
- Demographic Factors
- Employment
- Per Capita Income (PCI)
- PCI Growth Rate
- Employment Projections
- Feeder Transport
- Rail / Road / Barge Traffic
- Cost / Capacity of Systems
- Technology Introduction
- Ship Arrivals
- Routes Served and Rates Forecasts
- Transshipment Traffic
- Inter and Intra-port Transport

A regional or hinterland economic analysis normally yields the best projection with substantial supporting evidence and, as a result, develops high user confidence. Such an approach examines all the major factors determining the cargo and traffic flow and estimates how the current patterns will be projected into the future.

An in-depth analysis of a single commodity should attempt to identify the principal causal relationships and determine the key factors that contribute to movements of goods through the port. Among the causal factors that should be considered are the following:

- Principal sources of the commodity together with information on the present and future capacities of these sources conditioned on various developments (such as port expansion).

- Principal components of major domestic and foreign demands with respect to the nature of the demand, the product end-use, the product form and the elasticity of the demand.
- Constraints on cargo flow imposed by regulation or other constraints to the free flow of goods.
- Available modes of transportation, both complementary and competitive, their capacity and relative appeal.
- Impact of technology, both current and anticipated with regard to the production, distribution and consumption of the cargoes under study.

Only after a clear understanding of the commodity flow pattern has been achieved can one prepare models that relate levels of domestic and world-wide demand and supply of potential interest to a port.

III. BULK SHIPPING ECONOMICS

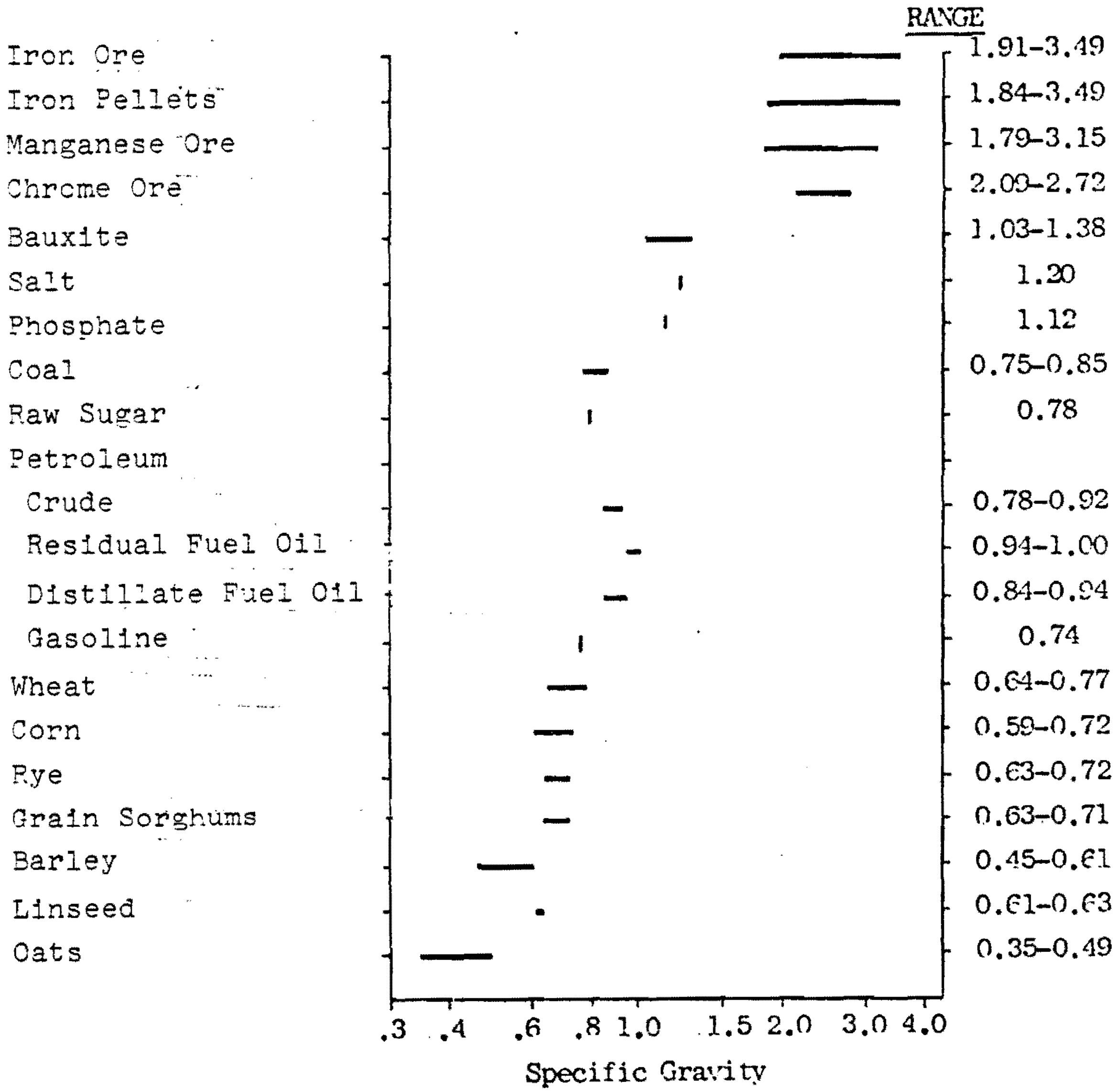
III.1 Bulk Carriers and the Bulk Carrier Fleet

Bulk cargoes are generally powders, granules or lumps stowed in the vessel without packaging. Typically, they are dry and should be kept dry while they are being handled. They are often shipped in grades, and the lot size is usually large enough so that a single grade will fill the hold. However, grades can also be separated with tarpaulins. The materials are strong enough so that they can fill an entire hold without support. Although the cargoes are loaded in a simple way, the loading technique is quite sophisticated because bulk cargoes tend to move with the ship when it rolls. Recently, considerable research has been done to find ways to prevent this movement from damaging the ship.

The most important difference between bulk cargoes is their stowage factor (called bulk density in literature about mining and materials handling). The stowage factor ranges from 14 cubic feet per ton for iron ore to over 60 cubic feet per ton for wood chips. Figure III.1.1 lists the specific quantities of common bulk cargoes. Bulk cargoes also differ in the lot sizes in which they are shipped, the hazards (such as fire) to which they are prone, and the type of handling equipment that should be used. However, the shipment size and stowage factors are the most important details to consider in designing bulk carrying ships and other portions of the bulk logistics system.

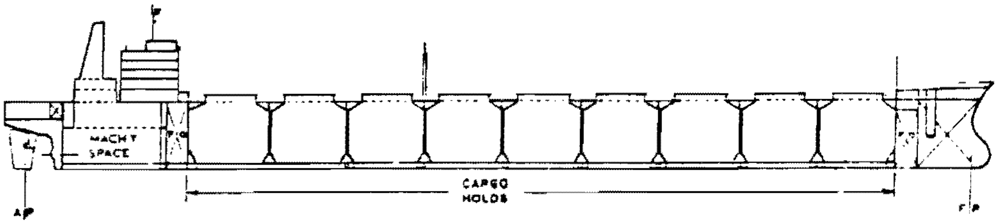
Basically there are three types of bulk carrying ships. Pure bulk carriers are designed to carry only bulk (see Figure III.1.2), small general purpose ships are designed to carry a variety of cargoes besides bulk (see Figure III.1.3), and combination carriers are designed to carry

FIGURE III.1.1 DENSITIES OF BULK CARGOES



Source: World Bank staff.

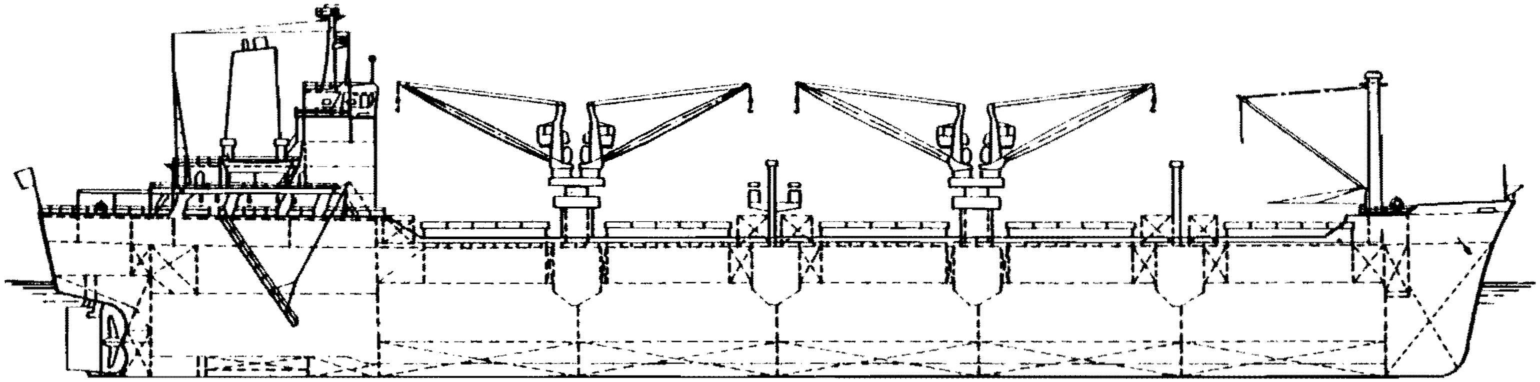
FIGURE 111.1.2 - GEARLESS PURE BULK CARRIER



Length Overall	186.5 m (611.8 ft)
Length Between Perpendiculars	178.0 m (584.0 ft)
Beam, Molded	28.4 m (93.2 ft)
Depth, Molded	15.3 m (50.2 ft)
Draft, Molded Designed	9.8 m (32.0 ft)
Draft, Molded Scantling	10.7 m (35.2 ft)
Sea Speed, Knots	16.9
Deadweight At Design Draft	32,100 Tons
Gross Tonnage U.S. (Approx)	23,500 Tons
Net Tonnage Panama Canal (Approx)	19,000 Tons
Net Tonnage Suez Canal (Approx)	21,000 Tons
Cargo Hold Capacity (Grain)	45,417 m^3(1,603,880 ft^3)
Water Ballast Tank (Full)	19,763 m^3(697,920 ft^3)
Fuel Oil Tank	2,010 m^3(70,990 ft^3)
Fresh Water Tank	230 m^3(8,120 ft^3)
Diesel Oil Tank	190 m^3(6,710 ft^3)
SHP, ABS Max	15,288
Crew Accommodations	26
Total Accommodations	34
Propeller (1), Blades	5
Machinery, Twin diesel engines	

Source: World Bank staff.

FIGURE III.1.3 TYPICAL DRY CARGO SHIP



DIMENSIONS AND TONNAGES

G.R.T: 13200
D.W.T: 20000
L.O.A: 161.5m
L.B.P: 152m
BREADTH: 22.8m
DEPTH: 13.6m
DRAFT: 9.8m

MACHINERY DETAILS

MAKE: Burmeister & Wain
TYPE: 7K67GF
ENG. BLDR: Hitachi Zosen
OUTPUT: 13100bhp @ 145 rpm
FUEL CAPACITY: 1610 cu.m.
CONSUMPTION: 46.5 t/day
RANGE: 12000mls
GENERATORS: 3x 400 kW
SPEED: 16.25

CARGO DETAILS

GRAIN: 26900 cu.m.
BALE: 25000 cu.m.
SADDLE TANKS: 2600 cu.m.
CONTAINERS: 305
NO. OF HOLDS: 5
NO. OF HATCHES: 5
TYPE OF HATCH: Single

CARGO GEAR: 2 Cranes
2 x 10.5 T
2 Derricks 10T

HATCH DIM: (1) 13.6m x 9.94m
(2)-(5) 13.6m x 11.6m

OTHER DETAILS

No. of Crew: 33
Classification: ABS

REMARKS

Conforms to St. Lawrence Seaway Regulations
185 containers can be stowed in the hold, 120 on deck
Alternative Classification - LR, NV.

Source: World Bank staff.

oil as well as bulk.

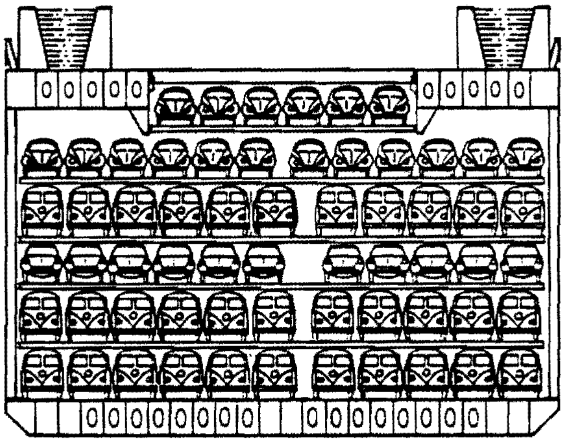
Even the pure bulk carrier is, to some extent, flexible because it can be cheaply converted to carry containers. Although such conversions do not use either the volume or the deadweight of the ship well, they can be competitive on short routes when charter rates for bulk carriers are low. Pure bulk carriers are sometimes fitted with portable car decks, allowing automobiles to be carried. Ships of this type are somewhat out of favor now because the hold ventilation system cannot prevent condensation from damaging the cars. These carriers are rarely fitted with cargo gear, as it interferes with more efficient, shore-based loading and unloading equipment.

The smaller, general purpose ships are usually fitted with derrick-type cargo gear. The cargo gear allows the ship to work cargo where bulk facilities do not exist and to perform as a general cargo carrier. Much ingenuity has been put into the design of these vessels to allow bulk cargoes to be loaded without trimming. (Trimming means filling up small voids left in the cargo hold because the ship's structure casts shadows in the stream of cargo being loaded, hence preventing large ship loaders from filling the hold completely). Figure III.1.4 shows this type of a ship fitted with car decks.

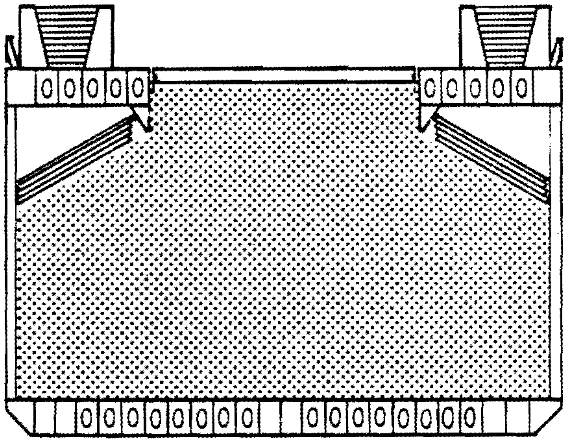
Because the structure and machinery of tankers and pure bulk carriers is similar, certain aspects of the two were combined and the combination carrier evolved. Building this dual-purpose ship costs about ten percent more than a single-purpose ship. Having a dual-purpose ship allows the owner to operate in whichever trade offers higher freight. Results with this type of ship have been mixed because, despite their flexibility, these ships generally operate in one trafe for

FIGURE III.1.4

CAR DECK IN MEDIUM-SIZED GEARED BULK CARRIER



Employed as a car carrier.



Employed as a bulk carrier.

Source: World Bank staff.

extended periods of time, and the reliability of the equipment intended for the other trade is reduced from lack of use. To ready the ship for a change in trade often requires a shipyard overhaul. Such an overhaul may increase the cost of the trade to the point where the new trade may no longer be justified by the difference in freights.

Because bulk materials vary in density, they require different amounts of space for the same material weights. Fifty thousand tons of iron ore fills about 700,000 cubic feet, 50,000 tons of grain 2,250,000 cubic feet and 50,000 tons of wood chips over 3,000,000 cubic feet. As a result, bulk carriers tend to be specialized and carry cargoes that fall within only a small range of stowage factors. However, a few designs exist for "universal" ships which are suitable for a wide range of cargo densities.

Bulk cargoes can be carried in general cargo ships (so-called hybrid liner/bulk), but special arrangements to trim the cargo and to restrain it mechanically (with "shifting boards") make their use costly.

The LASH (lighter aboard ship) vessel is ideal for carrying small consignments of bulk cargoes. As the name implies, these ships carry barges loaded with various cargoes. However, the general trend has been to convert LASH vessels to container ships, which indicates that the technical merits of this ship do not compensate for its high cost and the cost of supporting barges.

Bulk carrying ships usually are slow vessels that have service speeds between 14 and 16 knots. The low value of bulk commodities and the organized trades, in which they move, do not provide incentives for speed. Because fuel costs are high, new bulk ships tend to have even lower speeds in order to conserve fuel.

Grain has been carried in great volumes in tankers. The grain is loaded and discharged through manholes in the deck. This is not as efficient a process as is possible with a shore-based unloading facility for normal bulk carriers. Figure III.1.5 compares grain carriage in tankers with carriage in other vessel types.

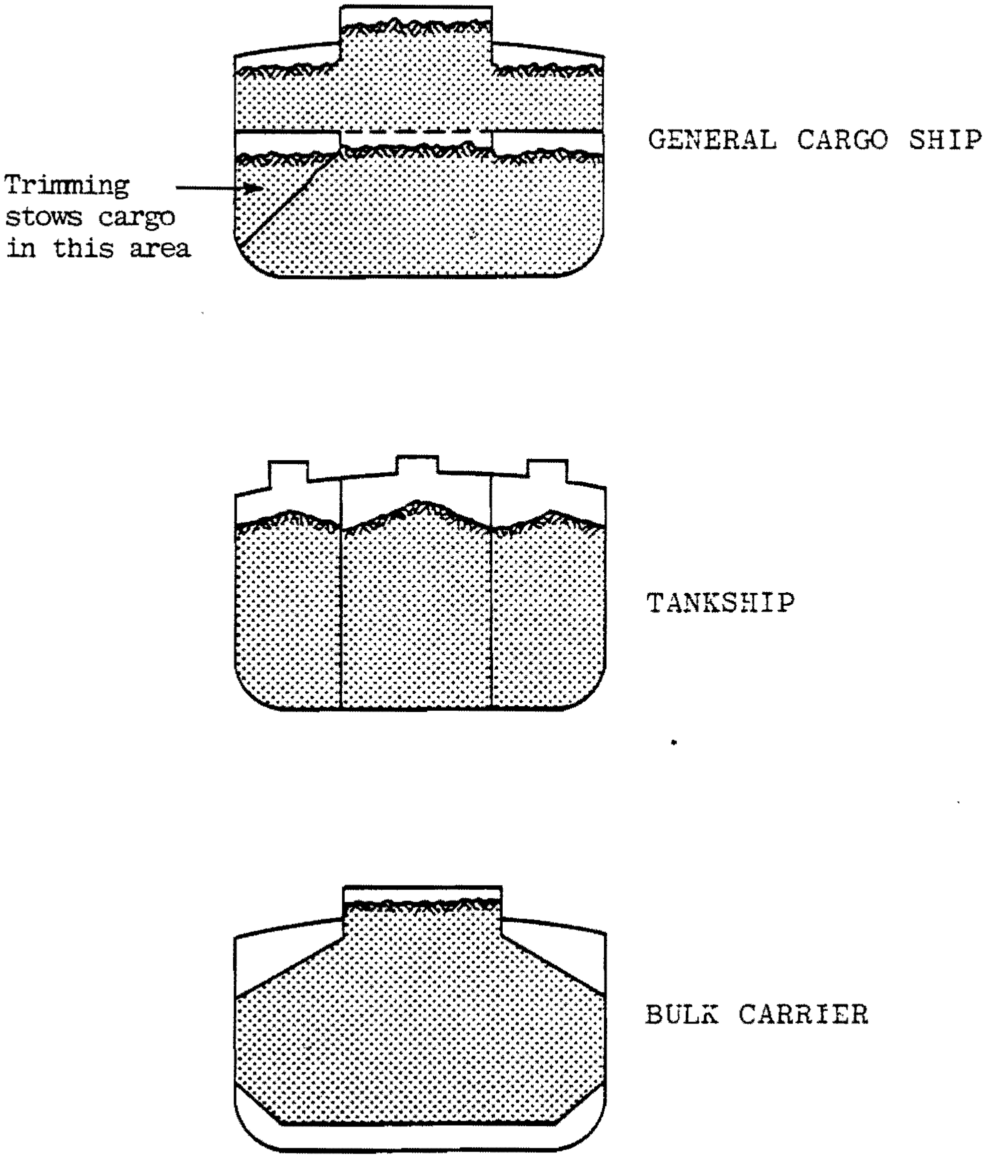
Moving grain in tankers does create an extra cost--that of cleaning the vessel before loading. This cleaning process involves removing loose, rusted steel, as well as oil residues, and it may require up to two weeks at berth. Cleaning becomes especially burdensome after several grain cargoes, as the grain draws the water from the rust scale, which loosens it from the base metal.

Figure III.1.6 breaks down different types of bulk carriers and their numbers. There are a few special types of bulk carriers, which can only carry one type of cargo. Lumber carriers, otherwise, provide large hold spaces for a given deadweight.

Ore carriers are specially designed to provide small spaces in the cargo holds while having sufficient displacement to support the ship and cargo. The ore is carried high in the ship to minimize ship motions and to keep the cargo from shifting in the holds. Figure III.1.7 shows the difference between the mid-ship section of an ore carrier and that of a general purpose bulk carrier.

FIGURE III.1.5

GRAIN STOWAGE IN TANKERS COMPARED WITH OTHER SHIP TYPES



Source: World Bank staff.

FIGURE III.1.6 APPROXIMATE COMPOSITION OF THE WORLD'S BULK FLEET

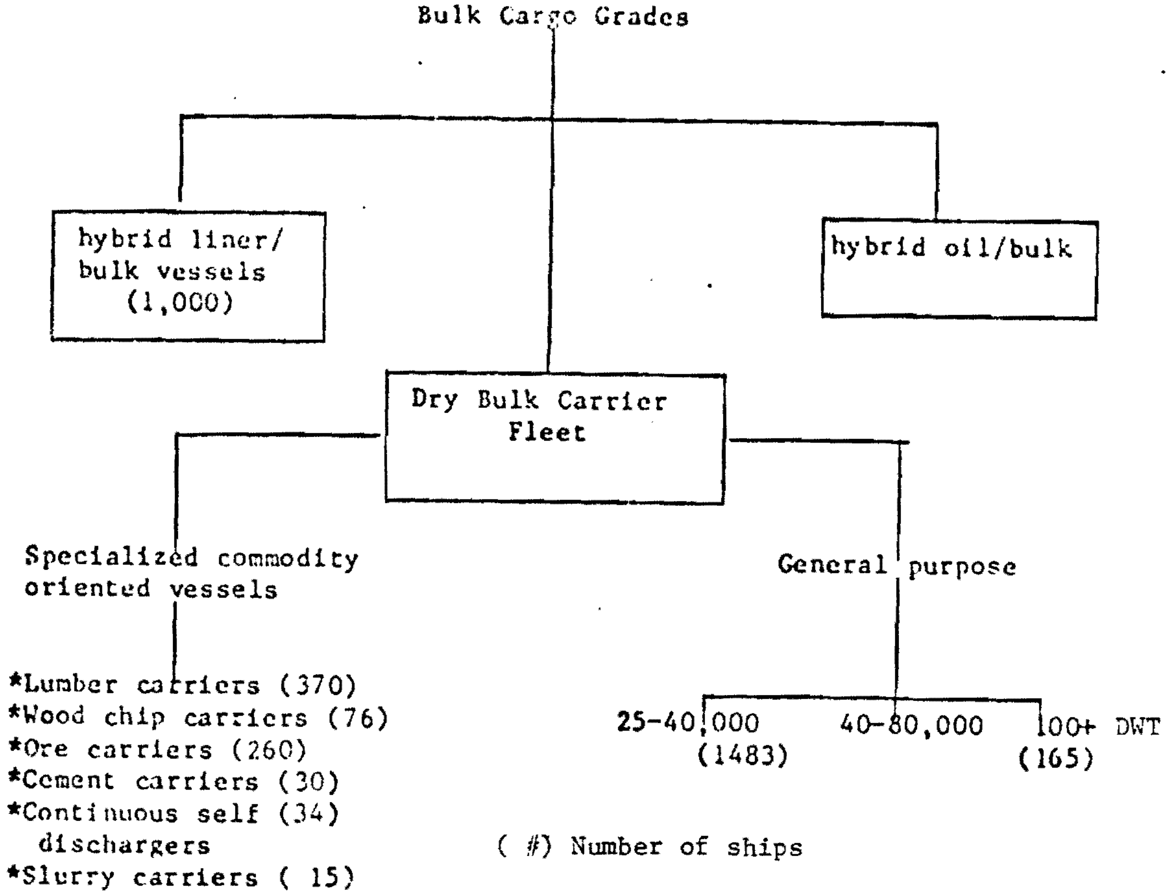
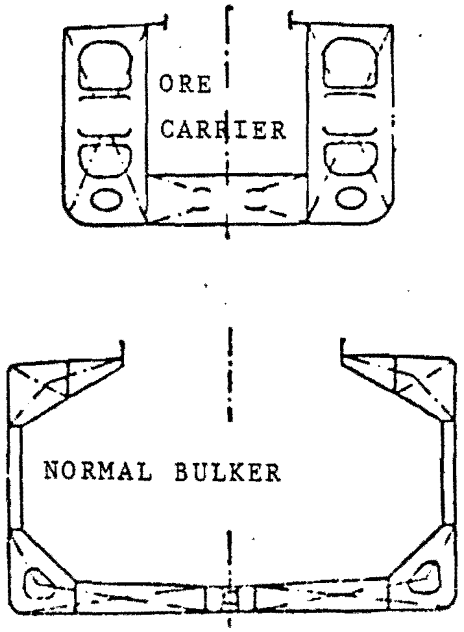


FIGURE III.1.7 COMPARISON OF ORE CARRIER WITH NORMAL BULK SHIP



Length	244.39M (801.79 ft.)
Beam	32.31M (106.00 ft.)
Depth	19.76M (64.83 ft.)
Draft	13.48M (44.21 ft.)

Length	281.94M (925.00 ft.)
Beam	44.20M (145.00 ft.)
Depth	24.99M (82.00 ft.)
Draft	18.46M (60.56 ft.)

Source: World Bank staff.

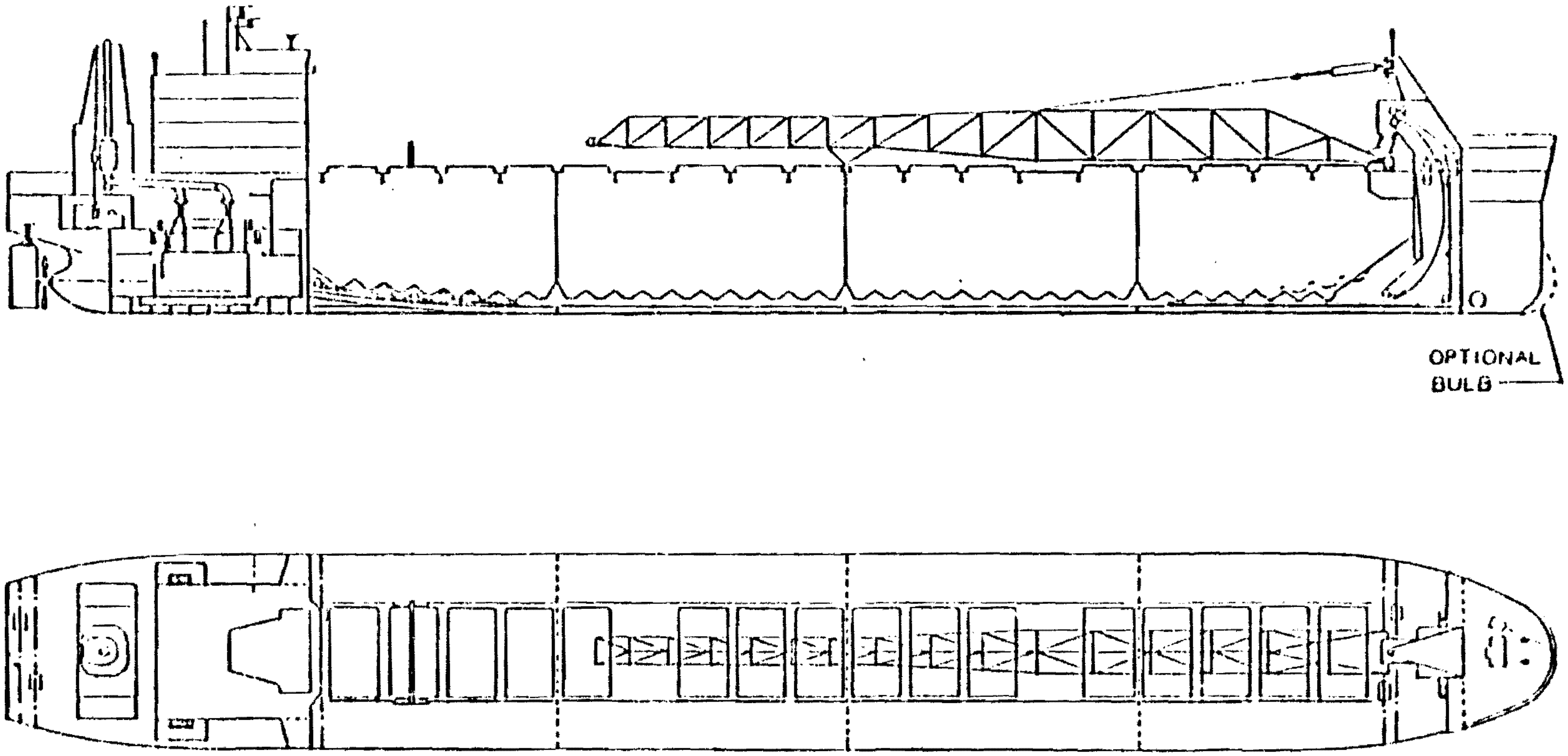
Continuous self-discharging ships have internal conveyors and discharge booms to unload cargo to the harbor facility. They are common on the Great Lakes and can achieve high unloading rates. There are about 34 in ocean service and these are optimally used when a single ship delivers cargo routinely to many ports, for example, coal shipments to power plants or fertilizer distribution. The largest self-discharging ship is a 150,000 ton salt carrier. Figure III.1.8 provides additional information about self-discharging ships.

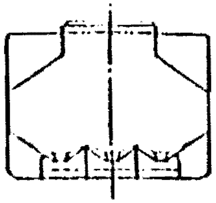
A sixth special purpose bulk carrier is the slurry carrier. These ships handle cargo that is a mixture of finely ground powder and water. Iron ore, coal and kaolin clay are sometimes handled as slurry. There are some disadvantages to this process. First, it is never possible to remove all the water from the slurry once the ship is loaded, so only part of the cargo carried is the actual commodity; the rest is water. Since a slurry is specialized, this vessel type is currently limited to few trading opportunities.

General purpose bulk carriers come in three general sizes - those able to cross the St. Lawrence Seaway, those which are just able to pass through the Panama Canal, and those that are even larger. Only a few vessels are so large that they cannot pass through the Suez Canal. Panamax bulk carriers are of two kinds--those which can manage the Panama Canal loaded and those which can only manage it in ballast.

Table III.1.1 lists bulk and combined carrier fleets by size. The majority of the bulk carrier fleet is under 60,000 tons deadweight, with 71 percent of the capacity beneath the 60,000 dwt mark. Approximately 94 percent of the ships in service are less than 80,000 tons deadweight. To be competitive as tankers, combined carriers must have larger

FIGURE III.1.8 SELF-DISCHARGING VESSEL





LOA, MLD.	634'-0"	CARGO DWT, COAL	29,998 LT. (33,597 ST.)
LBP	621'-6"	CARGO HOLD VOLUME	1,276,700 CU FT.
BEAM, MLD.	78'-0"	UNLOADING RATE	3,500 ST./HR.
DEPTH, MLD.	56'-0"	UNLOADING BOOM	250'-0"
LOADED DRAFT COAL	31'-4"	SHP	8,500
DISPLACEMENT	36,430 LTSW.	SPEED LOADED	14 KNOTS
BALLAST DRAFT	15'-6"FWD., 20'-10" AFT.	BOW THRUSTER	1000 HP. OPTIONAL
TONS PER INCH	112 LTSW.		

Source: World Bank staff,

NOTE: COAL CAPACITY FIGURED AT 38 CU.FT./ST.

Table III.1.1 Size Distribution of Bulk Carriers, January 1983 (Figures in number of ships and 1,000 dwt)

Size Group in dwt	Tankers		Combined Carriers		Bulk Carriers		Total	
10 - 18000	250	3612	3	45	744	11252	997	14909
18 - 25000	312	6565	5	114	912	19481	1229	26160
25 - 40000	626	20227	3	93	1680	52041	2309	72361
40 - 50000	93	4094	9	432	281	12353	383	18879
50 - 60000	163	8789	12	669	260	14202	434	23660
60 - 80000	252	17347	69	5096	400	25790	721	49233
80 -100000	311	27502	37	3294	52	4504	400	35300
100-150000	247	31047	126	15122	184	22804	557	68973
150-200000	80	13066	70	11404	25	4211	175	28681
200-250000	201	46169	18	4157	6	1325	225	51651
250-300000	294	79235	10	2719	1	268	305	82222
300-400000	83	28325	-	-	-	-	83	28325
400000	33	14945	-	-	-	-	33	14945
Total	2944	300923	362	43145	4545	169231	7851	513299

Source: World Bulk Fleet, Fearnleys, Oslo, August 1983.

capacities than pure bulk carriers. In fact, 60 percent of the combined carrier fleet has a mean deadweight between 100,000 and 200,000 tons.

Bulk ports should be designed to handle both "random" arrivals and regularly scheduled large bulk carriers in the quantities in which they arrive. When considering the possibility that a port will be required to handle exceedingly large ships, their availability in the marketplace and economic desirability should be noted. Large vessels usually have long-term charter parties for specific work, at least when they are new, because a firm bankable charter is required as collateral for the vessel's financing.

Table III.1.2 gives the dimensions for common, series built bulk

Table III.1.2 - Bulk Carrier Dimensions for Standard Classes

SHIP DESIGN	DWT	VOLUME (ft^3/ton)	LENGTH (ft)	BEAM (ft)	DRAFT (ft)	SPEED (kts)	BHP
a and p sd-14	14861	55.5	451.1	66.9	29.2	15.1	8600
bv liberty	14960	55.6	433.0	68.9	30.1	16.0	8400
ihi freedom mk ii	15353	57.0	440.9	68.9	29.5	14.5	6850
sasebo (mp) 16	15800	52.3	479.0	75.8	31.5	16.6	11400
hyundai 18b	17716	47.2	465.9	74.1	30.1	14.6	8000
mitsui concord 18	18208	51.9	458.3	65.1	30.5	15.2	8300
boelwerf 19	18700	56.7	504.5	75.0	33.7	15.5	12400
nippon kokan kk 20	19192	56.5	478.0	75.0	30.6	15.2	9000
hitachi zosen ut-20	20000	56.7	498.7	74.8	32.0	16.2	13100
nippon kokan kk 21	21349	47.1	478.0	75.0	32.5	15.0	9000
sumitomo 22	21500	50.1	506.9	74.8	31.5	15.3	11400
horten verft 22	21602	47.2	496.0	75.0	31.9	15.2	10000
ihi friendship	21751	53.7	509.8	75.1	30.8	15.0	7800
mitsui 22	22000	46.1	518.3	75.0	31.1	15.0	9400
ihi fortune	22000	52.9	510.0	75.0	32.3	15.0	8000
hyundai 24b(11)	24113	51.2	550.0	74.8	33.3	14.0	9400
sumitomo 25	24500	55.2	551.1	75.3	31.9	15.1	11400
harland & wolf 35	34445	45.4	590.6	91.8	34.4	15.2	11400
aesa	34447	44.2	606.9	79.4	36.4	15.2	11540
emaq-brazil 35	34447	51.6	600.4	90.5	33.9	15.0	02000
nippon kokan 35	34666	43.5	547.9	91.2	36.6	15.0	12000
sasebo 35	35400	49.3	577.4	91.2	35.5	14.7	12000
hyundai 35b	35431	47.9	550.7	105.8	35.7	15.0	11200
mitsubishi 35	35500	49.3	577.4	91.2	35.5	15.1	12000
helenic shipyards 37	36415	47.4	610.2	86.9	37.3	15.3	12000
korea shipbuilding	37000	48.1	570.0	105.8	35.5	15.4	11200
sanoyasu 40	40386	48.8	567.6	90.5	39.7	15.0	14000
swan hunter 40	40443	46.0	590.5	97.7	37.1	14.9	14000
stocznia paryskiej	53147	53.6	674.2	105.6	40.7	16.0	17400
mitsui	56930	50.7	688.9	105.6	40.0	15.7	16800
sumitomo 59	58100	48.1	715.2	105.6	40.0	15.1	14404
hitachi hi-bulk	59775	46.2	705.4	105.6	40.8	14.8	12200
burmeister&wain 60	59904	50.1	698.8	105.7	41.3	15.6	16650
nippon kokan kk 60	60035	49.1	721.8	105.6	41.0	16.0	17400
hyundai 60b	60528	45.9	705.3	105.6	40.9	16.5	16500
mirauviahi 63	62000	49.6	693.2	104.3	43.7	14.6	14000
harland & wolff 64	63675	45.6	721.5	105.8	42.5	15.2	16800
astano	69848	52.2	787.4	105.6	43.5	16.5	18400
gotabverken 72	70859	46.0	748.0	106.0	43.9	15.9	18500
sunderland 72	70918	47.0	715.2	105.7	46.0	15.0	20000
boelwerf 75	73812	42.8	761.1	105.8	45.6	15.0	19200
hyundai 76b	65261	43.8	775.5	105.6	45.2	15.6	20100
italcantieri 80	79800	44.5	813.6	105.8	45.9	16.0	20300

Source: U.S. Maritime Administration

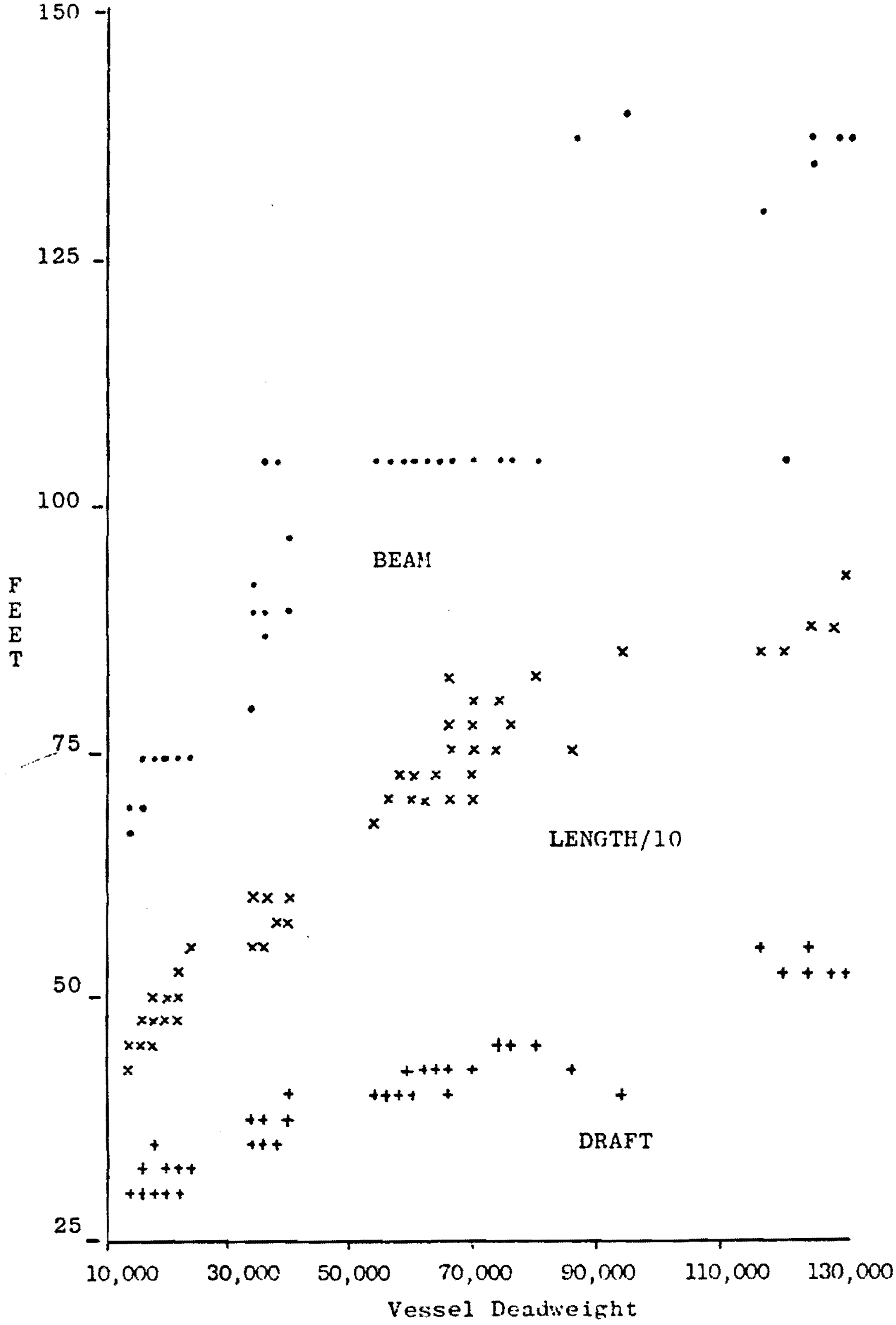
carriers up to the PANAMAX size. Figure III.1.9 present much of the same information on a graph plotted with typical larger vessels. Typical good practice design dimensions are shown in Figure III.1.10.

Virtually every dimension of those ships using shore-based cargo gear play a part in the design of harbor facilities. The beam of the ship is important because it determines the outreach (and cost) of ship loaders and unloaders. The hold's span length determines the length of crane rails (and support piers) for movable ship loaders and unloaders. It also determines what the dimensions (or number) of quadrant type ship loaders should be. The ship's draft determines harbor dredging requirements.

III.2 Efficiency in the Use of Bulk Carrier Tonnage

In liner shipping, because itineraries can be adjusted to meet existing demand, vessel utilization on outbound and inbound voyages can be high. In most tanker trades no return cargoes are available, and one leg of the voyage must be in ballast. The bulk trades fall in a middle category because cargo is frequently available for loading at ports not far from the vessel's discharge port. Because bulk cargo may not be available for prompt loading or may not have destinations appropriate for the vessels to resume their primary trade, vessels may pursue almost random trades to minimize steaming in ballast. A typical trading pattern for a small bulk carrier is shown in Figure III.2.1 and Table III.2.1. It is necessary to be able to arrange such cargoes in order to obtain the lowest cost operation of bulk carriers. An alternative to seeking return cargoes is to use larger vessels, as the costs of larger ships with a ballast leg will resemble those of a smaller ship

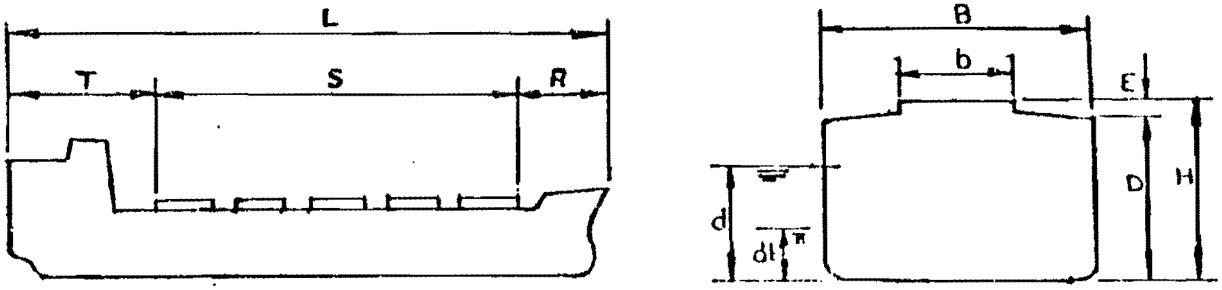
FIGURE III.1.9 BULK CARRIER DIMENSIONS



Source: World Bank staff.

FIGURE III.1.10

MAXIMUM GOOD PRACTICE DESIGN DIMENSIONS OF BULK CARRIERS



DIMENSION			SHIP SIZE (DEADWEIGHT TONS)										
			10,000	12,500	16,000	20,000	25,000	32,000	40,000	50,000	63,000	80,000	100,000
LENGTH	L		140	150	163	180	184	205	218	235	245	265	270
LGTH. FORECASTLE	R		14	15	16	18	19	20	22	24	25	26	27
SPAN OF HOLDS	S		101	102	118	130	140	143	157	169	176	191	191
LGTH. OF HOUSE	T		25	27	29	32	35	37	39	42	44	48	49
BEAM	B		19.0	20.2	21.8	23.2	25.0	27.0	29.2	31.7	34.5	37.3	40.3
HATCH WIDTH	b_1		9.0	9.4	9.8	10.2	10.6	11.4	12.2	13.2	14.8	16.6	18.8
	b_2		9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
DEPTH TO B/EDGE	D		10.8	11.3	12.2	13.5	14.0	15.5	16.9	18.0	18.9	19.6	20.4
CAMBER	E		1.2	1.4	1.4	1.6	1.6	1.6	1.6	1.8	1.8	2.0	2.0
DEPTH TO HATCH	H		12.0	12.7	13.6	15.1	16.6	17.1	18.5	19.8	20.7	21.6	22.4
LOADED DRAFT	d		7.7	8.1	8.5	9.2	9.7	10.4	11.2	12.0	12.7	13.2	14.0
LIGHT DRAFT	dL		2.6	2.7	2.8	3.1	3.2	3.5	3.7	4.0	4.2	4.4	4.7

1: ORE/BULK/OIL
2: ORE/OIL

SOURCE: MITSIBISHI HEAVY INDUSTRIES

A final general consideration is that of vessel size. While large economies of scale exist as the size of bulk carriers grow, it is not possible to evaluate the usefulness of large ships without noting the diseconomies of scale which exist. Considering only the positive aspects creates a false statement of worth for the larger vessel, and it biases decisions toward the use of large ships. Large ships need onshore storage for cargo being discharged, and there may not be adequate storage in existing or planned port facilities. It is not uncommon for a very large crude carrier to have to go to four ports in Europe to discharge a full cargo from the Persian Gulf. Multiple port calls forced by lack of storage ashore reduce the efficiency of large ships. Expenses of larger ships based simply on extrapolation from smaller vessels can be grossly underestimated. This is also true of a vessel's out of service time. Repairs that can be made on smaller vessels may require expensive drydocking. The implications of shipwreck are much more serious with larger vessels than with smaller ones, as are scheduling problems. These and other difficulties have depressed the resale and charter value of large bulk carriers more than smaller ships.

III.3 Interests of Organizations in Bulk Shipping

The bulk shipping industry produces an intermediate product, which is usually a component of a large scale distribution or production system. The transportation segment, including vessel loading and discharge costs, can be the largest single cost and typically the most variable. A ship user should try to obtain transportation at the lowest cost commensurate with the risk level acceptable.

The marine industry has produced a variety of market channels to procure shipping at varying degrees of involvement, risk and cost. Typically, there are five ways to offer the vessel's services. They are listed in Table III.3.1. The table also indicates which services are included as part of the basic contract and which must be provided by the ship user.

A spot (or voyage) charter is a contract to carry a specific cargo between two generally defined ports for one voyage. Occasionally, several are arranged in succession, creating a consecutive voyage charter. Voyage charters generally provide for all operating costs. Furthermore, voyage charters always specify the amount of time that the charterer may use to load the vessel and establishes a penalty (called demurrage) for each additional hour. They may or may not provide stevedoring services. Usually these are arranged for by the charterer. Generally, charter payment is made in advance and is considered earned when the cargo is on board.

A time charter makes provisions for the vessel to be available for a specific period of time, generally between one month and five years. Fuel is included in this type of charter account, as are other expenses connected with the ship's trade route, such as canal tolls. Short time charters are common. Long time charters occur only when the price expectations of the owners and charterers coincide. The variability of time charter rates depends on their period; the shorter ones change more rapidly with trends in the demand for shipping than longer ones. While time charters do reduce some of the organizational requirements for ship use, the arrangements that the charterer must take, including fuel oil, tug boats, berths, pilots, etc., consume a lot of organizational time.

Buying a vessel is the third way to procure tonnage. Owning a ship

Table III.3.1 Five Types of Vessel Service Arrangements

Arrangement	Cost Component	Ship owner	Ship user
1. Spot charter	vessel financial cost	X	
	operating expenses	X	
	insurance	X	
	fuel	X	
	port costs		X
	stevedoring costs	*	*
	demurrage		X
2. Time charter	vessel financial cost	X	
	operating expenses	X	
	insurance	X	
	fuel	X	
	port costs	X	
	stevedoring costs		X
	demurrage		X
3. Ownership (New) (Second hand)	vessel financial cost		X
	operating expenses		X
	insurance		X
	fuel		X
	port costs		X
	stevedoring costs		X
4. Bareboat charter	vessel financial cost	X	
	operating expenses		X
	insurance		X
	fuel		X
	port costs		X
	stevedoring costs		X
5. Contract of Affreightment	vessel financial cost	X	
	operating expenses	X	
	insurance	X	
	fuel	X	
	port costs	*	*
	stevedoring costs	*	*

* - Indicates that the responsibility could be either the ship owner's or user's

Source: World Bank staff.

may require no more organizational resources than the use of chartered tonnage, as it is common for one owner to contract for the management of a vessel. It is possible to buy both new and secondhand ships. While similar in organizational framework, these options differ greatly in cost, risk and potential return. Conceivably, a company that owns ships may never use them, but, instead, rely entirely on charters to meet its shipping needs. In that case, vessel ownership is seen as financial risk management rather than operational technique.

Bareboat charters are a cross between ownership and a normal charter. The charterer has most of the owner's responsibilities to man and repair the ship, but, like normal charter, these responsibilities end at a particular time, and the risk involving the value of the vessel is borne by its owner. While obligations are placed on the charterer to maintain the ship, they are not well-defined and it is common to defer maintenance until the ship reverts to the owner. Bareboat charters are frequently used as purely financial instruments. When both parties wish the ship to change hands, but cannot agree on the value or do not wish to renegotiate the vessel's financing with the holder of the mortgage, this type of charter can be employed. If a shipping company goes bankrupt, it may leave many bareboat charters in its wake.

A contract of affreightment is a common way to procure tonnage. It is an agreement to provide transportation for goods in defined quantities and between specified points. No specific vessels are named in the contract. It is not necessary to own vessels to enter into a contract of affreightment which operates as a futures market for shipping.

An important difference between a contract of affreightment and the voyage charter, and the other methods of obtaining ships, is that it is the responsibility of the shipowner to arrange for backhaul cargoes.

For a large scale organization, although all of these methods are viable ways to procure tonnage, they differ with respect to the following:

(1) Cost

(2) Organizational resources required

(3) Ability to service variable demand

(4) Market risk

(5) Risk of insolvency of contractual partners.

It is difficult to rank each market channel in the abstract, because so much depends on specific circumstances. A contract of affreightment, for example, is a potentially risky contract, because both sides may make important assumptions about the movement of spot and voyage rates and may be unable to complete the contract if their judgement is incorrect. The extent to which this matters depends on the resources and business ethics of the parties involved.

For intermittent ship users the spot market usually is the best way to procure shipping, as this is its basic function in the marketplace. Continuous users of bulk shipping will probably use a variety of procurement strategies. The general goals of arriving at the best mix are the following:

1. To obtain transportation at as close to marginal cost as possible at an acceptable level of risk.

2. To organize and finance the operation with an acceptable commitment of funds. (Because shipping can be highly leveraged, the commitment of funds may mean little or possibly zero commitment of own funds).

3. To minimize the taxes paid (if privately owned) or paid to others (if governmental).

4. To retain sufficient control to allow overall coordination.

5. To minimize risks, including foreign exchange, political casualty losses, and insolvency of business associates.

The matter of risk management has unfortunately become an area of vital concern in today's shipping market, as it is possible that all parties involved are in marginal financial condition - ship owner, ship charterer, ship yard, and financing bank. An accurate assessment of risks and subsequent steps to minimize exposure to them is an important feature of the agreement.

Ship users and suppliers have different attitudes toward risk. Large organizations, those which use marine transportation, tend to put premium on risk reduction because negotiating contracts of that magnitude requires long lead times. In addition, they would like to reduce the cost of ocean transportation, as it is the cost element with the largest variability.

Studies of the charter markets made by the Institute of Shipping Research in Norway[4/] indicate that the price of risk is very high in these markets. Hence, shipowners find it profitable to go for an agressive chartering policy. Ship operators can assume a role of almost an insurance company, agreeing to bear some of the long-term market risks in exchange for long-term charter payments considerably above costs of delivering shipping services.

There are three areas of risk in the bulk transportation field:

(1) Foreign exchange and financing risk

(2) Operational or "catastrophe" risk

(3) Business or "market"risk

Of the three, the foreign exchange and financial risk is the most difficult to manage because interest rates and currency values fluctuate.

[4/] Market Strategies in Bulk Shipping, Victor D. Norman, Studies in Shipping Economics, 1982, **Bedriftsokomomens** Forlag Als, Oslo.

Somehow the risk must be diversified since it cannot be eliminated. Actual problems with foreign exchange losses have not been common in the marine field (other than a few ships financed in Deutsche Marks).

Operational risks involve ship loss or damage. There are two types of risk - financial responsibility for the loss and consequential damage to the operations of the ship user. Under maritime law, the ship cargo owner and ship owner are considered to have a common venture and share many maritime risks in proportion to the value of the ship and cargo (called general average). The potential risk is especially large for the cargo owners. Many companies use general average claims to move profits from highly taxed areas to untaxed ones (i.e., shipping), so they obtain general average claims at every opportunity.

Specialized bulk handling operations, using slurry ships or continuous self-dischargers, are especially prone to operational risk. What to do should the ship sink must be addressed specifically in the project plan. The cost of replacing a vessel depends on the way the shipping is procured. If a voyage charter strategy is pursued, there is no additional risk because of the short contract. If the boat is owned, hull and machinery insurance will provide funds to buy another ship. Long time charters, however, pose the greatest risk because the charter terminates when the ship is lost and, unless the charterer had insured the ship for his own account, there is little recourse.

Market risk depends on uncertainty about the availability and cost of shipping and on the current shipping rate levels and expectations about the direction of future movements. For many reasons no formal options market has developed to institutionalize the risk of shipping rates. While the charter market for shipping meets many of the criteria for a commodity suitable for options trading, the high value of individual transactions and the availability of capital from other sources prevent the development of an options market for tramp or bulk shipping. It is not uncommon, however, for a ship user to make a long-term contract of affreightment with concerns that do not own any vessels but who fulfill the contract with chartered tonnage (both spot and term charters). It is also not uncommon for charters to be arranged so the vessel will be delivered up to eight months after the agreement is reached. Informal arrangements of this nature are the principal means of handling market uncertainties.

To the extent that international marine transportation makes up a significant part of bulk cost, the options market for the cargo may absorb some of the transportation risk, since most bulk commodities are traded on various exchanges.

III.4 Vessel Chartering

When a vessel is to be obtained for a fixed period, the usual instrument is a charter. While there exist many standard form charter parties for different trades, they all cover the general items outlined in Table III.4.1. Of these, the place where the ship will be delivered to the owner at the end of the charter is a potentially costly and easily overlooked issue.

The two most common charters are spot (or voyage) and time charters. Most statistics regarding spot charter costs relate to particular major trade routes; this is based on the assumption that other trades run in parallel. Specific spot charter costs may reveal little about the true cost of shipping, as they may only be revenue marginal to the ship

Table III.4.1 Vessel Charter Party Provisions

1. Vessel description and performance (including warranties of fuel consumption at various speeds)
2. Period and trading limits
3. Place and date of delivery of vessel
4. Place and date of redelivery of vessel
5. Vessel condition
6. Payment of hire
7. Off hire
8. Responsibility for fuel
9. Drydocking (including vessel cleaning and steaming to shipyard)
10. Pollution
11. Vessel modifications
12. Layup
13. Pollution
14. Settlement of disputes
15. Attachments

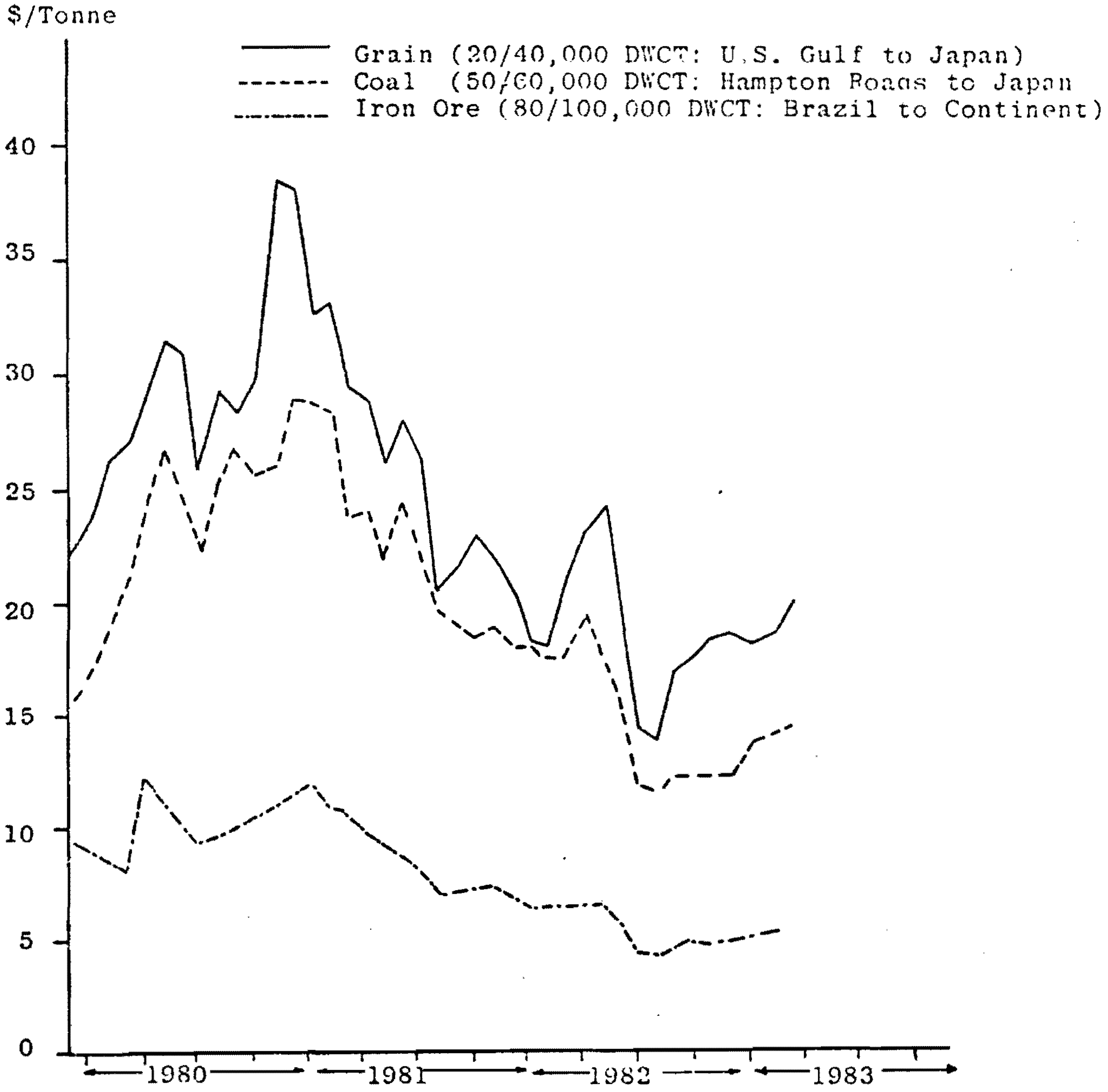
owner. A low rate may be quoted only to obtain the fuel to reposition the ship for a more lucrative charter. Averages of many charters may provide the best estimate of short-term costs of shipping. Table III.4.2

Table III.4.2 Single Voyage Charters by Commodity (April 83)

Ship size (1,000dwt)	grain	agr	forest	iron	mins	coal	ferts	steel	scrap	other
4-10	9	12	-	-	-	-	1	1	-	3
10-20	25	20	-	-	2	-	14	1	-	2
20-30	64	8	2	-	-	2	4	1	3	1
30-40	23	-	-	-	-	1	-	-	-	-
40-50	13	-	-	1	-	1	-	-	-	1
50-70	19	-	-	2	-	8	-	-	-	-
70-100	4	-	-	3	-	5	-	-	-	-
100+	1	-	-	9	-	3	-	-	-	-

Source: Dry Bulk Charter Markets: Developments and Trends, H.P. Drewry, London, 1983.

FIGURE III.4.1 SINGLE VOYAGE CHARTER RATES



Source: Cargo Vessels Voyage Rates 1980-1983, H.P. Drewry, London, 1984.

gives a general idea of the size of vessels working in the spot market of various trades in April of 1983. Historic spot charter rates are given in Figure III.4.1 with selected current charters given in Table III.4.3. For large vessels the spot market can be thin and may not represent the true, short-term value of the vessel.

Time charter rates are generally quoted in dollars/dwt per month and are segregated by ship size. As there is considerable variation in different ships' fuel consumption, some of the apparent variability of time charter rates is due to differences in ships' machinery. This is particularly true of larger ships in which a significant proportion of the fleet is steam-driven and consumes more fuel oil than diesel ships

Table III.4.3 Selected Current Charters

Annual rate of return, measured as revenue less operating costs under Norwegian flag as a percentage of building price, for an 80,000 dwt tanker, built 1966-1967.

Year	Alternative A spot market chartering	Alternative B 1-3 year time charters	Alternative C 3-7 year time charters
1967	46.7	13.0	12.7
1968	35.5	15.2	9.6
1969	18.8	20.1	13.3
1970	48.8	14.4	8.8
1971	36.3	34.9	9.8
1972	11.3	40.7	17.0
1973	77.2	18.1	18.4
1974	7.5	40.2	7.8
1975	-14.2	22.2	20.7
1976	- 1.6	- 6.0	25.6
Average rate of return	26.6	21.3	14.4
Standard deviation	25.5	13.0	5.0

Source: World Bank staff.

of the same size. The difference is compensated for somewhat imperfectly by differences in charter rates. When market rates are low, the difference between steam and diesel ships may be such that the steam vessel cannot be chartered at all. Figure III.4.2 presents historic charter rates for bulk carriers of different sizes. Figure III.4.3 is a typical charterer's voyage estimate form developed by Fairplay.

III.5 Ship Ownership

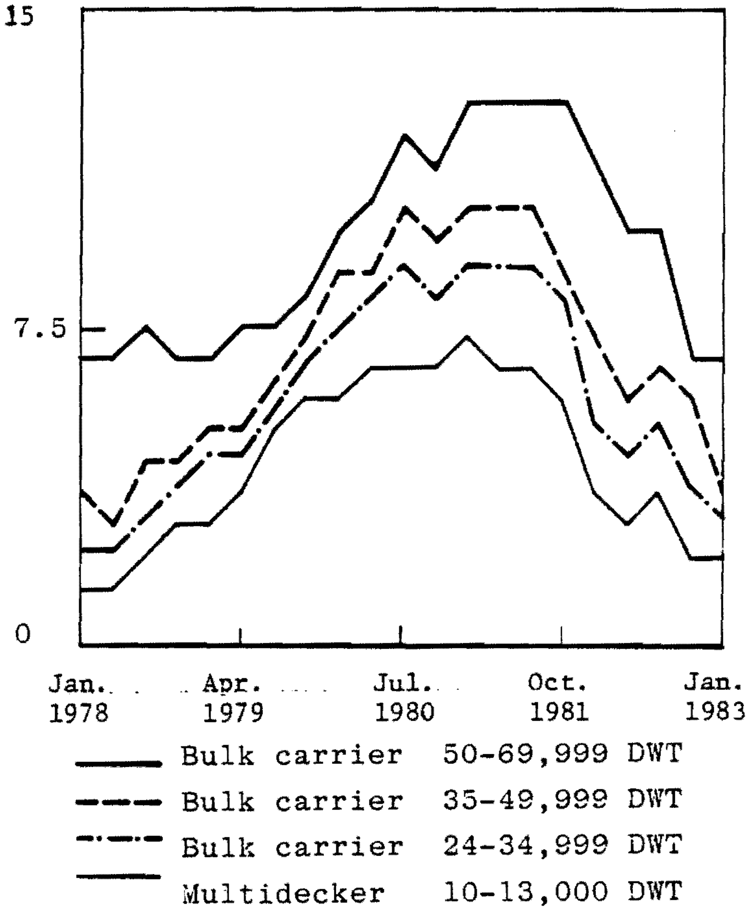
Ships can be purchased new, nearly new, used and ready for demolition. Each method of procuring tonnage has advantages and disadvantages. These are partially summarized in Table III.5.1.

Ship ownership is a common way to procure tonnage. As the costs of ownership do not change with the market level, ownership produces predictable ship usage costs. Most large organizations, those which do bulk shipping, use ship ownership as the way to manage risk exposure in the charter market, as owned tonnage is a "riskless" source of transportation against which a portfolio of charters can be built to provide the rate of return and risk levels desired. Even though the use of chartered tonnage cannot be avoided for operational reasons, owning tonnage equal to the capacity required and chartering it out eliminates the market risk from vessel chartering. The cost of this is the brokerage commissions. Hence, many bulk shippers own ships, even though their operating costs may be a little higher due to higher operation standards.

The most obvious way to obtain a ship is to buy a new one. In periods of medium to high shipping activity, this can be the least expensive approach. This is mainly because modern diesel engines have been improved and are able to burn low quality fuels. Because subsidized financing can always be a part of a ship purchase agreement, much smaller

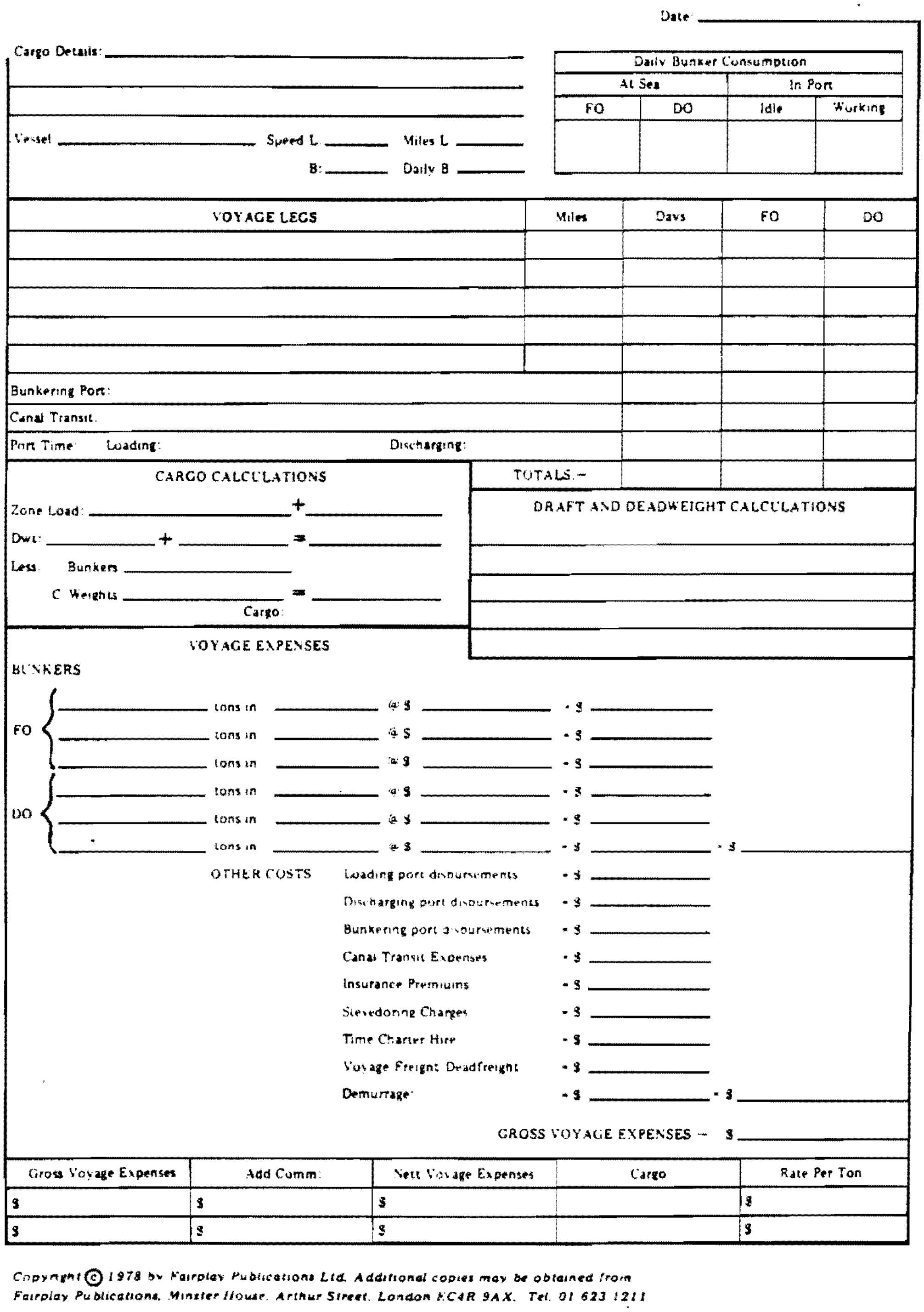
FIGURE III.4.2

TIME CHARTER RATES ($/DWT-MTH)



Source: Dry Bulk Charter Markets: Developments and Trends, H.P. Drewry, London, 1983.

FIGURE III.4.3 CHARTERER'S VOYAGE ESTIMATE FORM



Date: ________

Cargo Details: ________

Vessel ________ Speed L ________ Miles L ________

B: ________ Daily B ________

Daily Bunker Consumption			
At Sea		In Port	
FO	DO	Idle	Working

VOYAGE LEGS	Miles	Days	FO	DO
Bunkering Port:				
Canal Transit.				
Port Time: Loading: Discharging:				
TOTALS.–				

CARGO CALCULATIONS

Zone Load: ________ + ________

Dwt: ________ + ________ = ________

Less. Bunkers ________

C Weights ________ = ________

Cargo:

DRAFT AND DEADWEIGHT CALCULATIONS

VOYAGE EXPENSES

BUNKERS

FO ________ tons in ________ @ $ ________ = $ ________

FO ________ tons in ________ @ $ ________ = $ ________

FO ________ tons in ________ @ $ ________ = $ ________

DO ________ tons in ________ @ $ ________ = $ ________

DO ________ tons in ________ @ $ ________ = $ ________

DO ________ tons in ________ @ $ ________ = $ ________ = $ ________

OTHER COSTS

Loading port disbursements = $ ________

Discharging port disbursements = $ ________

Bunkering port disbursements = $ ________

Canal Transit Expenses = $ ________

Insurance Premiums = $ ________

Stevedoring Charges = $ ________

Time Charter Hire = $ ________

Voyage Freight Deadfreight = $ ________

Demurrage: = $ ________ = $ ________

GROSS VOYAGE EXPENSES – $ ________

Gross Voyage Expenses	Add Comm:	Nett Voyage Expenses	Cargo	Rate Per Ton
$	$	$		$
$	$	$		$

Table III.5.1 Methods of Vessel Procurement

NEW SHIPS

Advantages
- *Lower fuel consumption
- *Cheaper fuel grade
- *Easier private financing
  1. Lower equity
  2. Longer loan period
  3. Subsidized interest rate
- *Common spares if multiple ship procurement
- *Exact design requirements can be met
- *Known risk

Disadvantages
- *Break-in maintenance
- *Currently-higher cost
- *Delivery of ship not at first loading port
- *Unknown performance of custom features
  1. crude oil burning
  2. Ro/ro ramp

NEARLY NEW SHIPS

Advantages
- *Competitive fuel consumption
- *Currently-lower cost
- *Break-in maintenance accomplished
- *Technical performance known
- *Delivery of vessel more flexible
- *Possible to charter first to try out

Disadvantages
- *Shorter period before overhaul
- *Ship condition marginally riskier
- *Non-common spares
- *More difficult financing

OLD SHIP

Advantages
- *Lower cost
- *Delivery of ship flexible
- *Possible to charter first to try out

Disadvantages
- *Higher fuel consumption
  very high if steam
- *High maintenance especially if diesel
- *Poor financing terms
- *Unstable vessel value
- *Technically risky
- *Short useful life
- *Higher insurance
- *Higher crew cost
- *Probable imminent repair expense
- *Higher skills required of management

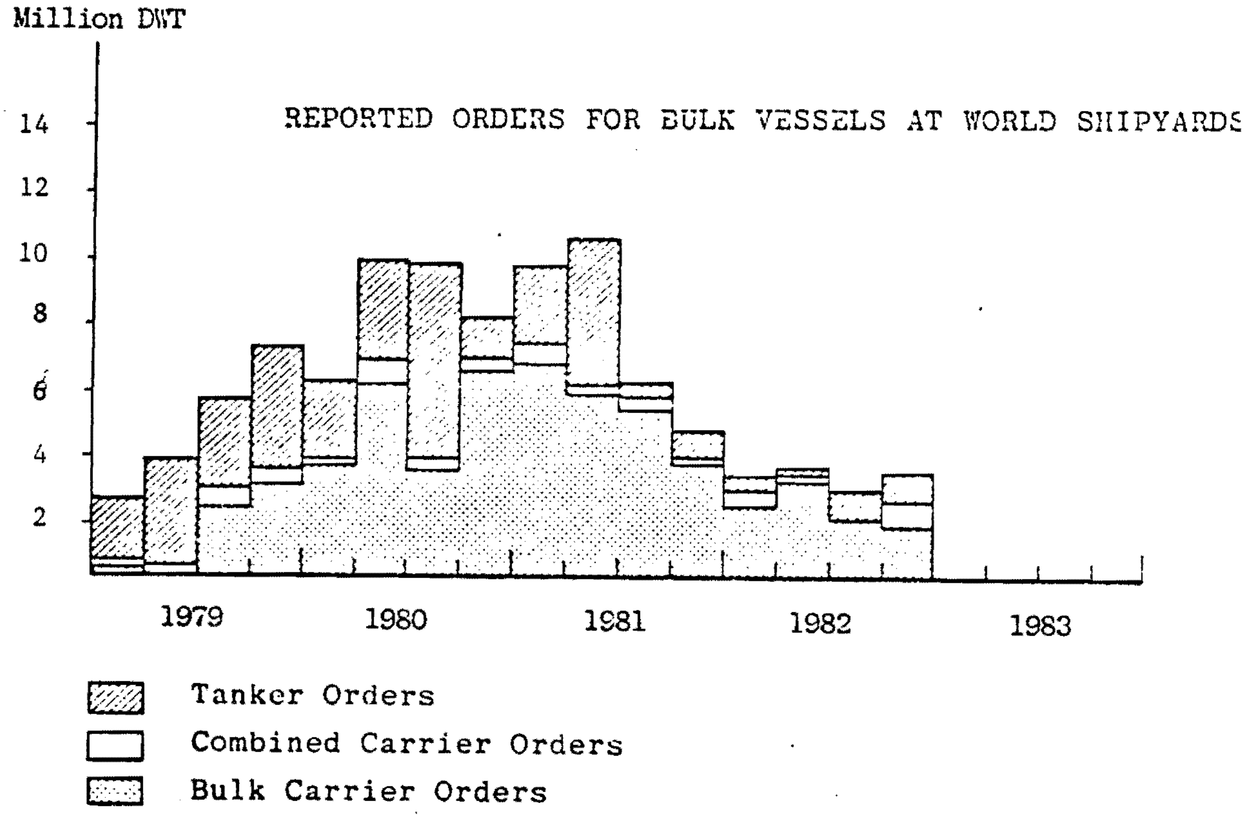
equity investments are required to buy new ships than otherwise would be required. Even under OECD financing rules, it is possible to obtain nearly 100 percent financing on ships obtaining an engine financed with export credit from country A and using it as a down payment for a ship built in country B.

As new ships need not be built, new ship prices have a floor, which is equal to the cost of building the ship minus the loss the shipyard is willing to take and any direct subsidy it is able to obtain. Because governments may choose to subsidize ship sales through indirect means (loans, guarantees, lower interest rates, etc.), the evaluation of competing offers must consider discounted cash flows and never be based on price alone. The terms are as important as the price in determining the viability of a ship sale.

Historic trends in orders for bulk carriers are shown in Figure III.5.1. One advantage for new construction is that properly engineered, new ships have much lower fuel costs than older vessels. Table III.5.2 projects bulk carrier deliveries based on shipyard order books.

Purchasing a nearly new vessel can be a good investment because their value fluctuates more than that of a new ship; the price floor usually is the outstanding value of the ship's mortgage. It is difficult to buy a nearly new vessel without retiring the existing financing. Nearly new ships may be more reliable than newly built ones because the initial owner may have solved most of the technical problems. The ship's performance is also a matter of record rather than specification. The life of the nearly new ship may be as long as newly built ones, as a continued program of good maintenance will keep the ship in good condition.

FIGURE III.5.1 HISTORIC TRENDS IN ORDERS FOR BULK CARRIERS



Source: World Bank staff.

TABLE III.5.2 The Bulk Carrier Order Book

SHIP SIZE (M.DWT)	CURRENT FLEET		FUTURE SCHEDULED DELIVERIES												TOTAL ON ORDER	
			1ST HALF 1983		2ND HALF 1983		1ST HALF 1984		2ND HALF 1984		1ST HALF 1985		2ND HALF 1985+			
	NO.	M DWT	NO.	M.DWT	NO.	M.DWT	NO.	M.DWT	NO.	M. DWT	NO.	M.DWT	NO.	M.DWT	NO.	M. DWT
10-20	1,044	16,633	11	181	3	53	1	18	-	-	-	-	-	-	15	252
20-30	1,467	37,592	43	1,128	20	490	23	567	16	432	6	147	3	60	111	2,826
30-40	833	29,179	64	2,254	54	1,878	19	699	16	582	9	333	4	160	166	5,906
40-50	295	12,949	28	1,179	17	725	32	1,325	8	351	-	-	4	160	89	3,740
50-80	644	39,603	70	4,424	53	3,271	20	1,265	12	792	2	140	2	130	159	10,022
80-100	57	4,927	-	-	2	169	-	-	-	-	-	-	-	-	2	169
100-150	170	20,750	6	833	8	1,152	1	130	3	392	-	-	-	-	18	2,505
150-200	23	3,843	4	672	2	332	3	522	-	-	-	-	-	-	9	1,526
200+	6	1,352	2	421	-	-	-	-	-	-	-	-	-	-	2	421
Total	4,339	166,828	228	11,092	159	8,072	99	4,526	55	2,547	17	620	13	510	571	27,367

*Including ore carriers

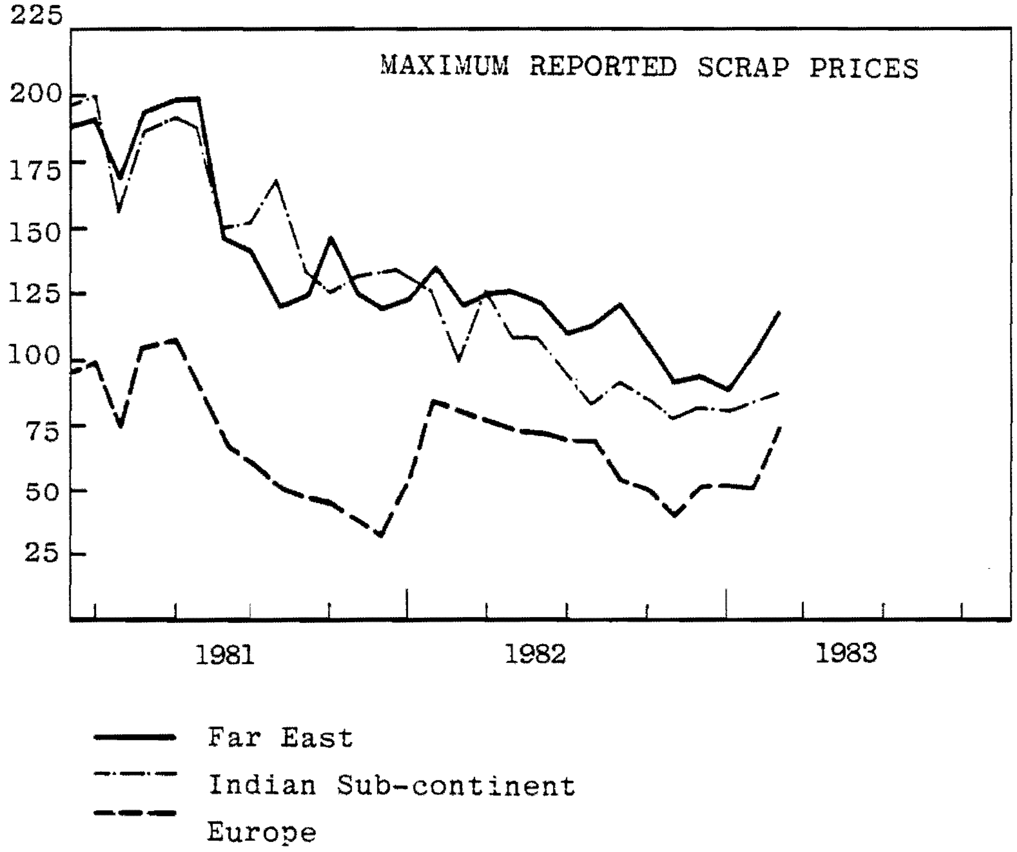
Source; *Dry Bulk Charter Markets: Developments and Trends*, H.P. Drewry, London, 1983.

A drawback to nearly new ship purchase is that it is difficult to find lenders who are willing to extend more than 50 percent of a vessel's sales price as a loan. Thus, projects involving used ships are initially less liquid and have negative cash flows in the first few years. As no one has an interest in subsidizing the financing of used ships, the interest rate will also be higher. If a ship owner has access to low cost financing from sources other than those typically available to ship buyers, many of the reasons to buy a new ship are eliminated, and the older ship becomes the better investment from every point of view.

In the purchase of used tonnage, there is less choice of ship configuration, and many types of specialized ships may not be available. One alternative here is to convert an existing ship to a new use. Tankers, for example, can be converted to bulk carriers. While this option can provide a satisfactory product at reasonable cost, the real advantage of conversions is that the ship is available for use sooner than new construction is. However, it is not always cheaper. For instance, to retrofit an inert gas system on a 30,000 ton tanker costs $4,000,000. An existing ship with a similar system installed in the last 10 years could be purchased secondhand for less than this.

The final way to acquire an equity interest in ships is to buy them in the last stages of their lives and operate them for a short time before scrapping them. The lowest value of such ships is determined by their value as scrap minus the cost of the voyage to the scrap-yard. The value of scrap is given in dollars/ton of ship (not deadweight tons) and is shown in Figure III.5.2. As the weight of the ship itself is about 20 percent of a vessel's deadweight, it can be seen from the figure that, in 1981, it was possible to buy a 60,000 ton bulk carrier for as little as

FIGURE III.5.2 SCRAP SHIP PRICES (USD per Lt. wt. ton)



Source: Ship Scrapping, H.P. Drewry, London, 1983.

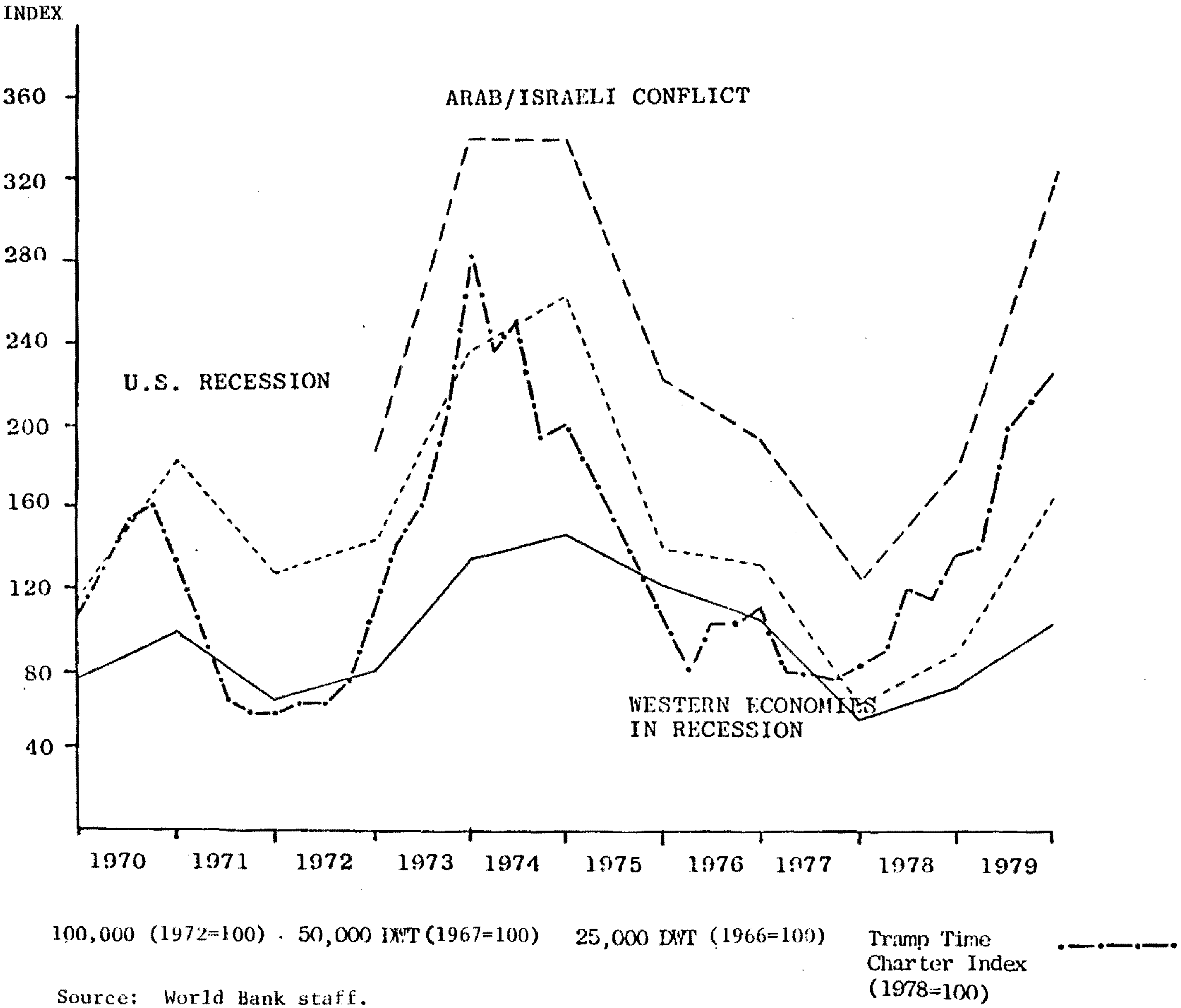
$600,000.

The actual value of old ships is the profits from the few voyages that can be sailed before scrapping it. Well-selected, old ships can stay in service sometimes for a few years before required repairs force scrapping. As in 1981, one month's time charter for the above vessel was $450,000, so a large fraction of a vessel's scrap value can be earned on the short-term. Many owners make most of their profit from speculation in older ships rather than operation.

Ship prices vary considerably (see Figure III.5.3), and the greatest risk of ship ownership is capital loss should the ship no longer be required. Figure III.5.4 shows prices for new building and two and five year old bulk carriers. New building prices are based on construction in Japan or Korea. The graph shows two year old vessels selling for about 70 percent of the cost of new vessels, and five year old vessels for about 50 percent of new ones. The 27,000 ton vessel (which is the largest which can pass through the St. Lawrence Seaway) has a higher resale value than the other sizes; the resale value is 90 percent of the new price for the two year old ship and 63 percent of the new price for the five year old one.

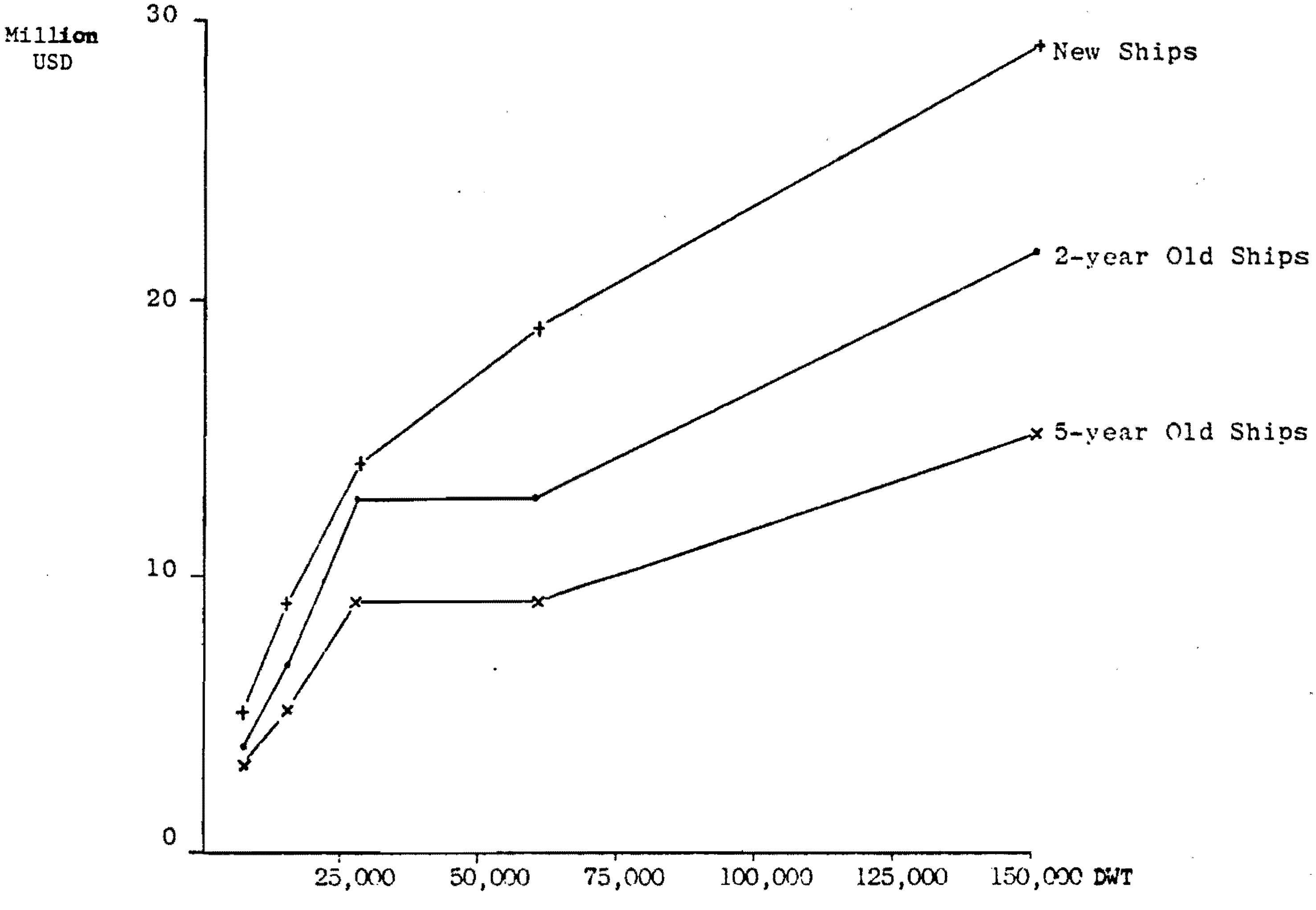
A comparative analysis of various options was carried out for a prospective shipowner and is printed here as an example. The break-even charter rate for various options for ship procurement was calculated and is presented against the one year time charter rate in Figure III.5.5. The ship, the one ready for demolition, was assumed to be purchased for cash while, for the sake of simplicity, the remaining ships were presumed to be 100 percent financed. The new ship, sold with OECD terms, was assumed to have an eight year, 10 percent mortgage and the

FIGURE III.5.3 TRENDS IN USED SHIP PRICES



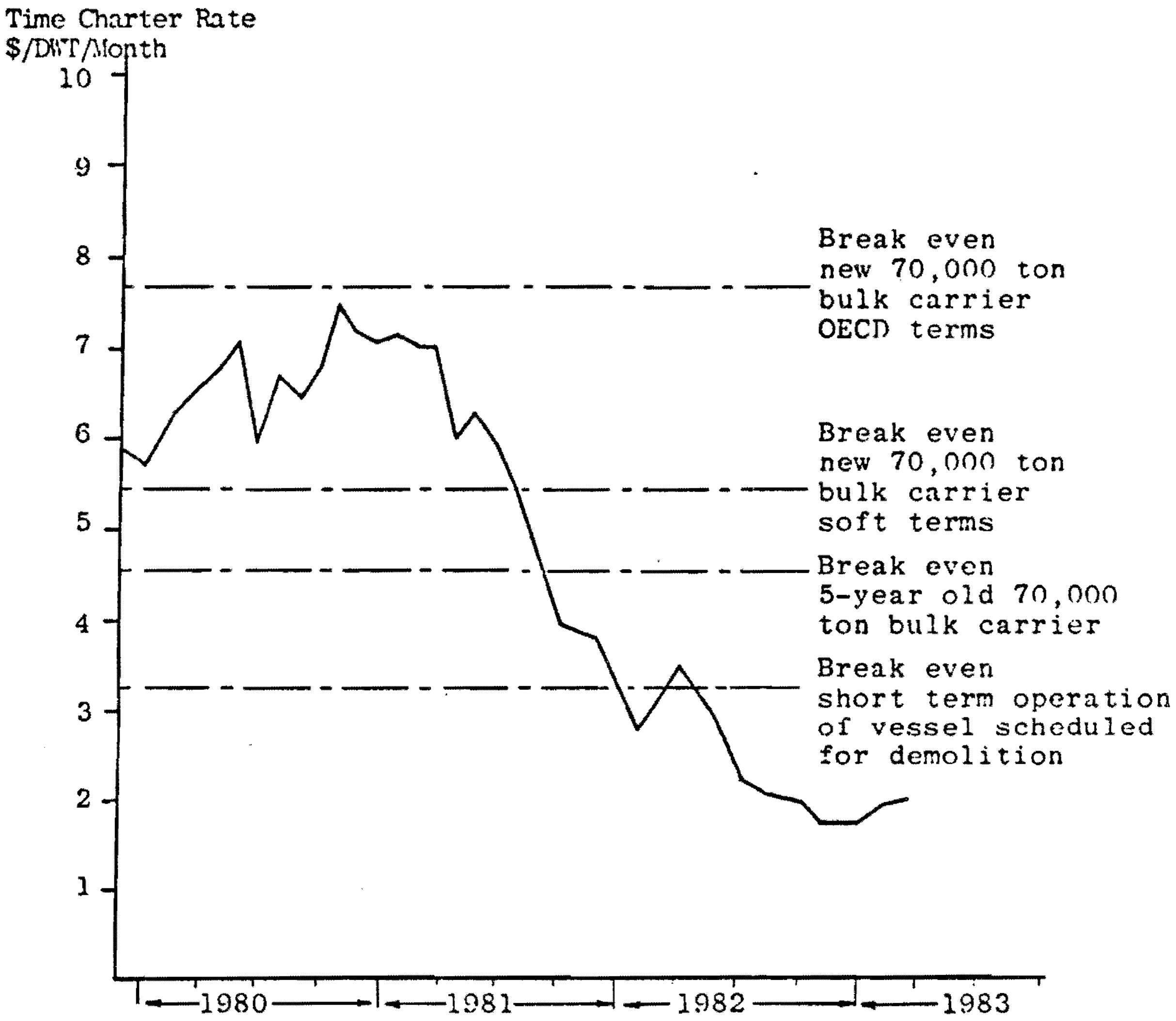
Source: World Bank staff.

FIGURE III.5.4 CURRENT BULK CARRIER PRICES



Source: Naess Hallman, Inc., - Shipbrokers, Oslo, 1984.

FIGURE III.5.5 COMPARISON OF RETURNS FROM DRY CARGO VESSEL OPERATION



Note: Based on one year period with fairly prompt delivery.
(Bulk carriers 50/69,999 DWT)

Source: World Bank staff.

same ship sold on "soft" terms was assumed to have a twelve year, 8 percent mortgage, but the five year old ship has a five year, 12 percent mortgage. The comparison does not treat the different lifetimes of the vessels adequately, since it ignores the decreased costs when the mortgages of newer vessels are paid off. These effects, however, are of second order because, if the analysis were done using discounted cash flows, the future cash flows would be heavily discounted.

From the graph it appears that the older the ship, the less it costs to use it because of the lower financial cost. This will be true if the older ship is only slightly less efficient than the new one and if its off-hire time can be kept to comparable levels. In general, vessels less than 8 years old have mechanical performance that is as good as that of a new ship and they do not have higher off-hire times.

The operation of demolition bound ships (those over 15 years old) is a different matter and inexperienced maintenance on these ships is often more detrimental than beneficial because it creates more off-hire time and higher repair costs. Maintaining older ships is a very specialized skill, as only machinery required should be kept in good condition, some machinery should be temporarily repaired, and some items, particularly the hull steel and paint, should not be repaired. One must remember that all repair work will be scrapped in a few years with the ship anyway. It is, therefore, tempting not to repair even the items that are required for the safety of the ship, if the ship is able to move the cargo and the required repairs are expensive.

Even if a ship user intentionally avoids the buying of old ships, lack of space and problems related to coordinating his chartering policy may leave him with no option but to charter old ships without inspecting them. Chartering old ships can be just as risky as owning them. A general average claim, for example, would be almost all for the cargo, as the value of the cargo would easily be ten times that of the ship carrying it.

One point that can be drawn from the graph is that owners of newly built ships in the 70,000 dwt range lost money over the last three years. The purchaser of the older vessel at least broke even. It is clear that investment in new ships is today advantageous only under special circumstances.

IV. INLAND TRANSPORTATION TO ALTERNATIVE TERMINAL SITES

IV.1 Introduction

Usually there exist several possible sites on which to build a bulk facility. The options available may include expanding an existing port or constructing a new port(s) at one or more alternative locations. New sites may have the advantage of having lower site preparation costs, as the sites can be selected where the water is deep and there are small filling costs. Expanding an existing port is advantageous because much of the infrastructure development work is complete and, as a result, development costs will be decreased.

Experience demonstrates that one of the major differences between alternative sites is the cost of inland transportation to and from the port. When no inland transportation facilities exist, their cost may equal the difference between development costs at the least expensive and the most expensive alternative port sites. A large scale iron ore exporting port, for example, may cost approximately $75 million (U.S.). Of this, work done at the port site may cost about $20 million (U.S.). Of this total it is unlikely that different sites vary by more than 50 percent or $10 million. If the cost of railway construction is about half a million dollars per mile, the cost of the inland transportation will exceed the variable element in the port's cost should the line haul distance exceed twenty miles. In such a situation, selecting the least expensive port facility will require optimizing the combined cost of development at the site and the inland transportation facilities.

There can be advantages to developing existing port facilities: for instance, using the existing road and rail transportation system. It is important, in the feasibility study, to determine early whether or not these facilities are in reasonable condition and their design is adequate.

Table IV.1.1 lists the transport alternatives available for inland movement for bulk goods. This information is presented with a qualitative evaluation of the different transport modes. The second portion of the table indicates the magnitude of the relative costs of right of way, vehicle acquisition and operating costs. These are for typical situations and have no universal application. If a railroad right of way already exists, for example, it may be much cheaper to lay new track than to construct a road. There are many situations in which the intermittent foundations required for a pipeline are less expensive to construct than the continuous civil engineering works required for both roads and railroads.

IV.2 Truck Transport

Where roads already exist, trucks provide flexible transport that can be installed in stages and removed if the demand decreases. Often, existing roads may be adequate to handle additional traffic, and the only additional investment required is for the vehicle fleet. Expanding the system is easier and cheaper than most of the other options available. Additionally, since trucks (and rail cars) have recoverable salvage values, truck transportation can be used as an interim step, while construction of the final distribution system is progressing. Trucks can also be used to defer installation of the final distribution system until available traffic justifies the higher costs of the other modes. While not always the case, road developments required for the road alternative may also be beneficial for other areas of commerce.

Table IV.1.1 Comparison of Alternate Transport Modes

Modes	Highway	Train	Inland Water	Pipelines	Aerial Tramways	Belt Conveyor
Route Flexibility	med	low	low	low	high	low
Terminal Flexibility	high	med	med	low	low	low
Speed	med-high	low-med	low	low	low	low
Operating Range (miles)	high	high	high	low	low	low
Expandability	high	high	high	low	low	low
Independence	med	low	--	high	high	med
Climate Independence	med	high	med	very high	high	very high
Flexibility	high	high	med	low	med	med
Capacity	low-med	med-high	low-high	--	low	--
Impact on Environment	med-high	med	low	low	med-high	med

Cost Elements

	Right-of-way	Carrying Vehicle	Operating
Highway	Medium	Low	High
Train	High	Medium	Low-medium
Ocean Ships	Low	High	Low
Inland Water	Low	Low	Medium-high
Pipelines	High	None	Low
Belt Conveyors	High	None	Low
Aerial Tramways	Medium	Low	Medium

Source: World Bank.

Truck transport delivers many small loads frequently by mechanically independent means. Barring major accidents on the road, truck-centered transportation systems are less susceptible to complete breakdowns than other systems. This means that maintenance problems must be large before the overall system performance is degraded. On the other hand, conveyor systems must be almost completely operational to ensure that the system is available for use as needed.

Trucks also provide a more diverse distribution system than other means of transport and are particularly good if the source of supply or delivery is not a single point. For this reason truck or rail transport are the only viable options for many bulk commodities, such as grain.

Truck transport can be the most expensive of any transport system if it is operated only during the normal work week (one or two shifts, five or six days a week). Additionally, truck schedules are difficult to maintain, as variations in the time between arrival for trucks is generally larger than for other systems. Both of these factors, in essence, mean that the system needs more storage. The first factor requires that operational reserve storage be installed at both the truck loading and unloading facilities. If a pure conveyor system were installed, investments in storage facilities for these factors would not be necessary.

When port facilities are not used often and are served by trucks, there must be enough bulk storage capacity so that stevedoring work on the ship is not interrupted by any lack of truck capacity. If this is done, it is not necessary to invest in the truck capacity that would be required to meet the peak demands when a ship is being stevedored.

Road haulage costs are difficult to estimate because costs depend to a large extent on the quality and design of the roads. Poor roads raise vehicle maintenance costs, tire wear, and fuel consumption, and lower the average speed. This increases the number of trucks that will be needed.

The cost of building roads depends largely on the terrain, climate and soil conditions. Additionally, much domestic labor is used in road building, so that portion of the cost depends on local wage rates. As an estimate, the cost of non-urban, two-lane paved roads in flat-rolling terrain may vary between $150,000 to $300,000 per kilometer in 1982 prices; costs in urban areas or more hilly terrain may be 2 to 4 times as much.

IV.3 Rail Transport

Rail transport plays an important role in bulk transportation and is generally found to be the least costly transport mode when distances exceed 20 to 30 miles from the port and the quantity to be transported is in excess of 500,000 tons per year. As a result, rail connection and transfer facilities are usually incorporated into bulk terminals. Rail interface facilities usually consist of marshalling, classification and transfer yards, loading/unloading tracks, car dumpers (unloaders/loaders), car cleaning facilities, run out and transfer tracks and related facilities. In-terminal railway services including transfer, consolidation, and movement of railcars is usually performed by the bulk terminal, which as a result, requires shunting locomotives, tracking winches, and various communication and safety equipment to perform these in-terminal rail operations.

Railway service to and from bulk terminals is usually by unit or block trains consisting of 50-100 cars. Such trains are broken up in the marshalling or transfer yard into smaller train sections for effective transfer by shunting locomotive to particular port locations. Cars can be unloaded (using car dumpers, unloaders, or gravity gates on the car) onto conveyors which either transfer the cargo to a stacker and hence, to a stockpile or which transfer the cargo directly to ship/barge loaders. Facilities usually provide for both direct and indirect transfer of bulk cargo between railcar and ship. Similarly, direct and indirect service can usually be performed in the transfer of cargo from ship to railcars. In the import mode, railcar sections are after loading, assembled into unit or block trains in the marshalling and classification yards.

Rail networks in bulk terminals usually have zero grade and are laid on well compacted leveled soil. Because the speed of operations in the terminal or port is quite low (only shunting and transfer operations), used rail is sometimes utilized for laying out of the track at substantial savings in investment.

The most important consideration in the design of a rail network in a bulk terminal is assurance that unloaded (or loaded) cars can be readily returned to the marshalling yard and outside rail network without affecting terminal operations. In other words, effective switches, branchings, return tracks, turnouts, turntable crossings and other facilities which assure the means for efficient railcar turnaround under any foreseeable operating conditions, must be provided. Railcars should not be parked or marshalled in the terminal and should achieve an in-terminal turnaround of a few hours.

It can be shown that rail transport using new rail can be cheaper than road transport. Existing rail can be cheaper than even barge transport for all but the very large tows found on the Mississippi River, over short distances.

However, before a decision to use an existing rail link is taken, the condition of the link should be carefully assessed. In general, for bulk traffic, track conditions are not critical to efficient operations, and if the line is presently in operation, it will probably prove adequate.

Use of railway presents a number of advantages over truck use for bulk movements. Railcars sometimes present advantages in blending different grades of bulk materials. Blending can be accomplished relatively easily by selectively dumping railcars carrying various grades. The need for blending should, however, be carefully assessed. In the case of coal, the need for blending at the port is much greater when the port serves a number of small producers as opposed to a larger mine where blending can be carried out prior to loading the coal into railcars.

In general, for in-terminal rail operations a number of factors must be considered:

- need to construct additional rail spurs
- the transport distance, diversity of traffic and shipment sizes
- ease of access to the main rail links
- availability of yard facilities at the port

The investment cost for track can vary considerably depending on terrain, soils, labor costs, availability of materials and other factors.

IV.4 Inland Waterways Transport

Inland waterways provide the least expensive transportation available in many regions of the world. The system relies on barges with 1,500 to 3,000 ton capacities. These can be combined into multiple "tows," which consist of many barges attached together. The size of waterways in Europe limits the size of tows to four barges, while in the United States, tow sizes of up to forty barges are common on the lower Mississippi River. Many different types of cargo can be carried in the same tow, and it is possible to realize large economies of scale, even though each shipment is relatively small. Where this system is in use, industrial facilities are located on the water and "door to door" delivery is common.

River barges are simply and inexpensively constructed. Consequently they allow for low investment costs per ton of capacity. Barges are available in many types and those typical of American practice are shown in Figure IV.4.1. River transportation provides high transport momentum because of the large tow size, even though the speed of the tow is low. The typical speed for river transport is eight miles per hour. The low speed and high transport momentum provide lower transport costs and low fuel costs. While the barges can carry a variety of cargo, the system presents the lowest costs when the barge load is carried between single shippers and single receivers located on the river front.

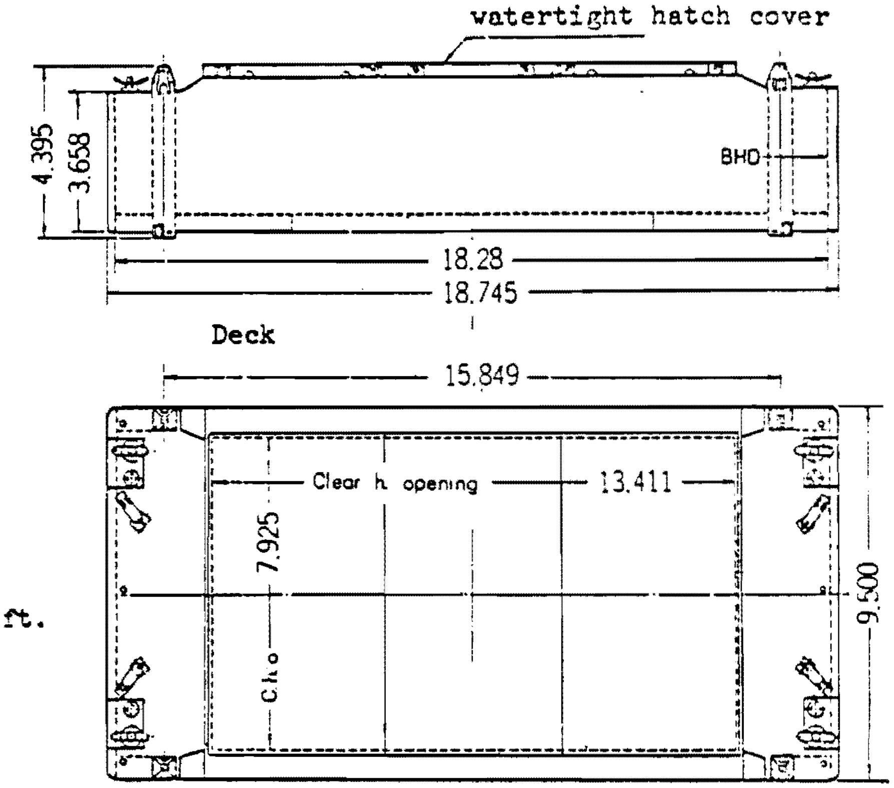
Tows are made up of a group of barges usually pushed by a tow boat or less frequently pulled by a tug boat. The tow boats come in a variety of sizes and range from small units (100 horsepower - 36 feet long by 12 feet wide) to large units (12,000 horsepower - 230 feet long).

A six thousand horsepower tug can move a tow of about 15 barges with a cargo capacity of 40 to 50,000 tons. A similarly powered diesel locomotive can pull about 120 cars with a payload of 6,000 tons.

The inland waterway's transport system was originally the only way to move large volumes and, as a result, most population centers grew up where there was easy access to waterways. For this reason a large percentage of the world's industry can be served by inland waterway

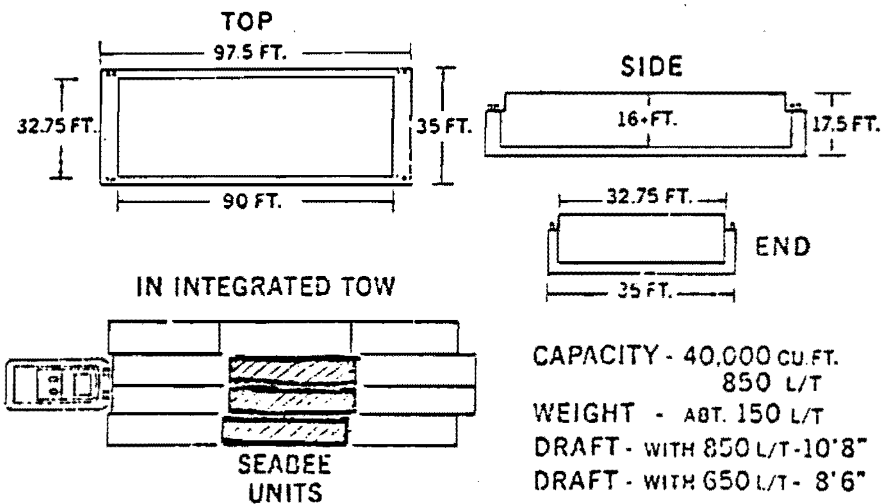
FIGURE IV.4.1 LASH AND SEABEE BARGE EQUIPMENT

LASH UNITS



Particulars	
L.o.a	18.745 m
B.o.a	9.50 m
D at side	3.96 m
d max f.w.	2.66 m
d max f.w.	2.74 m
Bale	19.500 cu. ft. (·563 m^3)

SEABEE UNITS (Commercial Service)



CAPACITY - 40.000 CU.FT.
850 L/T
WEIGHT - ABT. 150 L/T
DRAFT - WITH 850 L/T - 10'8"
DRAFT - WITH 650 L/T - 8'6"
DOUBLE SKIN CONSTRUCTION

transport.

Barges are easy to integrate with ship loading and unloading. The most obvious way is to load the barge itself on a ship. The LASH and SEABEE systems both function in this manner. Figure IV.4.1 showed both LASH and SEABEE barges. LASH barges are lifted onto the ship with a crane, and SEABEE barges are loaded onto an elevator. Both barges have a relatively small capacity and are suited to "neo-bulk" cargoes, such as construction grade marble slabs, graded chemical clays, etc. SEABEE barges are easily pushed in floats, while LASH barges must be towed in strings, which limit the number that can be towed with a single tug.

Historically much of the world's stevedoring has been done by lightering barges to ships anchored in a river without port facilities. As port facilities - and the road and rail transport systems required to support the land-based port - were erected, lightering operations usually stopped. However, the lightering of large grain cargoes is still common. Timber and rubber cargoes are usually loaded from barges or directly from the water.

In order to exploit the cost advantage of inland water transport, one must eliminate the double handling of cargo (i.e., discharge from the barge to a shore facility with subsequent shiploading). Recently much progress has been made in this regard and the direct transshipment rates from ships to barges - or the reverse - have risen to approach handling rates possible with shore-based facilities. Costs are considerably lower, because rehandling of the cargo has been eliminated and so have the requirements for shore storage.

Equipment to transship directly between ships and barges can be barge-, ship-, or shore-mounted, as in the case of shore-based pneumatic grain handling systems, barge-mounted ship unloaders/loaders and more.

IV.5 Small Ocean Bulk Carriers

There is a growing market for small ocean-going bulk carriers to carry bulk cargo in areas where the weather and sea conditions do not permit the operation of barges which have small freeboards. Smaller ocean-going bulk carriers can be either integrated tug barges[5] or small ships.

The feeder ship, in the bulk trades, was created to reduce the time larger vessels spend at ports by having smaller ships make the actual pickups and deliveries and transship the cargo, in turn, to a large vessel for mainline ocean transport. In addition to their feeder function, these ships commonly support a shorter mainline trade. Bulk feeder services are organized on an ad hoc basis in the grain trades to allow large shipments of grain (over 100,000 tons) to be discharged to lighters. These go to four or five different ports, none of which has the capacity to receive the entire shipment. While international trade in steam coal is small, it is likely that a coal feeder trade will evolve. This will make it possible to transport coal in large vessels and, then, to have it distributed to individual powerplants on small,

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[5] An integrated tug barge is a barge and tug boat fastened together semi-permanently. The ship's operating profile does not call for their separation, except for repairs. This results in cheaper transportation, because crew costs are less due to differing work rules for tugs and ships and also due to construction rules for tug barges which result in a cheaper vessel than a ship.

feeder colliers.

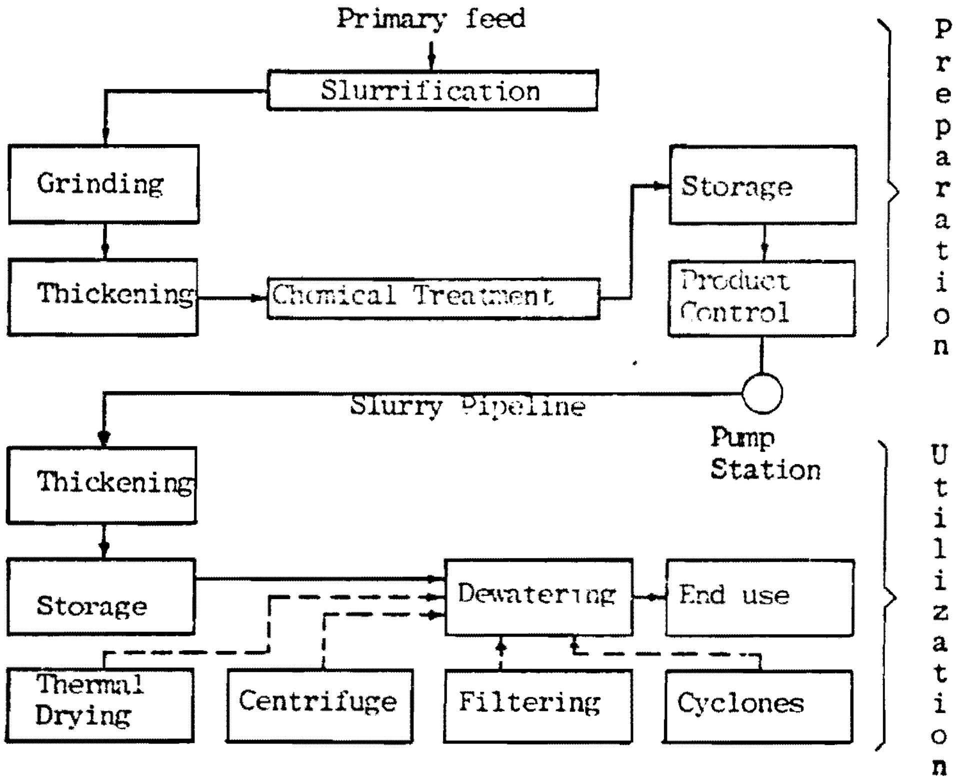
Small bulk vessels can be most economical as feeders when they are used to distribute intermediate bulk manufactures, such as fertilizers and cement. These commodities are shipped in bulk from the point of manufacture to intermediate distribution points for storage, packaging, and shipment to retail markets. The PUSRI fertilizer company in Indonesia has installed such a system; it uses seven 7,000 ton self-discharging vessels to distribute urea and other fertilizers throughout Indonesia.

Overall it does not seem that there are advantages to using ships smaller than 7,000 tons to distribute cargo, because the delivery cost per unit of cargo rises very quickly when the size of the ship is smaller than 7,000 tons.

IV.6 Slurry Pipelines

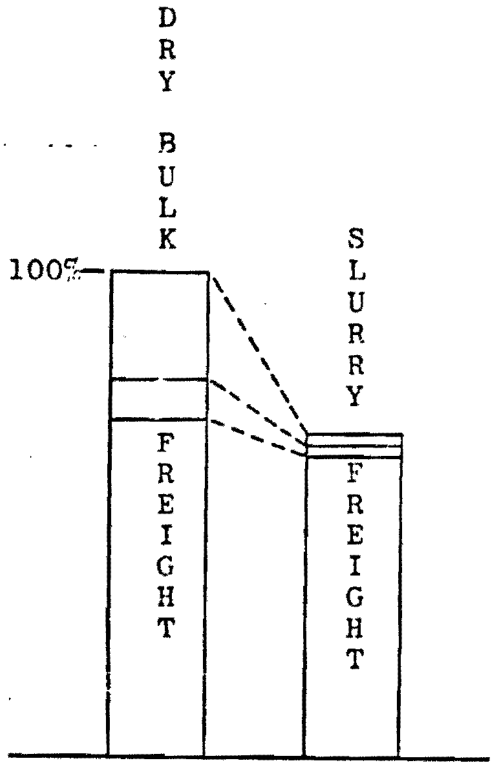
Slurry pipelines are used to ship bulk material as a finely ground powder in a moving stream of water. The general process for the slurry system is shown in Figure IV.6.1. In areas of rugged or difficult terrain the slurry pipeline process may be the only way to transport cargo, as with the famous Savage River project in Australia. One of the major costs, created by using a slurry transportation system, is removal of the water from the transported solid. As a rule decanting (i.e., allowing the solids to settle and pumping the water off the top) leaves a mixture that is still 10 percent water. If the material is to be dry, the rest of the water can usually be removed from the mixture by heating it. Coal transported as slurry, for example, has a lower heating value than usual because of the extra water content. Thus, slurry transporta-

FIGURE IV.6.1 GENERAL PROCESS FOR SLURRY SYSTEM



Source: World Bank staff.

FIGURE IV.6.2 COMPARISON OF RELATIVE FREIGHT RATE



Source: World Bank staff.

tion is most economical when used for commodities whose processing is in slurry form or where a small water content is not detrimental.

Slurry transportation in ships is technically well-developed. Indeed several slurry ships have been in service for many years. The process is used in international shipment by the Marcona Mining Corporation and by transporters of kaolin clay. When the slurry carrying ship was being designed, optimistic reports were developed about the economics of slurry carriage. Figure IV.6.2 gives comparisons of the relative freight rates (for slurry and conventional freight) and Table IV.6.1 shows the total system cost of slurrying with conventional shipment. This information is the original data used in 1967 as a basis for the slurry system's development. There is little evidence that the economics of the system in service differ greatly from the estimates used in the system's design. In practice, slurrying is reported to have worked well.

Despite the obvious technical advantages and success of prototype operations over the course of many years, no slurry carrying ships are currently on order and no more than six were built or have been converted to carry slurry. A possible explanation for this is that slurry ships are extremely specialized in nature which means that there is no margin for error in the plans. The system depends on the good faith of those parties involved with its use. This is perhaps more than the business climate in the minerals industry can provide.

The initial slurry system developed uses a finely ground slurry and was intended to be used for the transport of iron ore. With this process the carrying water settles and is decanted in the ship. The resulting solid is mud-like - "sticky" and not free flowing.

Table IV.6.1 Comparison of Costs between Marconaflo and Conventional Transportation Systems: A Hypothetical Case
(Dollars per ton, except as otherwise indicated)

	Land transport	Loading port	Ocean transport	Receiving port	Total
Marconaflo	(100 pipeline miles)		(5000 ocean miles)	(slurry tanks)	
Capital expenditures (total cost)	15 million	5 million	60 million	5 million	85 million
Capital charge a/	0.45	0.15	1.80	0.15	2.55
Total	0.65	0.20	2.80	0.20	3.85
Conventional	(130 railway miles)	(stockpiles, loading equipment)	(5000 ocean miles)	(stockpiles, unloading equipment)	
Capital expenditures	40 million	15 million	70 million	20 million	145 million
Transport cost					
Direct cost	0.80	0.30	2.00	0.40	3.50
Capital charge a/	1.20	0.45	2.10	0.60	4.35
Total	2.00	0.75	4.10	1.00	7.85

Source: Engineering and Mining Journal, September 1970, p. 72.

a/ Based on annual rate of 15 percent of total capital cost including interest, insurance and depreciaton

When discharged, the slurry can form steep walled piles as high as forty feet. This makes it difficult to use conventional ship unloading equipment. Thus, supplying slurry to a port which uses this process is possible only where there exists an integrated system of slurry carrying ships and special purpose slurry discharge terminals.

A new slurry process is being developed for coal. Here the basic slurry element is small lumps. This is called Integrated Pipeline Transportation and Coal Separation System (IPTACSS). Large pieces of coal are crushed, then the small pieces are made into briquettes to raise their particle size to a set minimum. A hydrocarbon, such as diesel fuel or gas oil, is mixed with the coal to adjust its viscosity when the coal is mixed with the transport water. The mixture of coal, hydrocarbon and transporting water can then be pumped.

The IPTACSS process has many advantages for coal transport. The slurry preparation process can be integrated in the coal washing process. Low grade coal, with as much as 70 percent ash content, can be improved until it has as little as 15 percent ash content. Furthermore, the transport water can be removed from the slurry simply by draining the mixture over a screen and the resulting product can be loaded on the ship with a conventional ship loader. If the coal is loaded on the ship as a slurry, the water can be decanted aboard the ship and the resulting cargo can be discharged with conventional unloaders. This ensures that the product has a wide market. Also, the ship can be fitted to discharge the coal using the slurry system when facilities exist to receive slurry. This system is the most economical. The hydrocarbon can be removed at many stages of the process, or it can be burnt with the coal.

Figure IV.6.3 indicates what the cost of slurry transport and competing modes were in 1982. The breakeven distances with rail for various volumes is given in Table IV.6.2. Although this information is not current, the relative costs presented are probably still valid. It is important to note that slurry in low volumes is the least expensive means of transport.

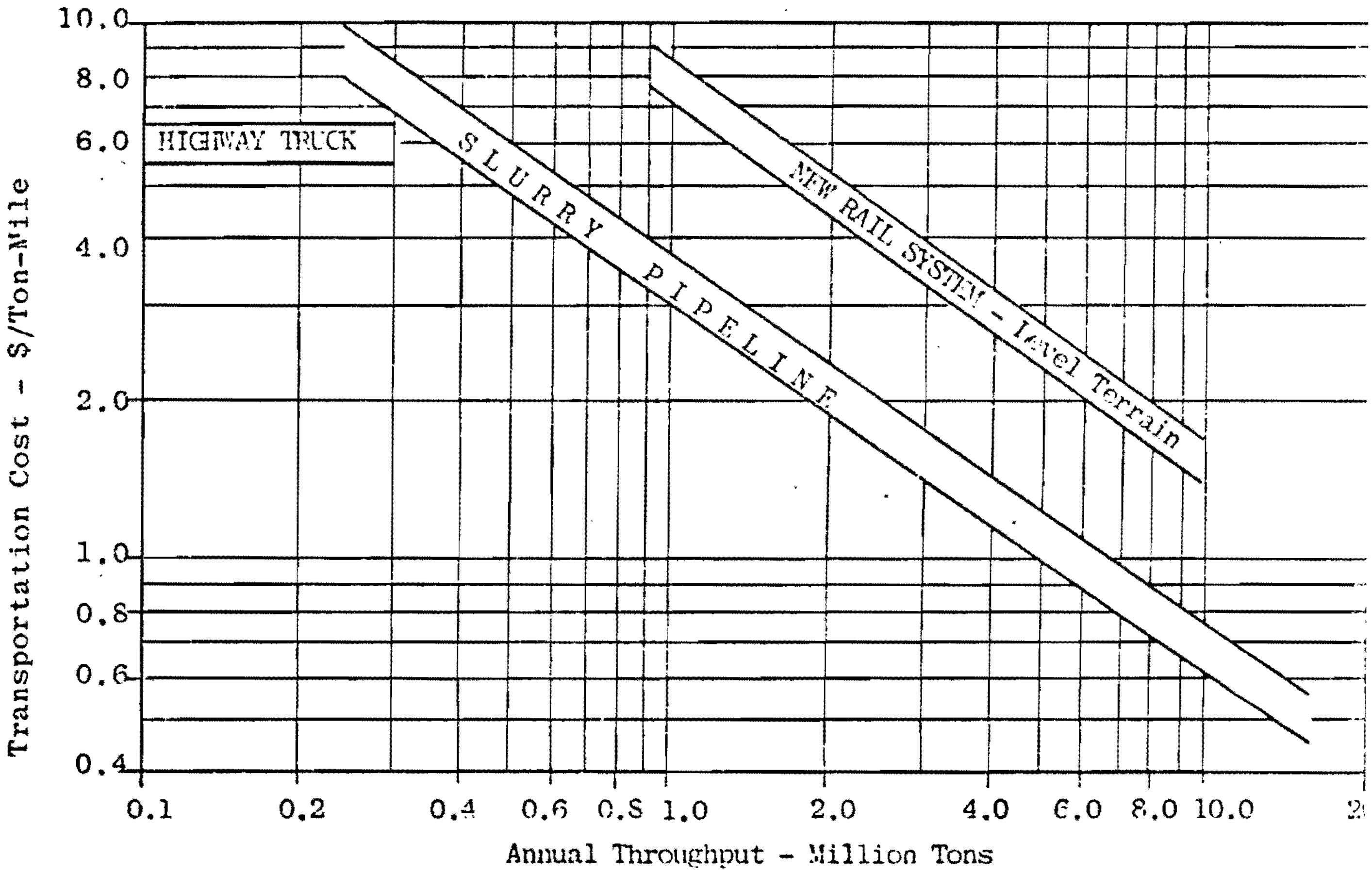
Table IV.6.2 COMPARISON OF SLURRY PIPELINE COSTS WITH RAILWAY COSTS

Tons per year	Distance over which competitive with railway
0.5 million	All distances
1 million	Over 70 miles
2 million	Over 150 miles
5 million	Over 250 miles
10 million	About equal over 300 miles

Source: J. H. D. Sturgess, and J. D. Weldon. "The economic prospects for solids pipelines in lieu of new rail branch line construction." Presented before eighth annual meeting of Transportation Research Forum, Montreal, Canada, September 1967.

There are over eighty slurry pipelines in use throughout the world These carry coal, iron ore, sulfur, potash, kaolin, phosphate, limestone, and other materials. More information about many of the projects is given in Table IV.6.3.

FIGURE IV.6.3 SLURRY PIPELINE TRANSPORTATION COST - IRON CONCENTRATE, COPPER CONCENTRATE, AND LIMESTONE (1982)



Source: Transportation & Traffic Engineering Handbook, Ed. Wolfgang S. Homburger, Institute of Transportation Engineers, Prentice-Hall, Inc., New Jersey, 1982.

Table IV.6.3 Selected Commercial Slurry Pipelines

	Length (miles)	Pipe Size (in)	Capacity (tons/yrx10^6)	Operational (year)
Coal				
Consolidation	108	10	1.3	1957
Black Mesa	273	18	4.8	1970
ETSI	1378	38	25.0	198-
Alton	180	24	10.0	198-
Iron Concentrate				
Savage river	53	9	2.25	1967
Waipipi (Iron Sands)	6	8 and 12	1.0	1971
Pena Colorado	28	8	1.8	1974
Las Truchas	17	10	1.5	1976
Sierra Grande	20	8	2.1	1978
Samarco	253	20	12.0	1977
Copper Concentrate				
Bougainville	17	6	1.0	1972
West Irian	69	4	0.3	1972
Pinto valley	11	4	0.4	1974
Limestone				
Rugby	57	10	1.7	1964
Calaveras	17	7	1.5	1971
Phosphate Concentrate				
Valip	80	8	2.0	1979

Source: World Bank staff.

IV.7 Conveyors

In many ways conveyors are the best suited device to carry bulk materials. Transfer equipment, required to load and discharge material from the conveyor, is simple and inexpensive. Conveying systems usually have the smallest requirements for internal storage of any transport system. Environmental considerations are easily solved, as are requirements about protecting the cargo from the weather. Furthermore, for distances less than five miles, conveyors also tend to be the cheapest transportation mode for bulk materials. For distances over five miles, trucks will have lower costs. Thus, most long distance conveyors are less than five miles long and very few are longer than ten miles.

Besides the cost over vast distances, the most significant disadvantage of a conveying system compared to the use of trucks is that a breakdown usually causes the entire operation to stop. Truck and rail services often can continue to operate despite a breakdown, although at reduced capacity. Shorter conveying systems used in material stockyards usually have redundant capacity, but this is seldom available on long distance conveyors.

In some situations the long distance conveyor may be the best transport option. This was the case in the Spanish Sahara, where a 62 mile long conveyor is used to move phosphate rock. This choice of transport system was made in part because the terrain is difficult and there is not enough water available to use the slurry approach.

Aerial Tramways

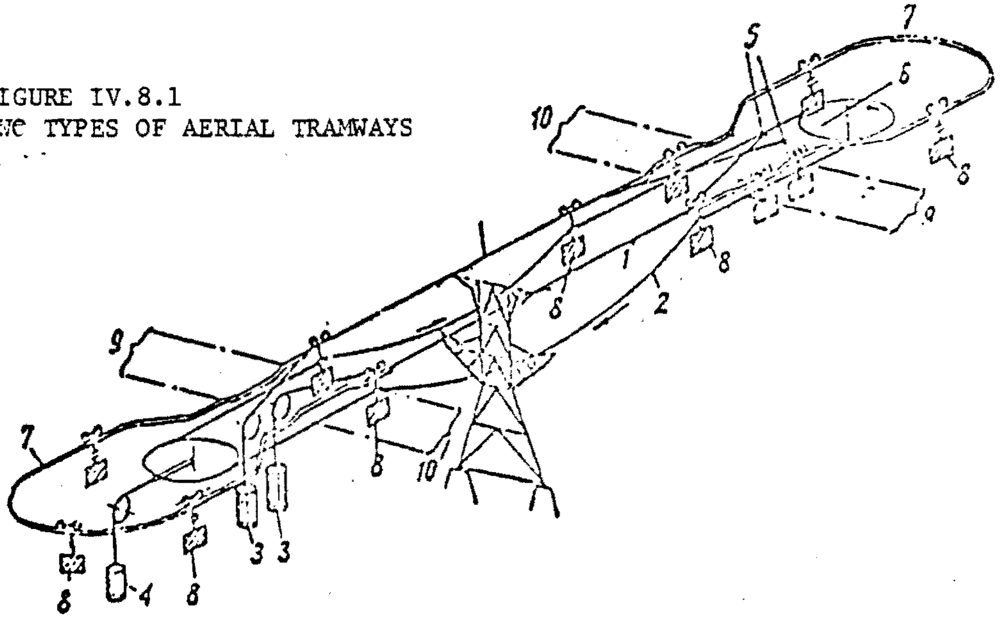
Aerial tramways consist of a loop of wire rope that is supported by towers spaced about every 500 meters. The rope is moved by a motor driven spool located at one end. Buckets are suspended from the cable and moved in the manner illustrated in Figure IV.8.1. The buckets, which carry the commodity, may each have a capacity of up to 150 tons. Cable means are well-adapted to difficult terrain. For transporting small quantities their capital cost is low and they are competitive with conveyors when there is only a small amount of cargo, even on the ground.

It is possible, although unusual, to mount one end of the tramway directly on the ship - this makes it necessary to assemble the device each time a vessel is loaded. This was a common way to load lumber schooners on the American Pacific Coast up to 1920. The tramway line was attached to the mast and the logs were slid down the line to the vessel.

Modern aerial tramways have either one cable or two. Cable ways using the mono-cable principle, employ the same wire rope to support and move the load (see Figure IV.8.1). The mono-cable is the less expensive arrangement because the tramway construction is simple. In the bi-cable tramway the weight of the moving buckets is supported by a stationary cable, while motive power for the buckets (mounted on wheels) is supplied by a second cable. The bi-cable arrangement makes sense because of the properties of wire rope. Rope, sufficiently flexible to be used in continuous movement over sheaves, must have a hemp core and is not as strong as solid steel wire rope that can be used where continuous movement is not required. The bi-cable ropeway separates the supporting and moving functions in a way appropriate to the types of wire rope available.

Over level terrain tramways are less costly than conveyors when less than 300 tons per hour is moved. It is approximately equal in cost to move any amount between 300 and 400 tons per hour. On difficult

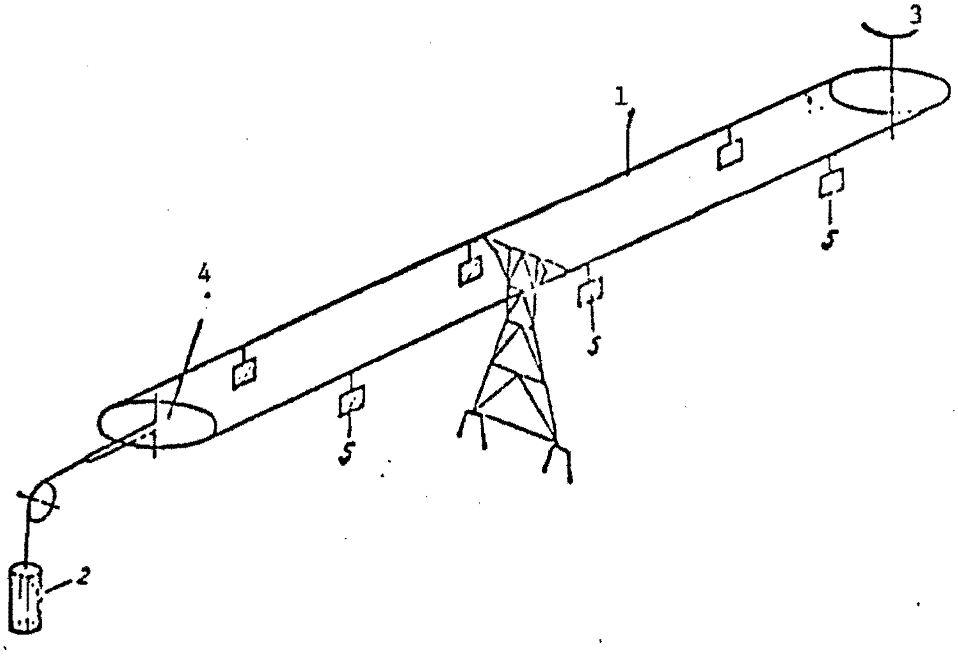
FIGURE IV.8.1
TWO TYPES OF AERIAL TRAMWAYS



Arrangement of a Bicable Aerial Tramway

1 - Track Cables	6 - Driving Sheave
2 - Traction Cable	7 - Shunt Rails
3 - Tension Weight for Track Cables	8 - Carriers
4 - Tension Weight for Traction Cable	9 - Locking Frame
5 - Track Cable Anchors	10 - Unlocking of Carriers

Source: E. Frankel Article.



Arrangement of a Monocable Aerial Tramway

1 - Track/Traction Cable	
2 - Tension Counterweight	4 - Return Sheave
3 - Driving Sheave	5 - Carriers

Source; E. Frankel Article.

terrain comparison is meaningless and the tramway may be the only feasible way to move bulk cargo. Properly designed tramways, incidentally, are very resistant to earthquakes, as much of the current technology was developed for ship to ship transfer of goods when each vessel is moving.

Tramways can have very low total horsepower requirements, as the only energy losses in the system are from internal friction in the wire ropes and wheel of the trolley buckets in the bi-cable system. The total power consumed is a function of the change in the loading and discharging elevation. Systems where the cargo is delivered at a lower point than where it is loaded from are sometimes fitted with generators to make use of the energy of the descending cargo.

Table IV.8.1 lists the estimated construction costs of a German aerial tramway in 1982. For convenience these costs have also been converted into dollars. Table IV.8.2 provides further information about some existing aerial tramways.

IV.9 Modal Comparisons

In selecting a suitable bulk transport system, the choice is usually restricted to some subset of the modes presented in this section. No general rule clearly can exist that indicates the dominance of one choice over others based on a few simple parameters. Each application can have characteristics which rule out, or put at a special disadvantage, certain systems. This section presents some comparisons that have been carried out in specific cases. These can serve as a guide for making comparisons among modes.

In many instances rail, truck, ropeway, and tramway are direct competitors. Table IV.9.1 presents a comparison of alternatives

Table IV.8.1 Investment and Operating Costs of a Ropeway System

Characteristics
Length (Conveying distance), km : approx. 10
Drop in conveying direction, m : approx. 700
Material conveyed : limestone
Conveying performance, t/h : 300
System : 2-cable continuous ropeway
Hauling rope speed, m/s : 4
Load capacity per ropeway car, t : 1.82
Interval between cars, s : approx. 22
Distance between cars, m : 88
Drive rating : none
Brake power, kW : 450

	xDM 1,000 approx.	x$1,000
Investment cost		
Machinery parts, steel structures and electrical equipment free to construction site	9,500	3,808
Ropes, free to construction site	2,000	802
Installation	3,000	1,203
Construction work	2,500	1,002
Other expenses	500	200
	17,500	7,016
Operating and transport costs		
7% interest and invested capital	1,225	491
Amortization of system in 20 years, excluding ropes (2,44% of DM 15,500,000)	380	152
Amortization of the ropes in 5 years (17.4% of DM 2,000,000)	350	140
Personnel costs (two shifts day) for a total of: 1 foreman DM 65,000 1 specialist DM 45,000 6 trained workers (+ 1 stand-by) DM 280,000	390	156
Electricity costs not applicable, since the system is generator braked, feeding electricity into the network		
Maintenance, lubricants, etc.	155	62
Operating and transport costs per year	2,500	1,002
Operating and transport costs per tonne	DM 1,90	$ 0.76

Source: Process Economics International, Vol III, Nos. 1&2 (1982)
($1 = DM 2,4941, May 1983)

Table IV.8.2 Selected Examples of Long-Distance Aerial Ropeways

Country	Commodity	Length (miles)	Capacity (thousands of tons per hour)	Capital cost Total (millions of dollars)	Capital cost Per mile (thousands of dollars)	Type	Year commissioned	Remarks
Brazil	Limestone	18.5	100	0.75	40	Mono	1957	Portland cement,Belo Horizonte
Gabon	Manganese ore	47	150 (now 250	8.0	170	Mono	1962	COMILOG, Moanda to M'binda (Kinshasa)
Germany, Federal Republic of	Limestone	1.4	300	0.95	680	Bi	1971	Portland cement, Dotternhausen
India	Sand	2.4 15.5	200 450	6	330	Mono Bi	1965	Sand-storing plant, Jharia, Bihar
India	Sand	6.2 21.6	200 450	12	430	Mono Bi	1967	Sand-storing plant, Jambad, West Bengal
India	Limestone	1.2	400	0.6	580	Bi	1971	United Provinces Cement Works, Marrapur
Sweden	Ore concentrate	60	50 (now 70)	4.0	67	Bi	1943	Kristenberg to Boliden

Source: The Application of Modern Transport Technology of Mineral Development in Developing Countries, United Nations, N.Y., 1976.

TABLE IV.9.1 Relative Costs for Alternative Modes of Mineral Transport Over Short Distances

Parameter	Conveyor	Railway	Ropeway	Truck
Relative Capital Cost a/	1.00	1.30	0.81	0.97
Relative Operating Cost	1.00	1.26	2.29	2.16

a/ Annual throughput of 3 million tons.

Source: World Bank staff.

for the transport of bauxite. The table uses indices with a base of 1.0 for the conveyor option.

When the waterway option is available, this can be extremely competitive with rail. The cost of waterway transportation may be about half of the railway cost. For vessels of 9 feet draught the cost in 1976 was 1.75-7.0 mills per ton-mile for waterway transport (1 mill = 0.1 cents). This compares with 5.8 mills per ton-mile for rail, and road haulage costs of 4.6 cents or more per ton-mile. Again, within a given option (i.e., belt conveyors), many configurations may be examined. Table IV.9.2 shows comparisons among belt conveyor options. We note that these are financial costs, the actual economic cost may be less depending on the effect of taxes and other factors.

TABLE IV.9.2 Putnam Coal Mine: Alternative Belt Conveyor Systems (1969)

Item	Multiflight conventional conveyor		Single-flight steel-cored conveyor		Single-flight cable belt conveyor	
Capacity (tons per hour)		200		200		200
Length (feet)	27x	500	27x	500	27x	500
Lift (feet)		130		130		130
Speed (feet per minute)		650		800		650
Width (inches)		42		36		42
Power required (hp)	2x	600	2x	400	1x	200
Number of transfer points	Terminals plus 5		Terminals only		Terminals only	
Reliability Ranking	2		3		1	
Capital cost comparison factor	1.15		1.35		1.00	
Projected operating cost						
Total per year (dollars)	260,000		155,000		230,000	
per ton (cents)	7.4		4.4		6.5	

Source: World Bank staff.

V. TERMINAL SITING

V.1 Introduction

In this chapter choosing a port site from among several alternatives will be discussed. In general the following factors are of importance:

a. Sufficient demand must exist to sustain the port's operation.

b. In order to attract sufficient demand, the port's natural conditions, such as depth, should impose as few restrictions as possible on prospective ships that would call on the port, and it should be easily accessible from trade routes of interest.

c. Over 55 percent of all port-related costs are the result of delays in ships' turnaround. Therefore, efficient material handling equipment is necessary for loading/unloading of ships and for transferring cargo to storage or to the inland distribution network.

d. efficient inland distribution networks should be available to minimize shipper's inland transportation costs.

Keeping the above factors in mind, a general methodology for bulk terminal logistics can be developed.

V.2 Methodology for Terminal Siting

The steps involved in selecting a bulk terminal site may be structured as follows:

Step 1 Description of the proposed bulk port projects. This will include a statement of objectives describing the potential benefits and beneficiaries and a description of the alternative port configurations that should be considered.

Step 2 Forecast of bulk traffic flow. The result of this forecast will be the basis for determining port capacity, bulk handling equipment requirements, and the choice of the inland transportation mode.

Step 3 Assessment of costs and benefits. The cost items in a port development can be categorized as follows:

(1) Port facility costs. Given the projected bulk handling requirement, a simple queuing model analysis can determine the number of berths needed to provide a satisfactory level of service to port users. The level of service is measured according to the average waiting time and the average number of ships waiting to be loaded or unloaded.

(2) Material handling equipment cost. These costs are affected by the type of bulk material to be transferred and also by the layout of the port.

(3) Inland transportation costs

(4) Benefits. The benefits that can be readily recognized from developing a port are savings in shipping costs due to the economies of scale in vessel size, reduction in ships' waiting time, savings in investment costs, etc. Other benefits, such as regional development and improved competitiveness in international markets, are less easily quantified.

Step 4 Alternatives for timing of investments. In determining the port capacity, one has to consider the possibility of later expansion to accommodate demand growth. The objective will be to determine a port expansion strategy which results in the minimum cost, while providing a desired level of service at all times. Possible strategies are to build enough capacity initially so that no further expansion is necessary over the planning horizon, or to expand capacity as needed, or to build something in-between.

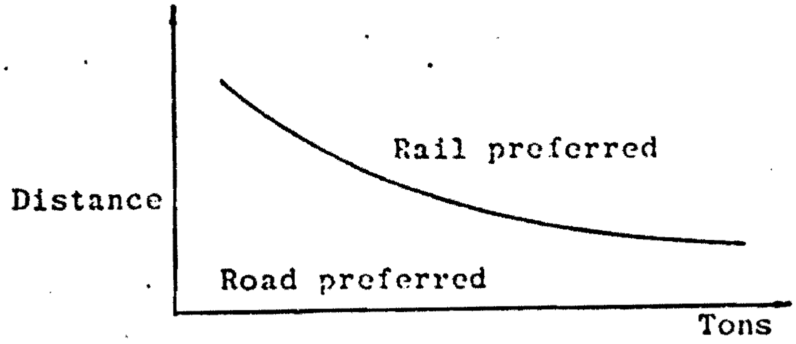
Step 5 Economic feasibility analysis. Present value and internal rate of return calculations can now be carried out. From the present value analysis, one can choose the combination of a port site and inland transportation alternative that gives the largest net present value of total costs and benefits. Table V.2.1 presents a format for calculating present values.

Step 6 Sensitivity analysis. After the best port site and the inland transportation mode from that site have been selected in Step 5, a sensitivity analysis is performed to understand how the selected site and the inland transport mode will be affected as traffic volume or capital investment costs change. For example, if investment costs for road facilities increase proportionally with traffic volume, the preferred inland transportation mode may be rail, instead of road. It is useful to develop breakeven distance/volume relationships among alternate inland transportation modes. Figure V.2.1 shows such a relationship.

TABLE V.2.1 Present Value Analysis (Step 5)

		Port Development Cost				Inland Alternative Costs								
						Road			Rail			Barges		
Alternate	Year	Capital cost	Operating cost	Total cost	p.v. (discount)	Cap. cost	Oper. cost	p.v.	Cap. cost	Oper. cost	p.v.	Cap. cost	Oper. cost	p.v.
A	1													
	2													
	3													
	4													
	econ. life													
B	1													
	2													
	3													
	4													
C	1													
	2													

FIGURE V.2.1 BREAK EVEN DISTANCE/VOLUME RELATIONSHIP BETWEEN ROAD AND RAIL (SINGLE ROUTE)



V.3 Information Requirements

The relevant data for terminal site selection analysis can be summarized as follows:

1. Characteristics of alternate terminal sites
2. Audit of current conditions
    a. Identifying demand centers in a region that is to be served by the bulk port.
    b. Accurate amount of bulk trade (import and export) generated by each demand center.
    c. Inventory of available resources including (i) the existing port, its facilities, and handling capacity, and (ii) the existing inland transportation network.
3. Information for economic analysis
    a. Inland transportation network distances from each alternate terminal site to each demand center.
    b. New investment costs for each alternate inland transportation mode and its actual operating cost.
    c. Financial resources available
    d. Revenue schedule
    e. Appropriate rate of return
    f. Foreign exchange earning
    g. Construction period and economic life of the project, equipment, etc.

V.4 Ranking Procedure

From the described general methodology for bulk terminal logistics, a site can be chosen based on a pure cost/benefit analysis. But, as stated earlier, Non-quantifiable factors also have important effects on terminal siting decisions and, thus, they should be taken into account. The following procedure will enable port planners to incorporate non-quantifiable factors into the terminal siting decision.

First, a list of relevant non-quantifiable factors along with the results of the economic analysis is developed. The relevant factors may include the following:

a. Availability of labor
b. Skill level of labor
c. Available financial resources
d. Port expandability
e. Existing infrastructure around prospective port site
f. Regional development considerations
g. Attractiveness of location to ship operators - a port's natural conditions, such as depth and the accessibility of the port to ship operators
h. Economic analysis result (NPV calculation)
i. Sensitivity analysis result

Note that, in performing the economic analysis, such factors as sufficient demand availability, efficient material handling system, transportation investment and operating costs have already been accounted for.

The next step is to assign weights to each factor, which would represent the relative importance of the factor with respect to others in planning for port development. Each factor is then ranked on a scale of 1 to 5 - 1 representing poor and 5 representing excellent - for each alternate site. The total weighted score for each alternate site is calculated by summing up the product of the assigned weight of each factor and the given rank. The example in Table V. .1 illustrates the procedure. From it one can see that, even though the alternate site A has the highest advantage in terms of the economic analysis result, alternate site C has the highest weighted score when all other factors are considered.

One difficulty with this procedure is that human judgements are required in assigning weights to each factor and ranking each alternative.

Table V.5.1 Ranking Procedure Example

Factors	Weight	Rank			Weighted Score		
		Alternatives			Alternatives		
		A	B	C	A	B	C
Labor availability	0.1	2	2	4	0.2	0.2	0.4
Labor skill	0.05	3	4	3	0.15	0.2	0.15
Financial resource	0.2	2	3	5	0.4	0.6	1.0
Port expandability	0.05	4	3	3	0.2	0.15	0.15
Infrastructure	0.05	4	5	3	0.2	0.25	0.15
Regional development	0.15	2	5	3	0.3	0.75	0.45
Attractiveness	0.15	4	2	4	0.6	0.3	0.6
Cost analysis	0.2	5	4	3	1.0	0.8	0.6
Sensivity analysis	0.05	5	4	3	0.25	0.2	0.15
	1.00				3.3	3.45	3.65

Rank 1 = Severe disadvantage
2 = Mild disadvantage
3 = Equal standing
4 = Mild advantage
5 = Great advantage

Nevertheless, the procedure provides a means for taking non-quantifiable factors into account in terminal siting decisions and through careful analysis reasonable judgements can be made on weight assignments and ranking alternatives.

V.5 Terminal Siting and Regional Development

In selecting the location of a bulk terminal, the costs, which include investment and operating costs for the port and for inland distribution, were used as the main criteria. However, appraising it from the national standpoint, balanced regional development of the country is equally important. It would be in the national interest to increase the income of depressed regions in order to decrease the differences in incomes among regions. This is difficult to include in the economic analysis presented earlier.

Per capita income of each region indicates the development status of that region in relation to tohers. The effect of this project on per capita income may be included within the ranking procedure described earlier if regional development is one of the goals of port development.

The development of a port in a region can increase the income of that region through new employment and development of infrastructure facilities. Appendix A describes the regional development analysis performed by Paul E. Smith of the University of Missouri. This methodology can be used to calculate the equilibrium income in relation to other regions, given the marginal and average propensity to spend, and the effect of new investment in one region on its own income and on the income of other regions. In Appendix B a number of computer-based techniques useful in port development analysis are presented.

VI. TERMINAL EQUIPMENT OPTIONS

VI.1 Introduction

The functions performed by bulk-handling equipment in a port can be classified as loading and unloading ships, storing and reclaiming material, transporting material, transferring material between equipment, and, occasionally, cleaning and weighing the material. Except for ship loaders and unloaders, most of the equipment available can be used in other industries, such as the mining industry. The materials handling equipment field is dynamic and offers a rich variety of equipment, which can only be summarized here in brief.

Table VI.1.1 lists the equipment available for port use for each of the major materials handling functions. Much of this equipment is produced in small numbers with a high unit cost for design and engineering. If the available equipment designs are not satisfactory, it is common to custom-design equipment to meet exacting specifications. While subsequent sections of this paper describe general characteristics of the equipment, there is a lot of variability in the precise dimensions available.

This is particularly true of the capacity of continuously acting devices using conveyors, such as stackers and ship loaders. Often capacity is poorly related to equipment size and weight. The physical dimensions of the machines and the weight of the materials being transported by the equipment determine the machines' weight and cost. Typically a machine's weight - and cost - varies with the square of its size and the first power of the supported weights. With conveyor-type equipment, it is possible to increase capacity without significantly increasing either its size or weight. This can be done merely by increasing the speed at which the conveyor operates. It is, therefore,

Table VI.1.1 General Equipment Options for Bulk Ports

- *Loading
    - Fixed loaders
    - Travelling loaders
    - Quadrant loaders
        - radial
        - linear

- *Unloading
    - Level luffing grab cranes
    - Trolley type grab cranes
    - Continuous unloaders
    - Pneumatic unloaders
    - Ship mounted equipment
        - grab
        - self discharging ships

- *Storing/reclaiming
    - Piles
        - gravity reclaim
        - bucket wheel excavator reclaim
        - dragline reclaim
    - Silos and warehouses

- *Transporting
    - Mechanical
        - vehicles
        - trains
        - conveyors
        - chutes and elevators

- *Transferring
    - Chutes
    - Hoppers
    - Gates
    - Feeders

- *Cleaning
- *Weighing and grading

important to think about the equipment in terms of its physical size rather than its rated capacity.

Equipment tends to be rated optimistically. Only a few types of equipment can be selected on the basis of their rated capacity. Determining when to ignore manufacturer's claims without being arbitrary is difficult, as the capacity which can be achieved depends to a large extent on how the equipment is used. Table VI.1.2 presents ship loading and unloading equipment capabilities. Care must be administered in applying these figures, as equipment vary as to the extent its actual performance differs from the nominal rate. For example, the average performance of continuous unloaders is closer to rated performance than the average performance of grab unloaders. Hence, a continuous unloader with the same rating is more productive than a grab unloader.

Table VI.1.2 Summary of Design Commodity Handling Rates (tons/hr)

Commodity	Typical present handling rate (s) load	Typical present handling rate (s) unload	Design handling rate load	Design handling rate unload
Grain-small	400	300	700	400
-large	1200	1200	2000	2000
Ores:bauxite	3500	2000	5000	3000
Coal-small	300	200	500	400
-large	2000	2500	5000	4000
Fertilizer	1800	1900	2000	2000
Sugar		250-400		400

Source: Future requirements for mid-America Inland rivers port system - A. T. Roselli, Mississippi Valley Coal Exporters Council, New Orleans, 1982.

VI.2 Ship Loaders

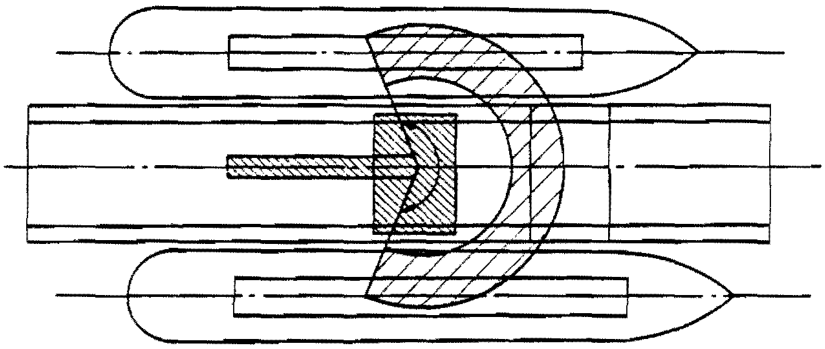
Ship loading involves two steps - base loading and trimming. Base loading is the filling of the ship to the maximum extent possible with the ship loader, and trimming is filling the remaining voids using auxiliary equipment. Most trimming is required because a typical ship's structure casts shadows. Often this prevents the ship loader from filling all the spaces in the hold. When a ship loader is too small for a ship, or it is otherwise geometrically incompatible with the ship, the ship may require a lot of trimming before it can sail. Since trimming is expensive, most of the design developments for ships and ship loaders have attempted to eliminate the need for manual trimming. General cargo ships have been the most troublesome, because portions of the cargo may require bagging before they are manually stowed in the voids of the ship. Because the trimming costs are high general-cargo ships are not, in most cases, competitive in the bulk trades.

Ships must always be trimmed, as specified in their loading manuals, to keep the cargo from shifting and damaging the ship. LASH ships are particularly susceptible to this kind of damage, as the loading of bulk into barges may not be supervised. Most bulk carrying ships no longer are required to trim manually, because the shape of their holds ensure that no voids remain when they are full.

All bulk loading (other than trimming) can be accomplished using conveyors, which raise the material, and a ship loader, which lets the material fall into specific areas of the hold. Using this two-step process, high loading rates are possible. Current problems have to do with the conveyor's capacity to supply the ship loader.

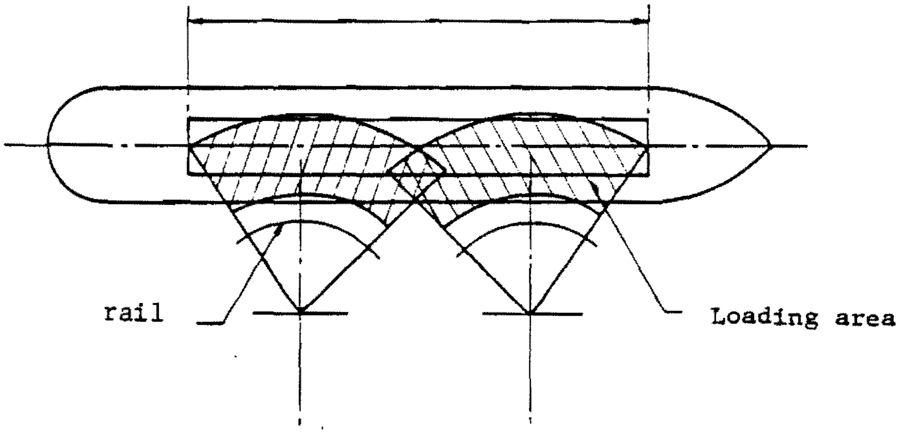
Modern mechanical ship loaders fall into two categories, travelling and quadrant. Travelling ship loaders are illustrated in Figures VI.2.1 and VI.2.3. Quadrant loaders are illustrated in Figures VI.2.2 and

FIGURE VI.2.1 LAYOUT OF PIER FOR TRAVELLING SHIP LOADER



Source: IHI Heavy Industries.

FIGURE VI.2.2 LAYOUT OF RADIAL SHIP LOADER INSTALLATION



Source: IHI Heavy Industries.

A third type of loader, the fixed loader, uses a spout or chute for each hold. These work well and are common on the Great Lakes. The dimensions of the ships there are standardized to fit under the loaders; no such standardization exists for ocean-going ships generally. The travelling loader moves on crane rails along a pier and, thus, can access the ship's entire hold. The quadrant type loader moves in an arc (see Figure VI.2.2) and, depending on the dimensions of the ship, two loaders may be used to reduce the number of times the ship must be moved during the loading. Quadrant loaders are either of the radial type, with a fixed pivot point, or of the linear type, with a movable pivot point (see Figure VI.2.4).

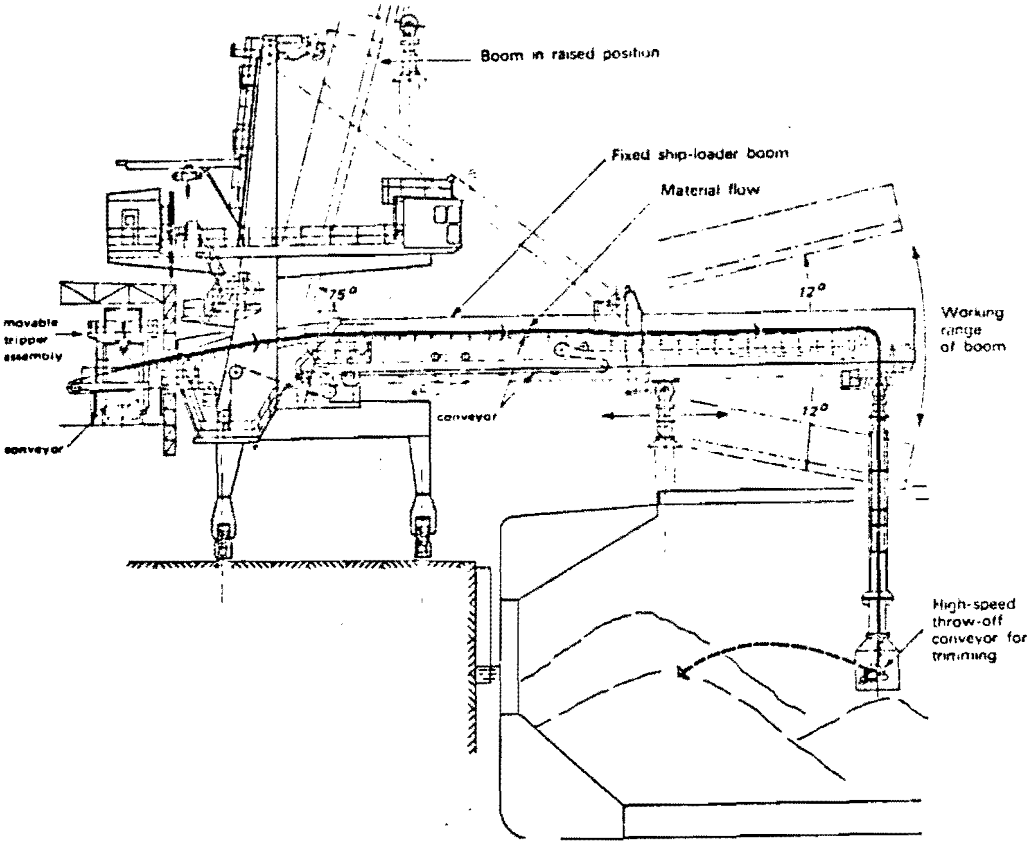
Quadrant loaders were developed to be installed offshore, and using them can reduce the amount of dredging and pile work that would be required to construct the port facility. They are also inexpensive. Their principal disadvantage is that they cannot be used to load all bulk ships for the following reasons:

1. They sweep out an arc over the deck, which means that a geared bulk carrier can be loaded only with much difficulty.
2. They have a fixed geometry, which means that problems may be encountered with gearless ships having dimensions different from those contemplated in the loader's design.
3. When they are installed offshore, they place the vessel in a fixed orientation to sea and, in severe weather conditions, the ship might have to leave the berth.
4. They are not able to trim the ship and can only partially load the ship if trimming is required.

Quadrant loaders can be assembled quickly at the site once their foundations are in place with the help of a floating crane.

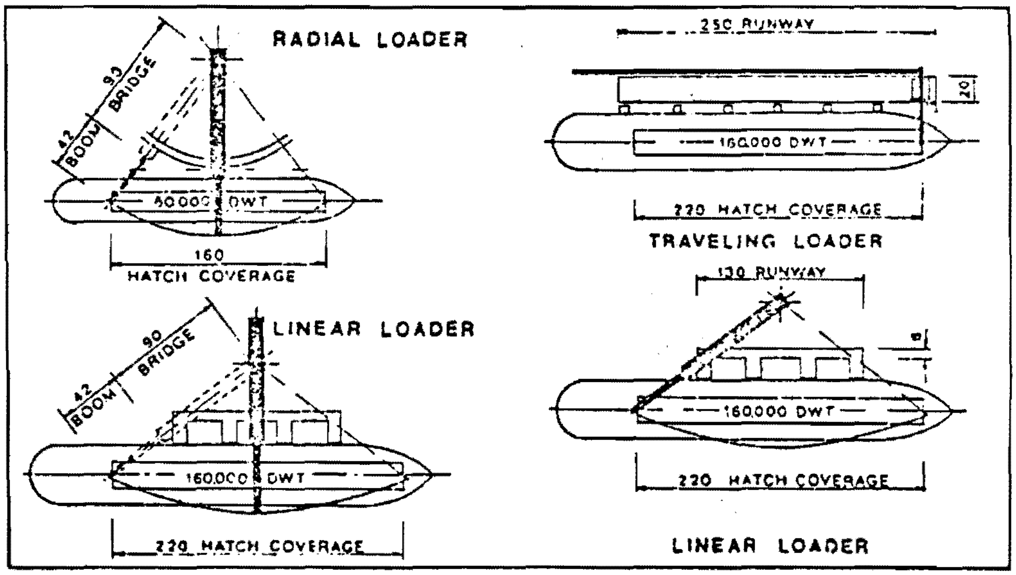
Travelling loaders are more expensive than quadrant loaders and need a pier on which to mount the rails. However, they are more flexible

FIGURE VI.2.3 TRAVELLING SHIP LOADER



Source: Port Development, UNCTAD, U.N., New York, 1978.

FIGURE VI.2.4 COMPARISON OF RADIAL AND LINEAR SHIP LOADERS



Source: Planning Layout and Design of Bulk Terminals, N. J. Ferguson, XXV International Navigation Conference, 10-16 May 1981, Edinburgh, Scotland, U.K., Permanent International Association of Navigation Congresses.

in the type of ship they service and can often load geared ships, although this cannot be guaranteed. Furthermore, they can be fitted to trim bulk carriers mechanically and this results in reduced loading costs. There are two types of travelling ship loaders: luffing types and slewing types. With a combination of revolving and longitudinal movement (see Figure VI.2.3), a slewing loader can vary the transverse position of material to be discharged. This arrangement can interfere with the loading of geared bulk carriers, but another type of loader is available that can vary the transverse position of cargo discharge by raising the loader's boom.

A loading facility designer must decide to what extent the loading facility should be required to move the ships during the loading. It is relatively easy to move a ship at berth, using its mooring winches, and, if the berth is properly designed, it should not take more than an hour and a half for a move. Turning the ship around is another matter. The ship must get underway, leave the berth and return. It requires the use of the engine and tug assistance. This operation takes about four hours.

Table VI.2.1 gives typical ship loader dimensions. The loader's boom outreach determines the maximum size of a ship that can be loaded without recirculation. The largest ship, however, that can be loaded is larger than that given in the table, because the cargo can be moved in the hold with bulldozers.

Table VI.2.1 Dimensions of Ship Loaders

	Travelling luffing slewing			Quadrant Radial	
Outreach from reference (m)	30	35	45	55	70
Maximum ship size (dwt) without cargo recirculation	100,000	100,000	200,000	250,000	300,000
Outreach from pier edge (m)	26	25	34	41.5	60
Quadrant radius (m)	--	--	--	50	60
Span of crane rails (m)	10	12	12	--	--
Minimum pier width (approx.) (m)	18	12	12	--	--
Speed data					
crane movement m/sec	30	20	30	--	--
boom shuttle sec (in&out)	10	20	20	10	10
slew (rotate) sec	--	15	20	7.5	9

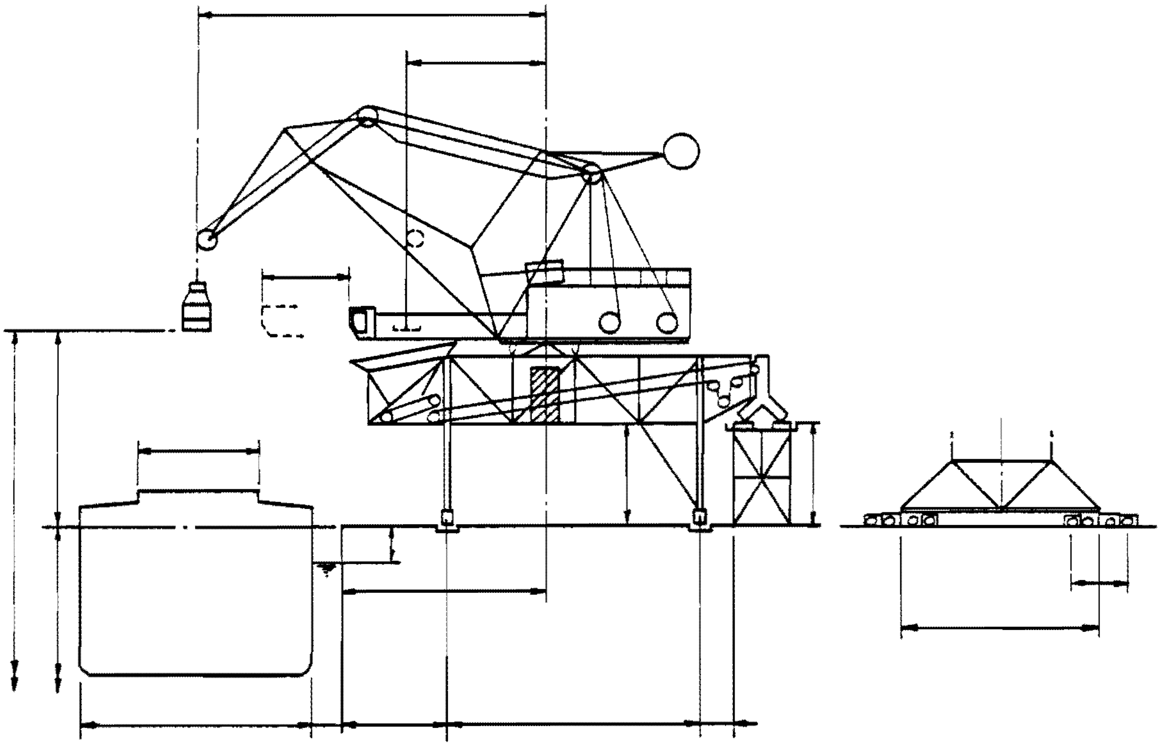
Source: World Bank staff.

VI.3 Ship Unloaders

Ship unloaders are larger than ship loaders for the same load. The unloader must access as much of the hold as possible to minimize cleaning expenses. Cleaning (i.e., the removal of the final portions of the cargo) is facilitated by bulldozers. These push cargo from areas that are inaccessible to the unloader to areas which are accessible. The smaller the unloader, in relation to the size of the ship, the greater is the cleaning work required. Not all bulk vessels are intended for in-hold bulldozer use, because the bulldozer blades can puncture bulkheads in unsuitable vessels. Each ship should be verified for suitability.

Ship unloaders use grabs, continuous bucket chains (or digging wheels), or pneumatic means to lift the cargo out of the ship's hold. Most ship unloaders are categorized as the grab or pneumatic type. Figures VI.3.1 and VI.3.2 illustrate two types of ship unloaders--the

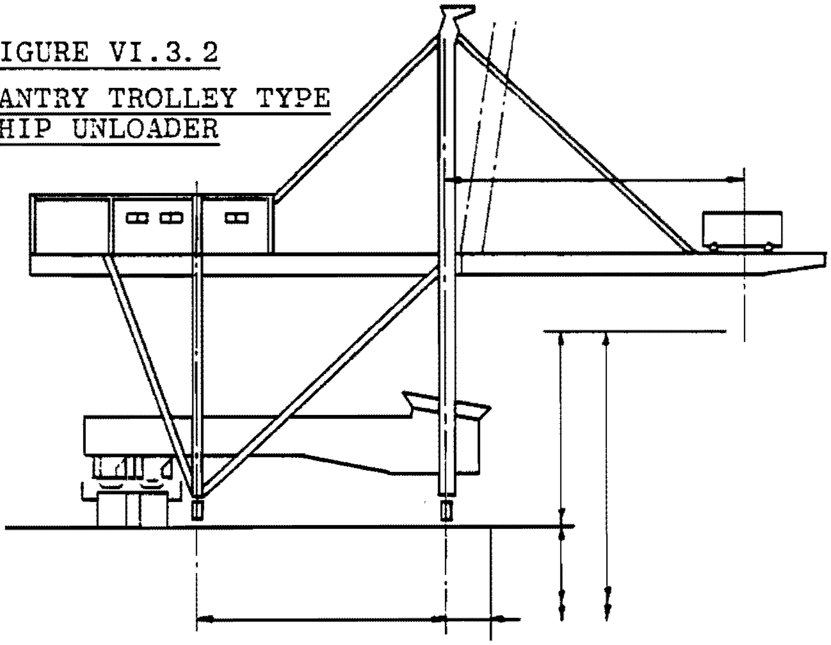
FIGURE VI.3.1 LEVEL LUFFING SHIP UNLOADER



Source: Mitsubishi Heavy Industries.

FIGURE VI.3.2

GANTRY TROLLEY TYPE SHIP UNLOADER



Source: Mitsubishi Heavy Industries.

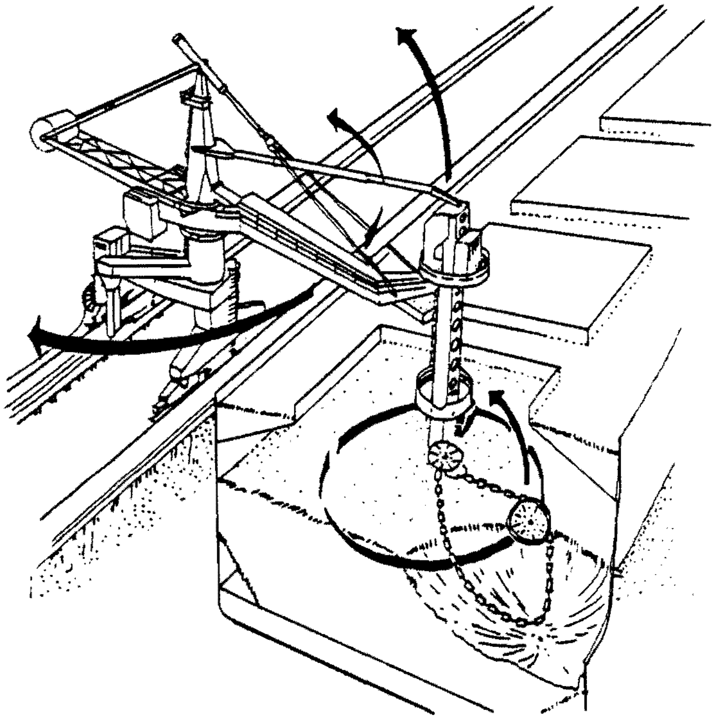
level luffing type and the trolley type. Both these are non-continuous unloaders. The continous unloader consists of a digging device which feeds a bucket elevator. This bucket elevator, in turn, raises the cargo to a discharge conveyor. Sometimes a digging chain (see Figure VI.3.3) or a digging wheel can be used instead of a bucket elevator. A disadvantage of the continuous unloader is that it is impractical to change the digging device and bucket elevator to suit the density of the cargo, and this unloader's production is reduced with less dense cargoes.

Because all three of these unloaders have large overhanging weights, which must be supported over the hold of the ship, their costs grow more with the size of the ship to be handled than with the discharge rate. As a result, the maximum ship size that can be handled is related to the discharge rate; faster machines being geared to larger ships. Figure VI.3.4 illustrates this relationship. It is possible, however, to unload larger ships than those shown. One can move cargo in the hold with bulldozers or turn the ship around at berth. Table VI.3.1 gives typical specifications for level luffing and trolley-type unloaders. Table VI.3.2 gives specifications for the capacity of continuous ship unloaders.

VI.3.1 Portable Ports and Transshipment Terminals

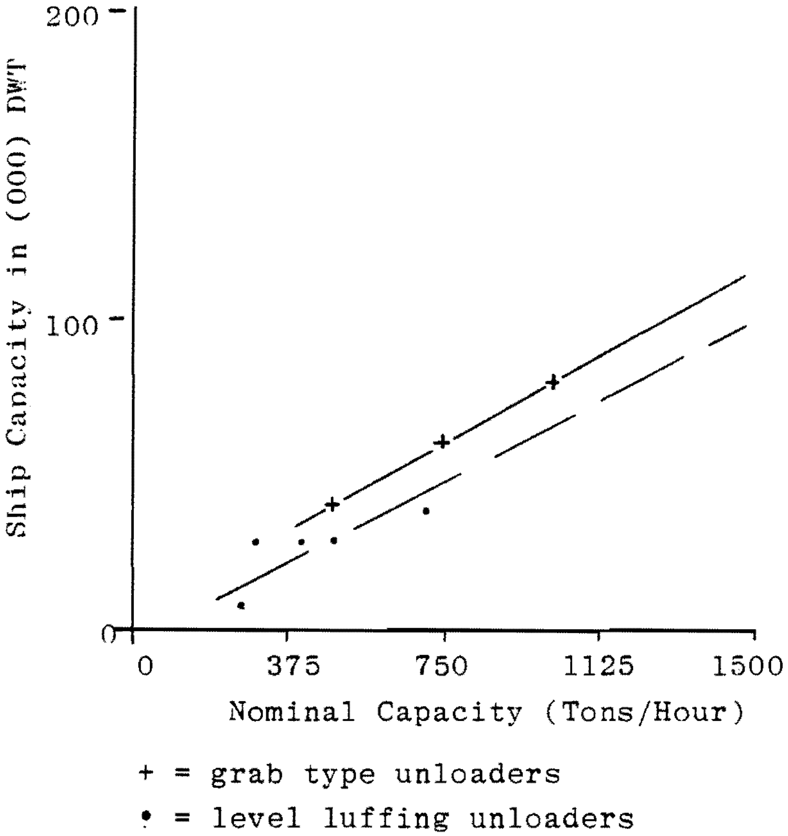
In many situations site development costs for the use of land mounted unloaders are high, or cargo can be directly transshipped to barges or small ships. In situations such as this a ship unloader (or combination ship loader/unloader) mounted on a catamaran barge can be used instead of a shore port. Figure VI.3.1.1 illustrates this device. Such devices are now in use on the lower Mississippi River, where they

FIGURE VI.3.3 CONTINUOUS TYPE SHIP UNLOADER



Source: Ship Design and Construction,
The Society of Naval Architects and Marine
Engineers, New York, 1970.

FIGURE VI.3.4 MAXIMUM SHIP SIZE FOR UNLOADERS



Source: Mitsubishi Heavy Industries.

Table VI.3.1 Typical Ship Unloader Dimensions and Rates

	Grab trolley type					Level luffing		
Capacity (t/hr)	500	640	1000	1500	2500	250	400	700
Hoisting load (tons)	16	20	30	40	42	6.3	10	25
Grab capacity (m^3)	8.5	11	16	22	21	3.2	5	13
Lift above crane (m) rail	18	20	20	22	23	12.5	15	18
Lift below crane rail (m)	15	16	18	20	19	11.5	13	15
Outreach from (m) reference	26	25	30	30	30	19.5	22.5	26.5
Span of rails (m)	20	25	30	30	30	14	14	20
Speeds (m/min)								
hoisting	90	100	100	110	140	100	100	100
lowering & grabbing	100	120	120	140	140	100	110	110
luffing	--	--	--	--	--	80	80	100
trolley movement	160	160	180	210	190	--	--	--
crane movement	20	20	20	20	20	20	20	20
Slewing (rad/min)	--	--	--	--	--	1	1	.8

Source: Mitsubishi Heavy Industries

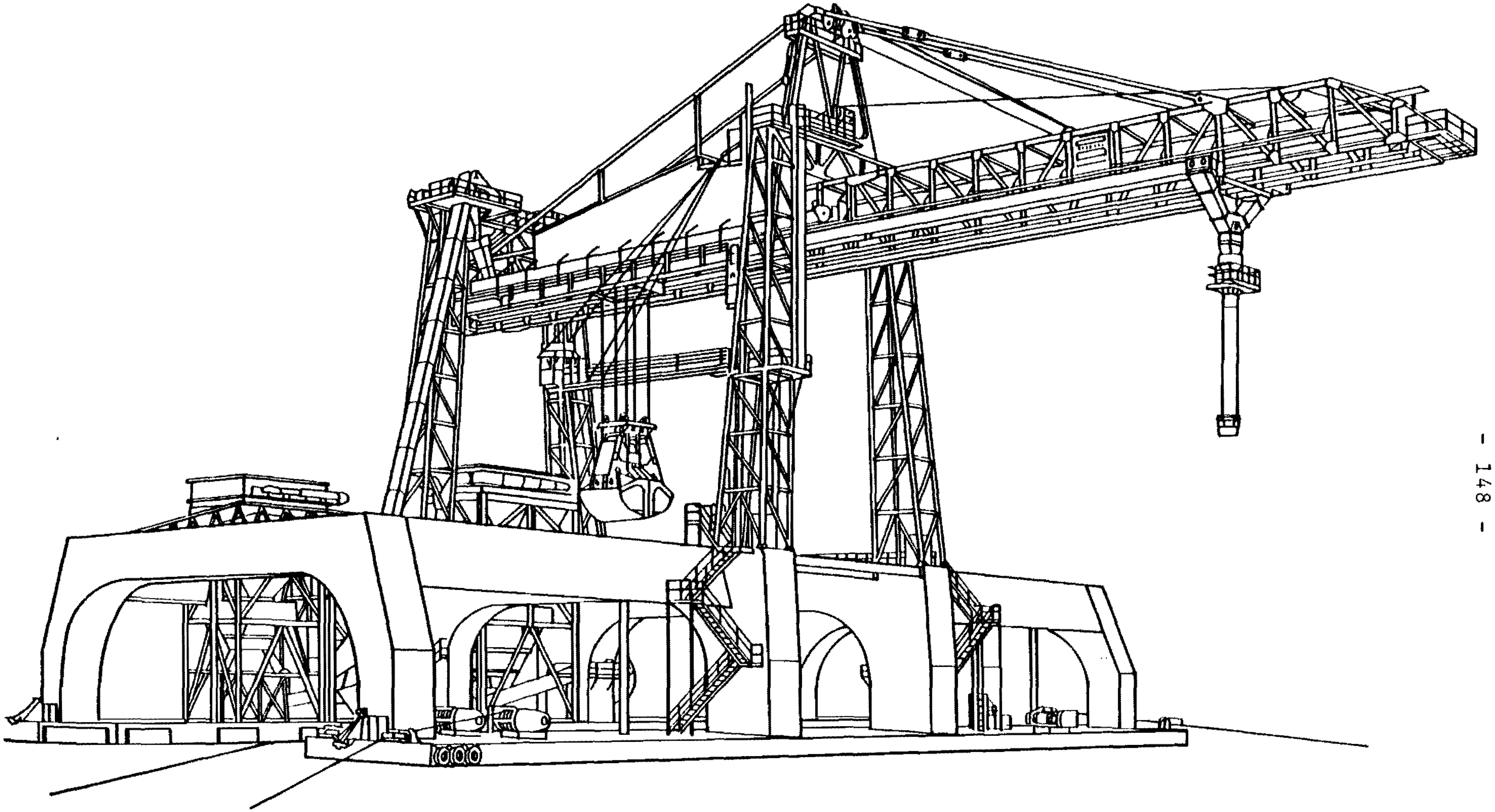
Table VI.3.2 Capacity of Continuous Ship Unloaders

		Rated Capacity-Free Digging Free Flowing Material-tons/hr							
Bucket Diameter	Line Speed	801 Kg/m^3 (50 lb/ft^3)	1201 Kg/m^3 (75 lb/ft^3)	1602 Kg/m^3 (100 lb/ft^3)	2002 Kg/m^3 (125 lb/ft^3)	2403 Kg/m^3 (150 lb/ft^3)	2803 Kg/m^3 (175 lb/ft^3)	*	Bucket Unit Capacity
254 mm	183 mpm	159	239	318	397	476	556	MT	0.0082 m^3
	3.05 mps	175	263	350	438	525	613	ST	
(10 in.)	(600 fpm)	156	235	313	391	469	547	LT	(0.29 ft^3)
381 mm	183 mpm	340	511	680	851	1021	1191	MT	0.030 m^3
	3.05 mps	375	563	750	938	1125	1313	ST	
(15 in.)	(600 fpm)	335	503	670	838	1005	1172	LT	(1.05 ft^3)
457 mm	183 mpm	499	748	998	1247	1497	1746	MT	0.052 m^3
	3.05 mps	550	825	1100	1375	1650	1925	ST	
(18 in.)	(600 fpm)	491	737	982	1228	1473	1719	LT	(1.82 ft^3)
610 mm	183 mpm	817	1225	1633	2041	2449	2858	MT	0.114 m^3
	3.05 mps	900	1350	1800	2250	2700	3150	ST	
(24 in.)	(600 fpm)	804	1205	1607	2009	2411	2813	LT	(4.03 ft^3)
762 mm	152 mpm	1179	1769	2359	2948	3538	4128	MT	0.248 m^3
	2.53 mps	1300	1950	2600	3250	3900	4550	ST	
(30 in.)	(500 fpm)	1161	1741	2321	2902	3482	4063	LT	(8.75 ft^3)
914 mm	146 mpm	1588	2381	3175	3969	4763	5557	MT	0.411 m^3
	2.43 mps	1750	2625	3500	4375	5250	6125	ST	
(36 in.)	(480 fpm)	1563	2344	3125	3906	4688	5469	LT	(14.5 ft^3

*Mt, metric tons; ST, short tons; LT, long tons.

Source: World Bank staff.

FIGURE VI.3.1.1 BARGE MOUNTED SHIP UNLOADER



Source: Amhoist.

transship grain and coal from river barges to large bulk carriers for export. Its specifications are shown in Table VI.3.3. Barge mounted units cost between 8 and 13 million dollars (U.S.), depending on purchase specification (American Chain and Hoist Mechanical Excavators Division).

In offshore discharge of grain to lighters, a similar device could be mounted on a very large crude carrying tanker with the internal volume of the ship serving as storage capacity for the discharge system. A variation would be to mount loading or discharge equipment on a newly constructed barge, allowing the entire ship handling facility to be constructed in a shipyard and towed to the site.

This approach has many potential advantages. First, while the cost of the barge, housing and power generation equipment mounted on the unit will be more than the land mounted unit's cost at the factory, the cost delivered may be less for the floating unit, because of cheaper shipping costs. Secondly, less site preparation is required at the port. Thirdly, because of the overcapacity in the shipbuilding industry, a very favorable price could be obtained. Depending on the device's usefulness in other situations, it could also prove possible to finance it through normal ship financing channels at subsidized interest rates.

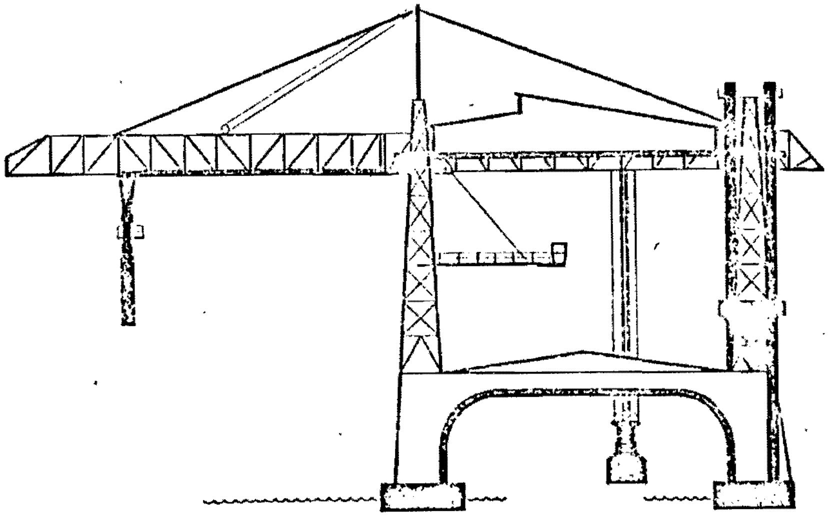
VI.3.2 Pneumatic Unloading Systems

Pneumatic unloading equipment is used to handle commodities with low density, such as grain, which also have little adhesion and are granular or powdery. These unloaders are continous and are made in sizes of up to 800 tons/hr. of grain with a single unit. As the commodity density increases, pneumatic unloader capacity usually decreases.

Table VI.3.3 Specifications for a Barge Mounted Ship Unloader

Dimensions	
Overall length	240 feet
Overall width	125 feet
Overall height above waterline	155 feet
Each catamaran barge	25 feet wide
Lateral space between catamaran barge	75 feet
Front apron length from side of catamaran barge	100 feet
Clearances	65 feet under bucket 100 feet clear of catamaran barge

Performance Specifications	
Hoisting capacity 140,000 lbs. at 100 feet from side of catamaran barge.	
Hoisting speed	220 feet per minute
Traverse speed	550 feet per minute
Fore-to-aft-speed of HH50 along ship	20 feet per minute
Theoretical cycle time barge to hopper	38 seconds
Production capacity in excess of 3000 tons per hour free digging.	
Power: DC electric from shore power via submarine cable, transformed to working voltages on board HH50	



Front apron supports conveyors discharge spout and clam-shell bucket. Apron can be raised up to 75-degree elevation to clear ship superstructure. Discharge spout can be remotely positioned anywhere along front apron and ir equippped with dust suppression equipment.

Operator's cab swings for optimum view of barges or ship holds, depending on mode of operation.

Machinery cab contains hoists and electrical control panels.

Fully-enclosed dual conveyor belts. Erie Strayer 50 cubic-yard clamshell bucket.

Fully-enclosed dual vertical conveyor belts.

Blending hoppers, complete with dust suppression equipment.

Collar frames stabilize catamaran barges. Center portions of collar frames contain facilities for crew lounge, control center, office, shop and storage space. Covers provide weather protection when unloading moisture-sensitive material.

Shallow-draft catamaran barges permit shoreside as well as midstream operations Catamaran design provides a protected ship for cargo barges.

Source: Amhoist

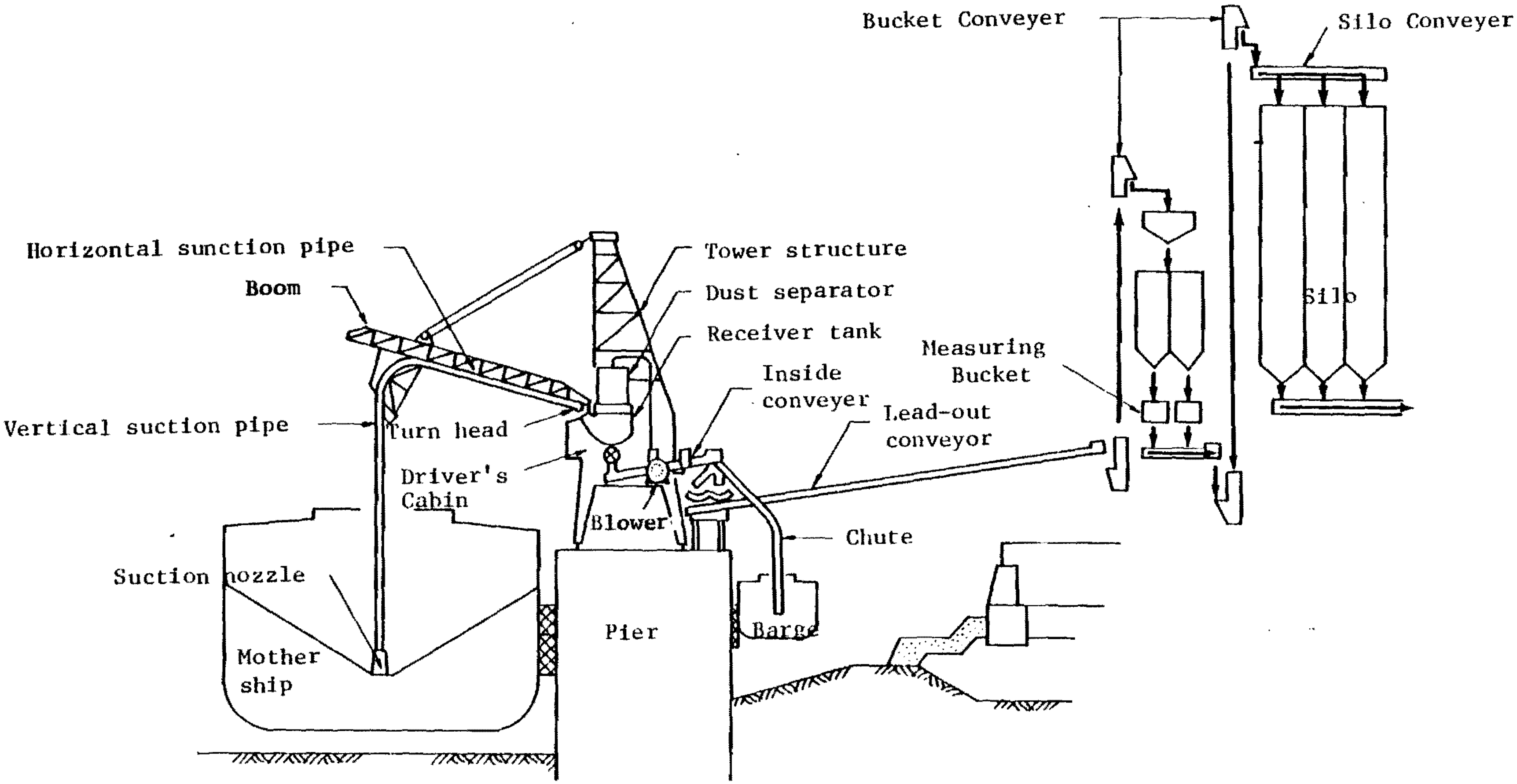
Similarly, the output is a function of grain size. Pneumatic unloaders are less expensive to procure than mechanical unloaders, but they require substantially more power to operate per unit throughput. Pneumatic unloaders (see Figure VI.3.2.1) have a vertical suction pipe with an attached suction nozzle. This is lowered into the hold of the ship by a level luffer or gantry crane, which also supports a horizontal suction pipe. A blower is used to generate the vacuum using a venturi device. The grain or other commodity discharged is sucked into a receiver tank which usually has a dust collector mounted on it. Transport from the unloader to a silo or loader can be by conveyor (as shown) or by pneumatic pipe transport.

VI.4 Material Storage

It is necessary to determine the best way to store a commodity in order to grade, blend, classify and protect it adequately. Material that does not require protection from the environment can be simply stored outside in a pile (or pond, if it is a slurry). Materials, requiring protection, can be stored in bins, silos, or warehouses (i.e., covered piles). Covered facilities are also used for material with low bulk densities that would, otherwise, blow away. While the materials handling equipment available for warehouses resembles that available for open piles, it may be less expensive to install equipment in a warehouse, because the structure of the building can be used to support the equipment.

Storage in a bulk handling system is either operational or reserve storage. Operational storage may be either long-term buffer storage,

FIGURE VI.3.2.1 TYPICAL PNEUMATIC GRAIN DISCHARGE SYSTEM



Source: Mitsubishi Heavy Industries.

required because of delays between shipments or deliveries, or surge storage, which is necessary to remove material and allow efficient equipment operations. Surge storage is frequently required where continuous devices, such as conveyors, operate with non-continuous devices, such as rail car dumpers.

Live storage refers to the portion of the material that a materials handling device can reach by itself. Dead storage is stored material that cannot be reached and additional equipment, such as a bulldozer, is needed to move it to a position where the materials handling device can reach it. Depending on the probability of use, reserve storage can be dead storage.

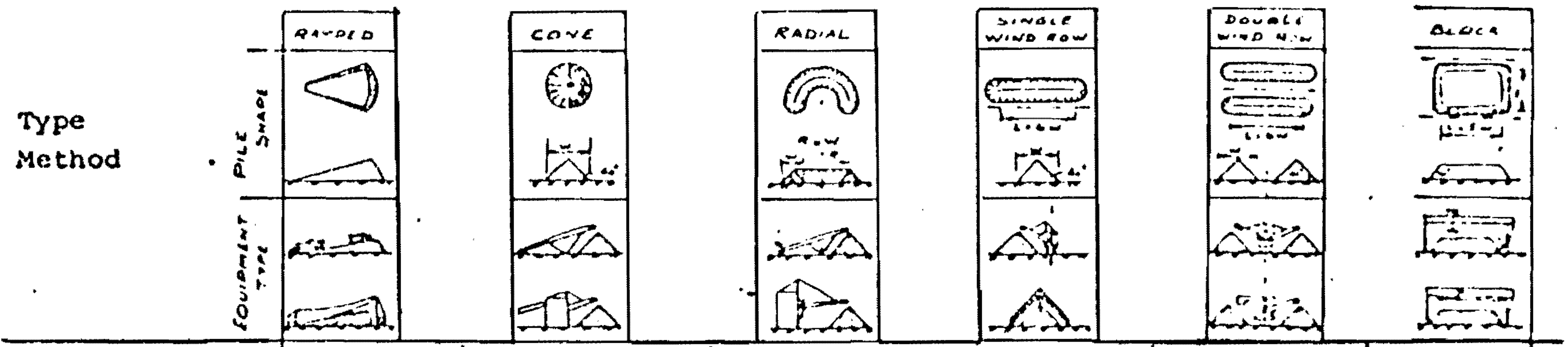
VI.4.2 Pile Storage

The configuration of pile storage depends on the equipment used to stack (i.e., build the pile) and to reclaim the material. There are six typical pile configurations and they are shown in Figure VI.4.2.1. When material must be covered, ramped or radial piles should not be used. These piles are expensive to build as they require larger than usual space in a building.

Every conventional method of stacking material involves conveyors or clamshell grabs. The simplest stacker is an inclined belt. If the frame supporting the inclined belt rotates, it is a radial stacker. Radial stackers make crescent-shaped piles (see Figure VI.4.2.1).

Conveyors can be used to make wind row (i.e., straight) piles. In such cases the conveyor is suspended over the pile and a "tripper" distributes the material along the length of the pile or creates a series of conical piles. A reversing shuttle (i.e., movable) conveyor

Figure VI.4.2.1 Typical Pile Configurations



	A			B			C			D			E			F		
Open O Covered C	O			O&C			O			O&C			O&C			O&C		
Pile Height M	2.5	5	7.5	2.5	5.0	7.5	2.5	5.0	7.5	2.5	5.0	7.5	2.5	5.0	7.5	2.5	5.0	7.5
Base Width in M	6	12	18	6	12	18	6	12	18	6	12	18	2x 6	2x 12	2x 18	11	22	33
Volume in $10^3 M^3$	0.85	0.53	0.85	0.3	0.53	0.85	1.9	3.9	5.8	3.5	7.0	10.5	7	14	21	15	30	46
Area Utilized %	65	65	65	75	75	75	90	90	90	80	80	80	90	90	90	80	80	80
M^2/ton *	0.60	0.45	0.3	0.6	0.45	0.3	0.30	0.23	0.15	0.46	0.30	0.19	0.36	0.27	0.18	0.20	0.15	0.1

*100 lb/ft^3 or 1633 kg/m^3 material

Source: Design Considerations for Storage & Reclaim Systems, H. Colijn, Bulk Materials Handling, Vol. 1, University of Pittsburgh, 1971 can also be used to build two wind row stacks (see Figure VI.4.2.2).

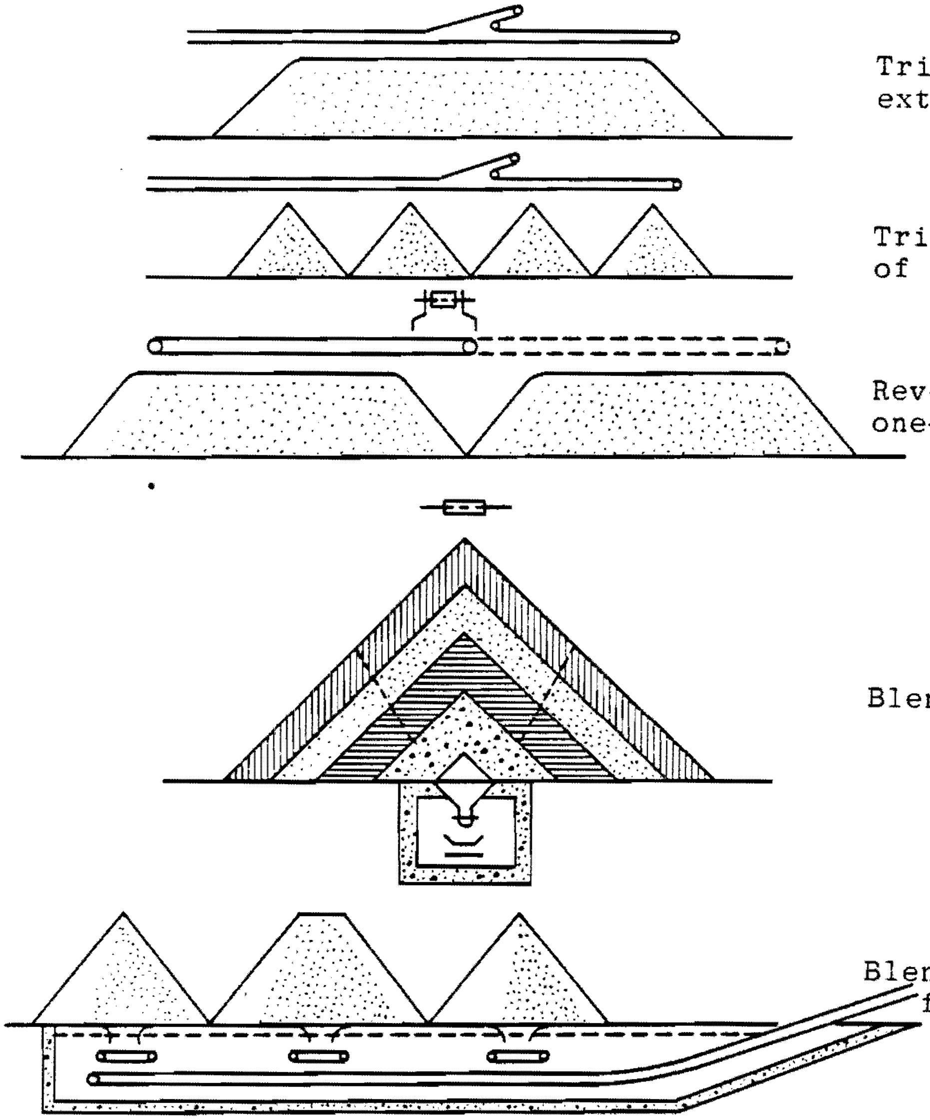
Stacking with conveyors makes it possible to blend materials, either when the material is stored or when it is reclaimed. Blending on reclaim is useful when blending proportions are not known in advance.

For large volumes fixed conveyor or radial stacker storage is expensive, as the area stacked by one device is limited by the height of material discharge, combined with the angle of repose of the material. Overhead conveyors also have a disadvantage; they require a structure over the entire length of the pile.

To increase the area stacked per unit investment, the mobile stacker was introduced. This machine mounts the stacking conveyor on a boom which can be rotated as well as elevated. The entire assembly is supported by a chassis, which can either move on crawler treads or rails. This device increases the area that can be stacked by allowing wider piles to be constructed on both sides of the machine. Since no above ground support is required, the foundation for the rail mounted version is less expensive. Crawler mounted stackers require little, if any, site preparation. Rail mounted stackers (see Figure VI.4.2.3) build wind row stacks parallel to the tracks, while the crawler mounted stacker can build virtually any size or shape pile.

Table VI.4.2.1 lists typical stacker dimensions. The boom structure and the need to keep the stacker stable at its maximum outreach are the most important contributors to cost. Therefore, the cost of the stacker is closely related to the square of the outreach. Increasing the belt speed is the most common way of increasing a stacker's capacity and larger capacity stackers, those having the same frame as smaller ones, do not cost proportionately more. The foundation costs of the high and low

FIGURE VI.4.2-2 STACKING AND BLENDING WITH CONVEYORS



Tripper forms long extended pile

Tripper forms series of conical piles

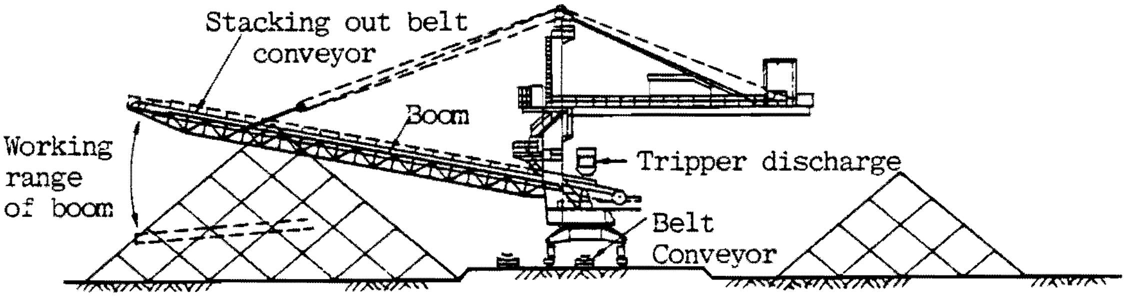
Reverse shuttle length is one-half of pile length

Blending from layered pile

Blending by selection from individual piles

Source: Second Operating Handbook of Minerals Processing.

FIGURE VI.4.2-3 TYPICAL RAIL MOUNTED STACKER



Source: *Port Development*, UNCTAD Secretariat, United Nations, New York, 1978.

Table VI.4.2.1 Typical Stacker Dimensions

Crawler Mounted

Pile width (m)	60
Rated capacity (t/hr)	4,717
Stacker radius (m)	38-45
Stacking belt (m)	1.07-1.83
Overall length (m)	64

Source: American Chain and Hoist Mechanical Excavator Division

Rail Mounted

Pile width (m)	30	40	45	50
Pile height(max) (m)	11.5	15	16	16
Minimum capacity (t/hr)	1,500	3,300	3,300	9,000
Maximum capacity (t/hr)	9,000	16,000	16,000	16,000
Stacker radius (m)	20	25	27.5	35
Stacker gauge	6	7	7	8
Speeds				
travelling (m/min)	30	30	30	30
slewing (rps)	.2	.15	.15	.2
derrick hoisting (m/min)	5	5	4	4

Source: IHI Heavy Industries

capacity stackers are also similar, because the weights are roughly the same.

It is important to select the proper pile width for stackers, because stockyard capacity can be increased by making piles wider and longer. Each alternative has a different cost. The number of stackers one will need is determined, principally, by each individual stacker's stacking capacity (in tons/hours) and by the total amount of materials stored.

Because stacking devices are becoming more complicated and expensive, they must move larger volumes of material in order to be considered the inexpensive alternative. Hence, the optimal stacker type depends on the total volume stored. Simple conveyor stackers are appropriate for small scale storage and larger devices are more appropriate for larger scale storage, as illustrated in Figure VI.4.2.4.

Reclaiming is the opposite of stacking. Table VI.4.2.2 lists the possible ways to reclaim material. The simplest is the gravity reclaim method.

Table VI.4.2.2 Alternative Reclaim Systems (Typical tons/hr rates)

Gravity systems	
Tunnel-chute	100-4,000
Tunnel-feeder	1-3,000
Tunnel-rotary plow	100-3,000
Earth moving equipment	
Bulldozer	50-600
Wheeled scrapers	100-800
Front end loaders	50-600
Mechanical equipment	
Clamshell-hopper-feeder	50-400
Dragline-hopper-feeder	100-500
Dragscraper-hopper-feeder	50-1,000
Shovel-hopper-feeder	100-700
Bridge crane-hopper-feeder	50-600
Bucket wheel excavator	300-16,000
Bucket wheel bridge type reclaimer	300-4,000

Source: Design Considerations for Storage & Reclaim Systems, H. Colijn, Bulk Materials Handling, Univ. of Pittsburgh, 1976.

Using it, material falls under its own weight onto a conveyor buried beneath the material.(see Figure VI.4.2.5). Gravity reclaim systems are occasionally supplemented with rotary plow feeders, which mechanically assist the flow of material onto the conveyor. Rotary

FIGURE VI.4.2.4 ECONOMIC REGIONS OF STOCKPILING SYSTEMS

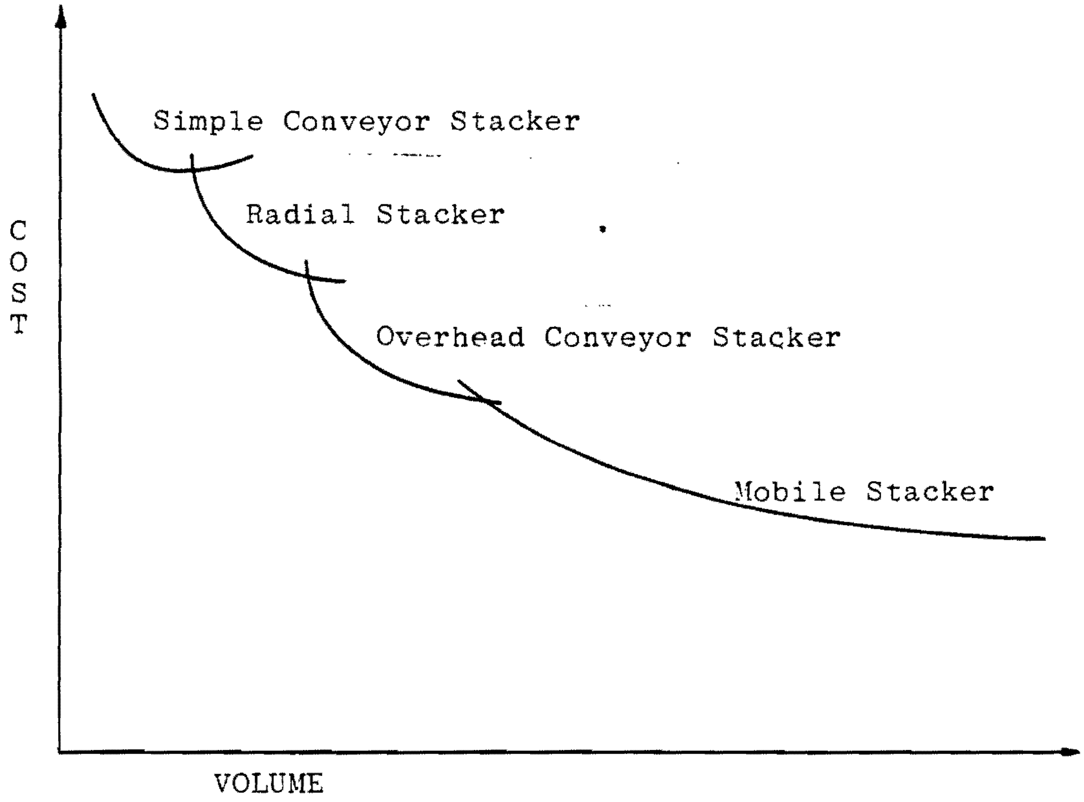
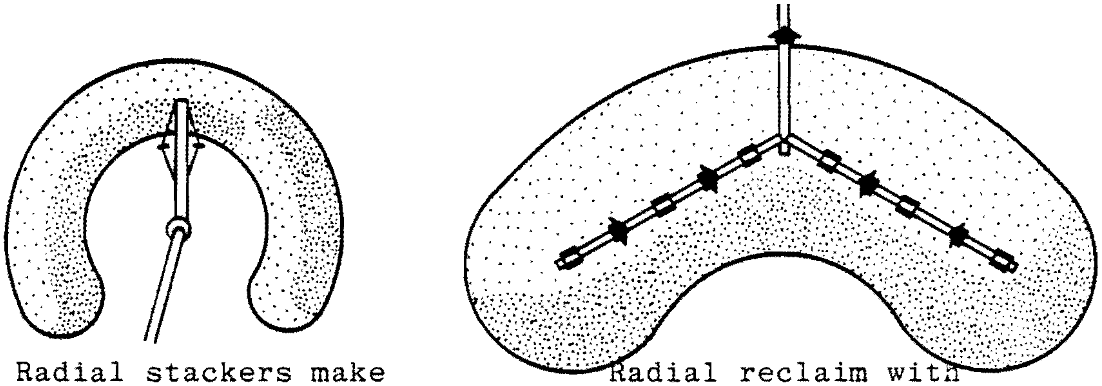
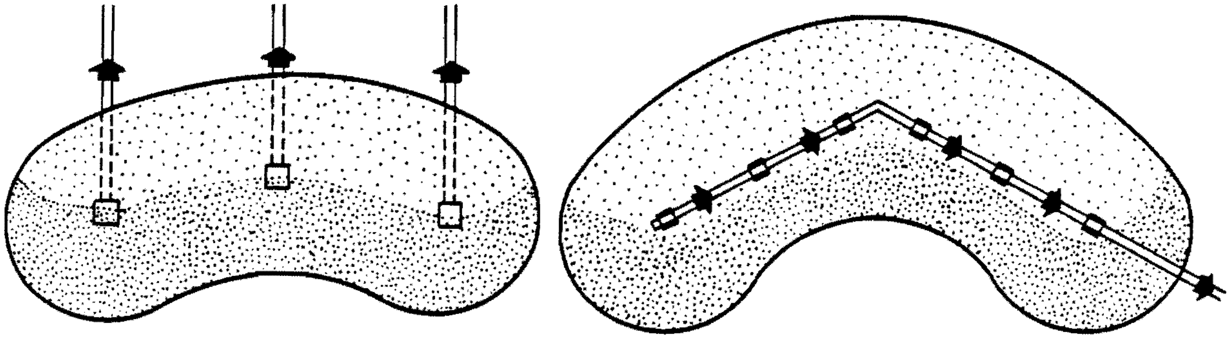


FIGURE VI.4.2.5 RADIAL STACKING AND RECLAIMING



Radial stackers make efficient use of available ground

Radial reclaim with conveying tunnels



Radial reclaim with parallel tunnels

Radial reclaim with tandem tunnels

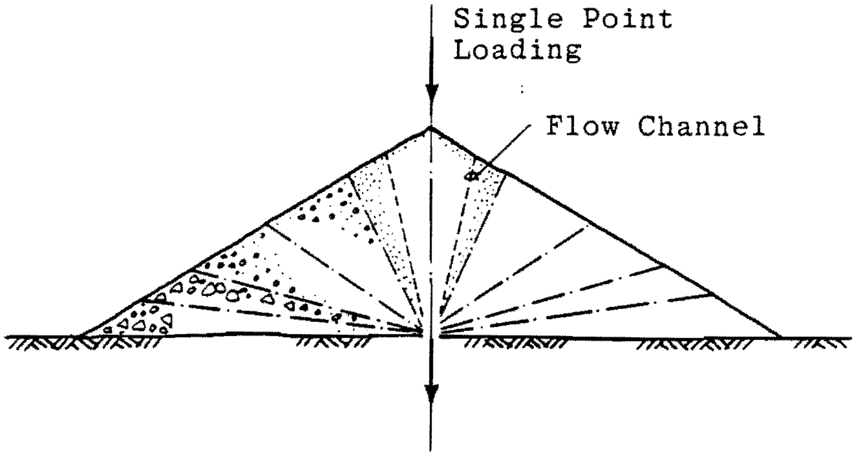
plows are used most often when the material is sticky. The system can be used to blend and recover materials from several pile configurations.

The gravity reclaimer has certain disadvantages. It leaves large amounts of dead storage (i.e., material that can only be reclaimed with the aid of a bulldozer). In fact, the gravity reclaimer cannot access about half of the pile. In many cases, the material stocked in the dead storage areas remains there indefinitely and is never used. This not only increases the amount of storage space needed, but also increases material inventory costs.

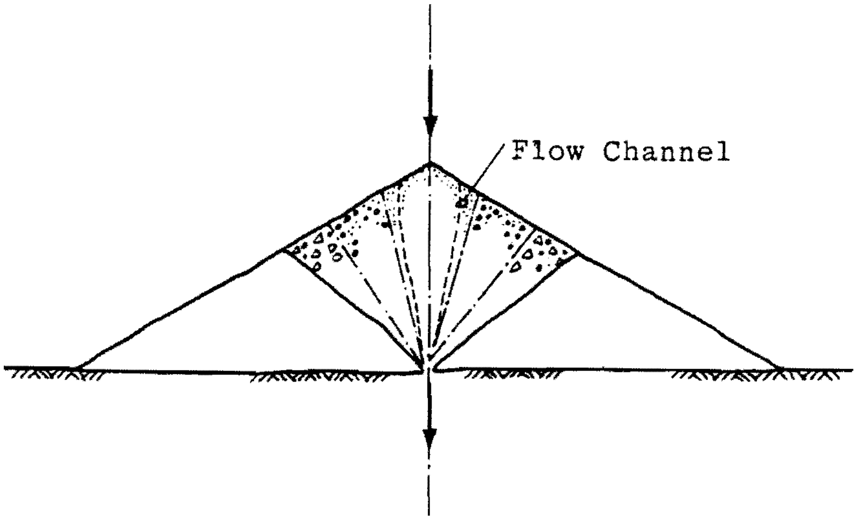
As material is stacked in a pile, it tends to stratify into layers of differing bulk density. The larger particles tend to fall to the bottom, while the finer ones stay close to the top. Thus, gravity stacked piles have a particle size distribution similar to that shown in Figure VI.4.2.6. Gravity reclaim systems tend to remove the fine material first and the coarse material later.

The bucket wheel reclaimer reclaims material with a digging wheel. A discharge conveyor removes the material from the machine. Bucket wheel reclaimers have many advantages over gravity feed mehtods. First, they can recover nearly all stacked material, thus eliminating the dead storage problem. Secondly, the mechanical digging wheel makes it possible to reclaim at a higher, more uniform speed; the gravity reclaimer's rate of material flow depends on the height of the material over the reclaim chute. Furthermore, they reduce the cost of the conveying system, because a single discharge conveyor fed by a reclaimer can service an area that would require many gravity feed tunnels. Table VI.4.2.3 gives typical dimensions of reclaimers.

FIGURE VI.4.2.6 SEGREGATION OF MATERIAL IN GRAVITY STACKED PILE



Initial Loading



Refill After Loading

Source: Design Considerations for Stacking and Reclaim Systems, H. Colijn, Bulk Materials Handling, University of Pittsburgh, 1976.

Table VI.4.2.3 Typical Dimensions of Bucket Wheel Reclaimers

	Crawler Mounted		
Theoretical capacity (cubic meters/hour)	2,500	4,403	5,504
Rated capacity (cubic meters/hour)	1,146	1,911	1,675
Rated capacity-iron ore (tons/hour)	2,292	3,822	5,350
Rated capacity-coal (tons/hour)	916	1,905	4,280
Digging wheel diameter (m)	5.5	6.7	7.6
Width discharge belt (m)	1.4	1.8	2.1
Machine length (m)	27.4	32.0	32.0
Machine width (m)	7.2	7.4	8.2
Pile width	unlimited	unlimited	unlimited

Source: American Chain and Hoist Mechnical Excavators Division

	Rail Mounted			
Theoretical capacity (tons/hour iron ore)	3,000	6,500	1,500	16,000
Theoretical capacity (cubic meters/hour)	1,500	3,250	5,750	6,000
Rated capacity (cubic meters/hour)	690	1,495	2,645	3,680
Rated capacity (tons/hour iron ore)	1,380	2,990	5,290	7,340
Rated capacity (tons/hour coal)	522	1,196	2,116	2,994
Digging radius (m)	30-35	35-45	45-55	50-55
Span rails (m)	6	7	8-10	10
Diameter digging wheel (m)	5	6	8	10
Speeds				
Travelling (m/min)	30	30	30	30
Slewing (rad/min)	.2	.2	.2	.2
Derrick hoisting (m/min)	5	5	4	4
Pile width (m)	30	35	45	50

Source: IHI Heavy Industries

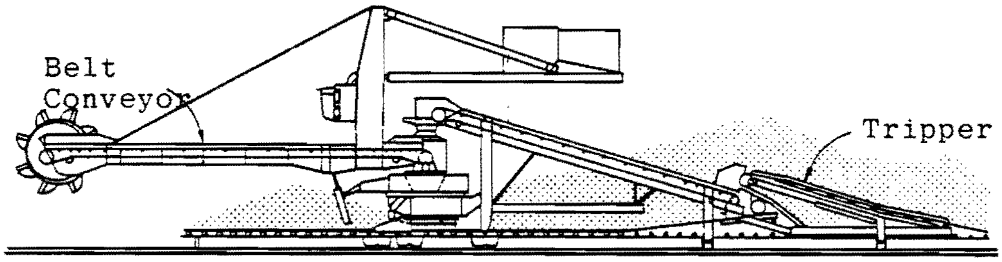
Stacker/reclaimers (see Figure VI.4.2.7) are a modification of bucket wheel reclaimers. They have a bi-directional belt that allows the machine to stack as well as reclaim. The advantage of the stacker/reclaimer is that one machine can perform two jobs, which reduces capital costs. However, the machine cannot stack and reclaim at the same time, and unless two units are installed, it cannot be used when simultaneous stacking and reclaiming are required.

A variation of the bucket wheel stacker/reclaimer is the stak-rake shown in Figure VI.4.2.8. Draglines are also available for bulk reclaiming, and one such installation is shown in Figure VI. 4.2.9. Draglines and stak rakes are common in covered storage areas, where the amount of building required for multiple grades can be reduced by using sheet piles to separate grades of material. The stak rake is sometimes installed in short silos, particularly when used for storing coal.

VI.4.3 Covered Storage

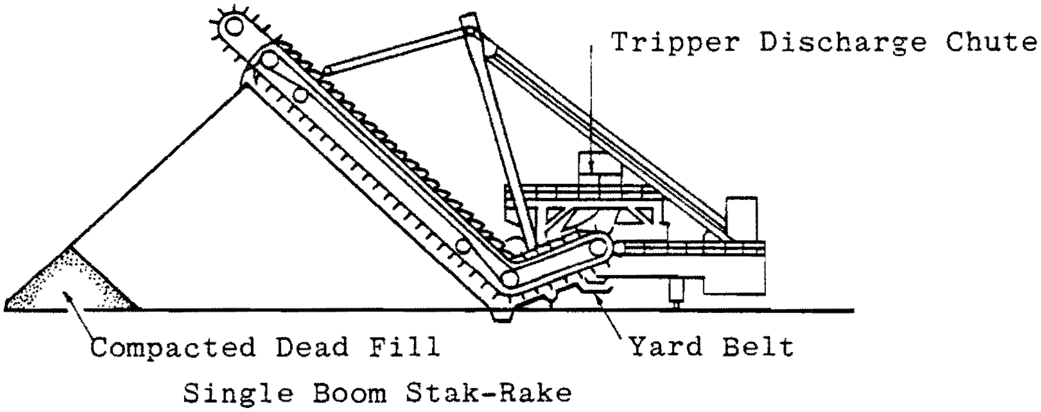
Covered storage for bulk material can either be in the form of silos or warehouses. Table VI.4.3.1 compares some charateristics of silos and warehouses. Silos are cylindrical buildings (see Figure VI.4.3.1). The material is lowered through the roof with a conveyor or bucket elevator and is stored in the building. The material is reclaimed with a gravity feed tunnel from the bottom. Silos, in addition to sheltering the material, increase the amount of live storage possible with gravity feed systems. However, the exact amount that will be accessible to the gravity feed tunnel depends on the height of the silo. The cost of a silo also depends on its height, diameter, and density of material stored in it (see Figure VI.4.3.2). The

FIGURE VI.4.2 .7 TYPICAL STACKER/RECLAIMER

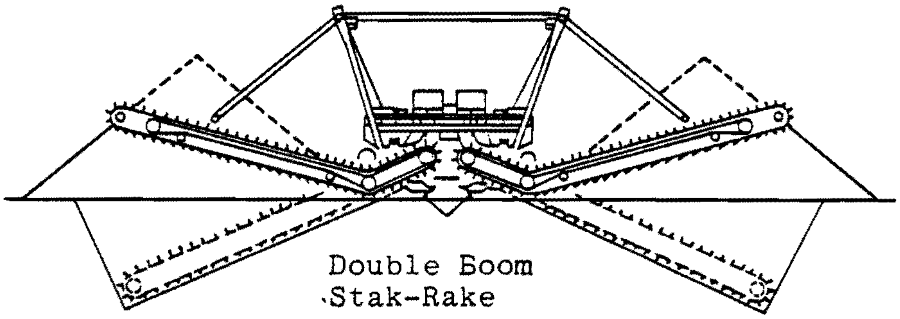


Source: Drag scraper systems for stockpiling and reclaiming bulk materials, J. R. Dillon, Bulk Materials Handling, University of Pittsburgh, 1976.

FIGURE VI.4.2-8 TYPICAL STACK - RAKE

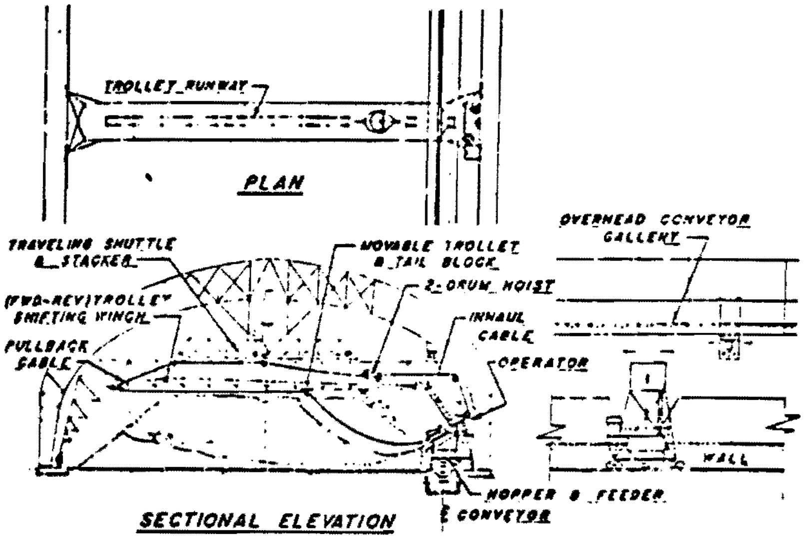


Single Boom Stak-Rake



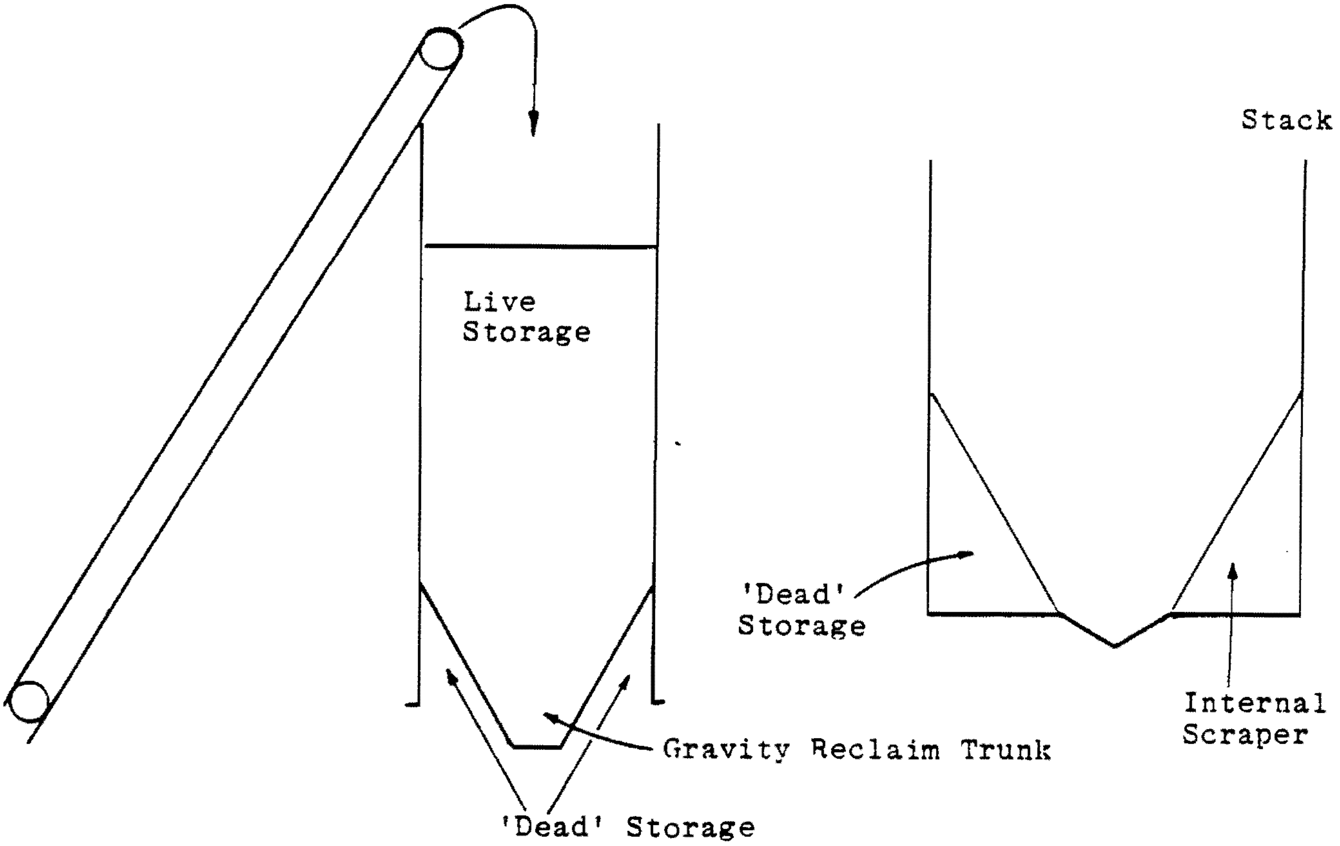
Source: Drag scraper systems for stockpiling and reclaiming bulk materials, J. R. Dillon, Bulk Materials Handling, University of Pittsburgh, 1976.

FIGURE VI.4.2.9 TRAVELLING SCRAPER BRIDGE



Source: Drag scraper systems for stockpiling and reclaiming bulk materials, J.R. Dillon, Bulk Materials Handling, University of Pittsburgh, 1976.

FIGURE VI.4.3.1. SILOS FOR DENSER MATERIALS



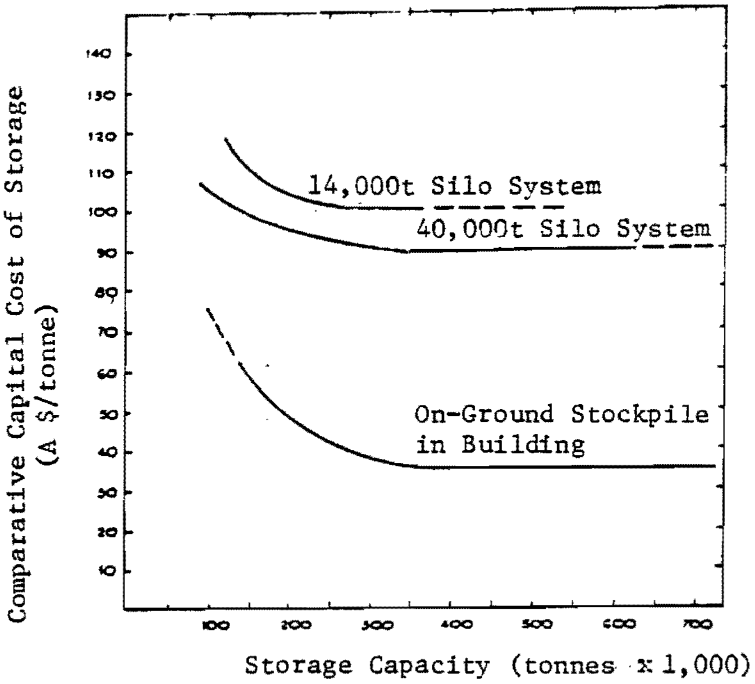
material density is very important, as it determines the amount of pressure on the silo.

Table VI.4.3.1 Comparison of Characteristics of Silos and Warehouses

Silos	Warehouses
Less land area	Cheaper
High throughput	Better environmental control
Less water damage	Multi-purpose
Grading and classification easier	Less ground pressure
Better dust control	Smaller earthquake risk
Less effected by equipment break downs	

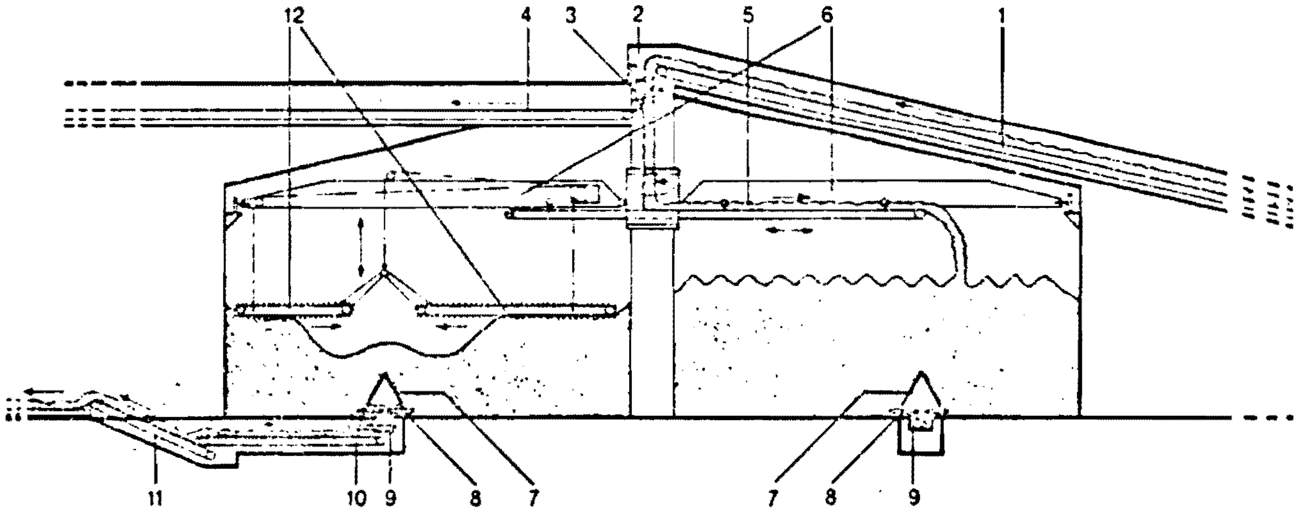
Large amounts of light material, such as grain, can be stored in simple silos. Since silos provide the largest amount of storage possible per unit area, they are particularly popular where land costs are high. Furthermore, silos do not "visually pollute" an area the way an open pile does. As a result, silos have been made for denser materials, for coal in particular. These silos are not as tall and have larger diameters than conventional silos, and they are fitted with an internal scraper to move material from the gravity reclaim system's dead storage areas (see Figure VI.4.3.3.).

FIGURE VI.4.3.2 COMPARATIVE COSTS OF COVERED STORAGE



Source: World Bank staff.

FIGURE VI.4.3.3 COVERED STOCKPILE SCHEME



Source: "Discharging - how big is beautiful", G. Schwenke, Coal Trans 81, C.S. Publications, Surrey, England, 1981.

VI.5 Cargo Movement and Transfer

Options available for transferring and moving cargo within a terminal range from mechanical earth moving equipment to fixed conveying systems to aerial tramways. Most systems can elevate material as well as move it. The air slide conveyor is an exception and only allows material to move down it. Table VI.5.1 gives general options available among materials transfer equipment together with some qualitative evaluations of each.

Since most bulk terminals are not large enough to require material to be moved more than 500 meters, conveyors are the most common equipment installed in bulk terminals. Conveyors fit in well with much of the other materials handling equipment installed. Their use also reduces the need for surge storage capacity.

While technical earth moving equipment can be used for "moving" material, its most common function is in cleaning up and for transferring materials stored in dead storage areas to live areas where they can be handled by the fixed materials handling system. Bulldozers are also an important part of ship loading and discharging process, as they are used for cleaning the last portion of cargo during discharge and occasionally they recirculate cargo during the loading of ships requiring larger outreach than the outreach of the ship loader.

The most common equipment in a bulk terminal are bulldozers and front end loaders. Bulldozers range in size from 30 to 400 horsepower. Front end loaders are available in capacities between one-half and ten cubic yards. The capacity of transfer equipment can be estimated using Table VI.5.2. The table gives the cycle times of various machines as a function of the distance that material is moved. The hourly capacity

Table VI.5.1 Material Transfer Equipment Options
(#s indicate relative suitability)

	BULL DOZER	SCRAPER	TRUCK	TRAIN	TRAMWAY	CONVEYOR	PIPELINE	AIR SLIDE	CHUTE
Length of haul									
0-100 mtrs	1	1				1	1	1	1
100-200 mtrs	2	1			3	1	1	2	
200-400 mtrs		1	4		2	1	1		
400-600 mtrs		2	3		1	1	1		
600-1000 mtrs		3	1		1	1	1		
1000-2000 mtrs			1		1	1	1		
2000-4000 mtrs			1	3	1	1	1		
4000-6000 mtrs			1	2	1	1	1		
6000+ mtrs			2	1	1	1	1		
Maximum adverse grade									
+ 3%	1	1	1	1	1	1	1	-	-
5%	1	1	1	2	1	1	1		
10%	1	1	1		1	1	1		
15%	1	1	1		1	1	1		
20%					1	1	1		
20%					1	4	1		
Required flexibility under various operating conditions									
Much	1	1	1						1
Little	1	1	1	1	1	1	1	1	1
Daily production rate									
Low	1	1	1			1	1	1	1
Medium		3	1	2	1	1	1	1	1
High			1	1	1	1	1		1

Source: World Bank staff.

Table VI.5.2 Cycle Times of Earth-Moving Vehicles

(in minutes)

Vehicle	Distance (m)						
	50	150	300	500	1000	2500	5000
Bull dozer-crawler	0.6	1.2	2.1				
Bull dozer-wheeled		0.7	1.4	2.2			
Scraper-crawler drawn			2.8	3.7	5.9		
Scraper-self-propelled					3.2	4.7	7.1

(Capacity/hour) = (payload) x 50/(cycle time)

Source: Mechanical Engineer's Handbook - Marks, McGraw-Hill, New York, 1969.

can be based on either 50 or 60 minutes per operating hour, depending on expectations for utilization. The cost of owning and running earth moving equipment is between 2.5 and 3 times its cost up to 10,000 hours of operation. Machinery normally in service (i.e., not standby or emergency equipment) typically is used 2,000 hours per year.

Aerial tramways, while they possess many special attributes that make them well-suited to service offshore berths, are not commonly installed. The principal reason for this is that, today, they are not available with capacities high enough to enable them to handle the periodically intense usage required of ship stevedoring. There seems to be little reason, however, why larger capacity units cannot be designed.

Pipelines are used in bulk handling when the slurry system is used. These are extensively discussed in the section on inland transport.

VI.5.1 Conveyors

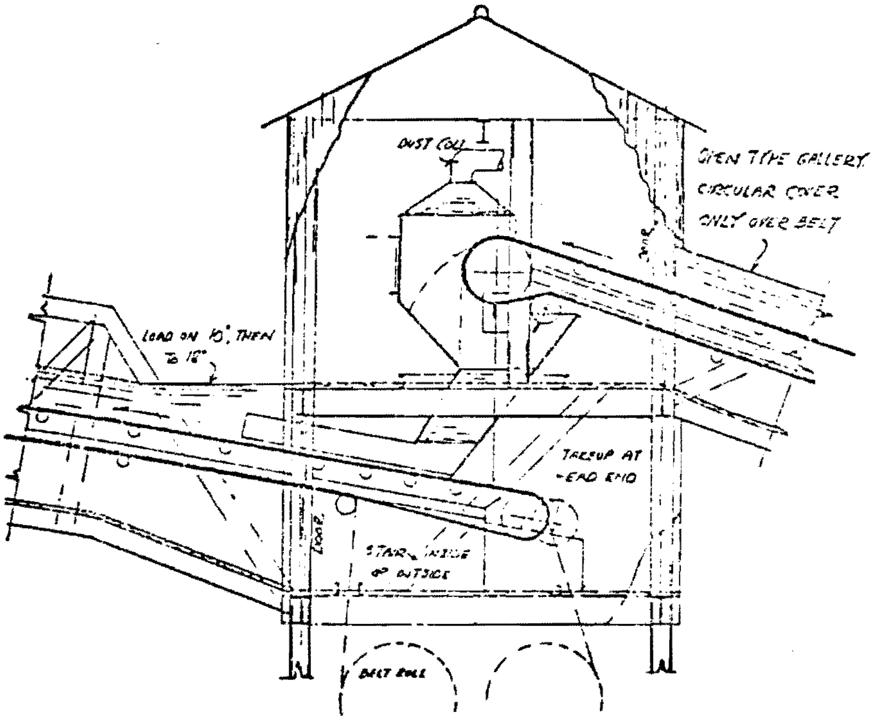
Conveyors are the most common type of materials handling equipment used in bulk ports. Conveyors can be designed to carry almost any type of bulk material. Apart from cost considerations, their principal drawback is that they generate dust at transfer points. However, the conveyor belt also wears at the point at which the material is loaded onto the belt.

Conveyors can cover a distance in one span or in many sections. Each section is called a flight. Each flight is slightly inclined and the next conveyor flight is lined up just below the end of the previous one, so the material falls from one flight to another. This occurs within a structure called a transfer tower. The equipment in the transfer towers is generally sufficient to control pollution and eliminate environmental difficulties. Figure VI.5.1.1 is a drawing of a typical transfer tower.

Conveyors are available in a wide variety of styles, ranging from pans mounted on a chain (called chain or apron conveyors: see Figure VI.5.1.2) to the common belt conveyor, to screws mounted internally on a pipe (called screw conveyors). Incidentally, the conveyor with the lowest cost is the screw conveyor. However, this variety of conveyor is not available in large enough frame sizes to be generally useful in bulk terminals. Table VI.5.1.1 indicates preferred conveyor types.

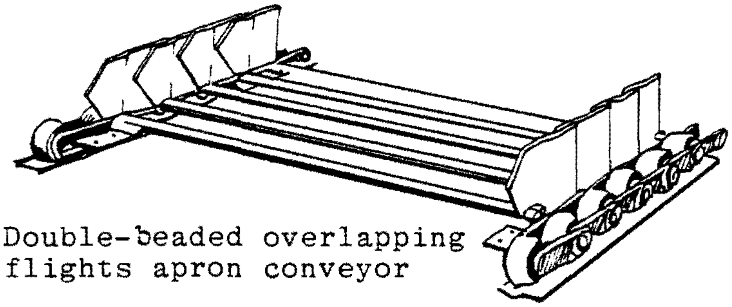
Most bulk port installations use either apron or belt conveyors. They have similar installation and operating costs. However, belt conveyors are easier to maintain, because maintenance is limited to occasionally repairing the belt and greasing and renewing the bearing in the idlers. Chain conveyors, however, have many moving parts and require more skilled maintenance. The different skills required to

FIGURE VI.5.1.1 TYPICAL TRANSFER TOWER

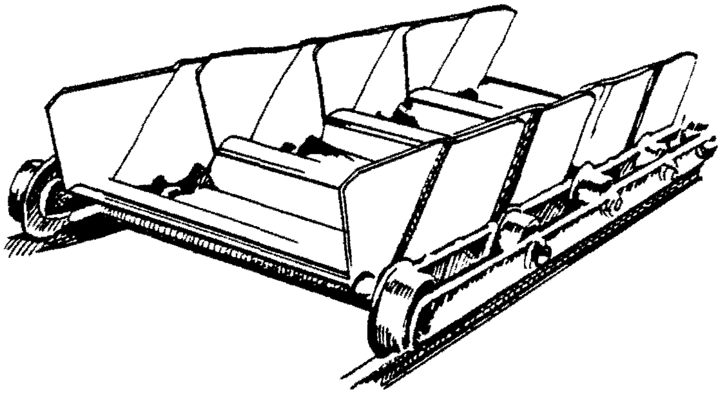


Source: Belt Conveyor Transfer Points, Colijn and Conners
Bulk Materials Handling, Vol.2, p. 69.
University of Pittsburgh, 1973

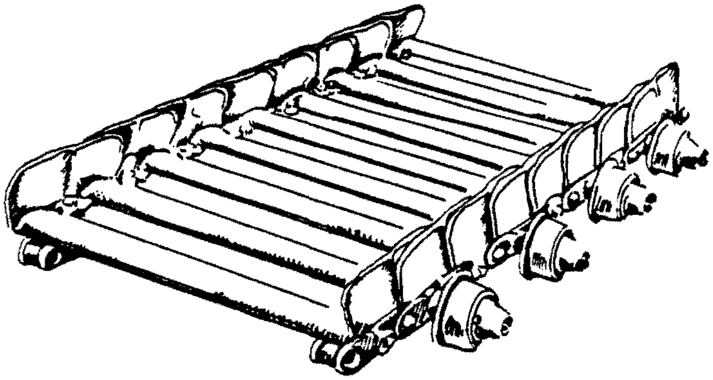
FIGURE VI.5.1.2 TYPICAL CONVEYOR INSTALLATIONS



Double-beaded overlapping flights apron conveyor



DP apron conveyor



Leak-proof apron conveyor.

Source: World Bank.

TABLE VI.5.1.1 Preferred Types of Conveyors for Bulk Materials

Material	Physical Condition	Av wt/volume		Reaction on Conveyor	Preferred Conveyors*	Preferred Elevators*	Comment
		lb/ft^3	kg/m^3				
Acid phosphate	Damp	90	1,440	Adheres	d,e	b	Sticky
Alum	Granular	60-65	960-1,040	Abrasive	a,b,c,e	g,b	
Aluminum oxide	Pulv.	60	960	Abrasive	a,e	g	
Ammonium nitrate	Pulv.	62	990	Hygroscopic	b,c,e	g,b	Explosive
Ammonium nitrate	Damp	65+	1,040+	Adheres	c,e	g,b	Sticky
Arsenic salts	Pulv.	100	1,600	Heavy	c,e	g,b	Poisonous
Ashes dry	Granular	35-40	560-640	Abrasive	d,f	b	Dusty
wet	Sticky	45-50	720-800	Abrasive	f	b,	Corrosive
Bone meal	Pulv.	55-60	880-960		a,b,c,d,e	g,b,c	
Borax	Pulv.	50-70	800-1,120	Abrasive	a,b,c,d,e	g,b	
Bran	Granular	16-20	260-320		a,b,c,d,e	g,b	Sometimes sticky
Brewers grains, hot	Granular	55	880	Corrosive	c,e,	g,b	
Carbon black (pellets)	Granular	40	640		a,e	g,b	Fragile
Cement, dry	Pulv.	90-118	1,440-1,890		a,c,d,e	g,b	Packs
Clays	Pulv.	35-60	560-960	Adheres	a,b,c,e	g,b	Sluggish
Coal: anthracite	Lumpy	50-54	800-860		a,b,c,e	g,b	
steam sizes	Granular	50-60	800-950		a,b,c,d,e	g,b,c	
bituminous, lump	Lumpy	50-60	800-960		a,b,e	b	
bituminous, slack	Granular	50-60	800-960		a,b,c,d,e	g,b,c	
Chalk	Pulv.	70-75	1,120-1,200		a,b,c,d,e	g,b,c	Sluggish
Coffee beans	Granular	40-45	640-720		a,c,e	g,b	Fragile
Copra, ground	Pulv.	40	640	May be abrasive	a,b,c,e	g,b	Sticky
Cork, ground	Pulv.	5-15	80-240		a,b,c,d,e	g,b	Sluggish
Corn, shelled	Granular	45	720	Abrasive shell	a,c,e	g,b,c	
Cottonseed	Granular	35-40	560-640	Sometimes sticky	a,b,c,d,e	g,b	
Cullet	Granular	80-100	1,280-1,600	Abrasive	a,b,e	g,b	Corrosive
Flaxseed	Granular	45	720	Shell abrasive	a,b,c,d,e	g,b,c	Free-flowing
Flue dirt	Pulv.	100	1,600	Abrasive	b,d,e,f	g,b	
Fly ash, clean	Pulv.	35-45	560-720	Mild abrasive	a,b,c,d,e	g,b,c	Free-flowing
Glass batch	Granular	80+	1,280+	Abrasive	a,b,e	g,b	
Glue	Granular	45	720		a,b,e	g,b,c	Keep cool
Graphite (flour)	Pulv.	40	640	Lubricant	a,b,c,d,e	g,b,c	
Gravel	Granular	95-135	1,520-2,160	Abrasive	a,e,f	g,b	
Gypsum	Pulv.	60	960		a,b,c,e	g,b	
Heavy ores	Lumpy	100+	1,600+		a,b,f	g,b	May be tough
Hog fuel	Stringy	15-30	240-480	May jam	a,b,d,e	g	
Lead salts	Pulv.	60-150	960-2,400	Sluggish	a,b,c,e	g,b	Poisonous
Lime, pebble	Granular	55-80	880-1,280		a,b,c,e	g,b	
Limestone dust	Pulv.	85-95	1,360-1,520	Abrasive	a,b,e	g	
Malt	Dry	45	720	May be sticky	a,b,c,d,e	g,b	
Manufactured products	Boxed	1-200	16-3,200		a,i,j		
Merchandise: Packaged	Boxed	15	240		a,b,i,j		
Garments	Hanging	5	80		i,j		
Metallic dusts	Pulv.	50-100	800-1,600	Abrasive	a,b,c,d,e	g,b	Sometimes difficult
Mica, pulverized	Pulv.	20-30	320-480	Free-flowing	a,b,c,d,e	g,b,c	Dusty
Molybdenum conc'ts	Pulv.	110	1,760	Abrasive	a,b,d,	b	Sticky
Petroleum coke	Lumpy	42	670	Mild abrasive	a,b,c,e	g,b	
Pumice	Pulv.	45	720	Mild abrasive	a,b,c,d,e	g,b,c	Polisher
Quartz (ground)	Pulv.	110	1,760	Very abrasive	a,b,c,d	g	
Rubber scrap	Stringy	50	800	Sluggish	a,b,e	g,b	Difficult
Salt: coarse	Granular	50	800	Hygroscopic	a,b,c,e	g,b	Corrosive if wet
cake	Pulv.	75-95	1,200-1,520	Flows freely	a,b,c,d,e	g,b	
Sand: dry	Granular	90-110	1,440-1,760	Abrasive	a,e,f	g,b	
damp	Granular	90-110	1,440-1,760	Sticky	a,e,f	g,b	
Sawdust	Granular	15-20	240-320		a,b,c,d,e	g,b,c	
Sewage sludge	Pulv.	60	960	Sticky if wet	a,b,e,f	g	Abrasive
Silica flour	Pulv.	80	1,280	Sluggish	a,d,e	g	Abrasive
Soap flakes	Granular	10-20	160-320	Fragile	a,c,e	g	Sticky if hot
Soda ash: light	Pulv.	25-35	400-560	Flows freely	a,b,c,d,e	g,c	Caustic
heavy	Pulv.	55-65	880-1,040	Flows freely	a,b,c,d,e	g,c	Caustic
Soybean flour	Pulv.	30	480	Sticky	a,b,c,e	g,c	Explosive dust
Starch	Pulv.	30-40	480-640		a,b,c,e	g,c	Explosive dust
Sugar: raw	Granular	55-65	880-1,040	Sticky	a,b,c,e	g	
refined	Granular	50-55	800-880		a,b,c,e	g	Handle gently
Sulfur	Pulv.	55	880	Corrosive if wet	a,b,c,e	g,b	Explosion risk
Talc	Pulv.	50-60	800-960	Mild abrasive	a,b,c,d,e	g,b	Adheres to metal
Tobacco stems	Stringy	25	400	Sluggish	a,b,d,e	g	
Wheat	Granular	48	770	Free-flowing	a,c,d,e	g,c	Keep clean
Wood chips	Granular	18-20	290-320	May arch	a,c,d,e	g,c	Corrosive if wet
Zinc oxide	Pulv.	20-35	320-560	May pack	a,b,c,d,e	g	Avoid discoloration
Zinc sulfate	Pulv.	70	1,120	May pack	a,b,c,d,e	g	

*Explanation of letter symbols: a-belt, b-flight, c-continuous flow, d-pneumatic, e-screw, f-drag chain, g-belt and bucket, i-overhead straight power, j-overhead power and free.

Source: World Bank.

maintain each type of conveyor can be a major factor in determining which conveyor is used. Even though renewing a belt is a relatively simple operation, it is not necessarily an inexpensive one, so it is questionable whether belt conveyors are the least expensive type.

Belt conveyors consist of a belt drive, tensioning unit, idlers - which periodically support the belt, a tail loading section, and the belt itself. Tensioning of the belts is frequently done by a hanging weight, but other means are available. One must clean the belt after the material is discharged, as a portion of the material carried will adhere to it. This cleaning is done with scraper cleaners mounted in the drive unit. Conveyors can be portable. Those used in mines, for example, are easily dismantled and reassembled at other sites.

The drive unit and end loading unit are the most expensive parts of a conveyor. The unit cost of belt conveyors, therefore, falls as conveyors become longer. Unit maintenance costs are also reduced because in a long conveyor there is only one drive unit and one end loading unit. However, repairing a damaged belt takes longer and is more costly because the belt is longer.

There are three types of belts:

1. Belts that have a tensioned carcass made of fabric covered with rubber.
2. Belts that have wire ropes embedded in the edges of the belt.
3, Belts that have wire ropes in the edges, but are covered with a built up rubber area (called flange belts).

It is difficult to determine the magnitude of total cost differences between belt types without a detailed study.

The capacity of a conveyor system depends on the width and speed of the belt, the density of the material and the shape of the pile of materials and the angle of repose of the material. Table VI.5.1.2

Table VI.5.1.2 Maximum Belt Speeds (ft/min) for Various Materials

Belt width (inches)	Belt speed normal (fpm)	max	Belt speed (fpm)	Capacity and horsepower 50 pound/cu foot material		
				capacity (tons/hr)	hp/10 ft lift	hp/100 ft centers
14	200	300	100	16	0.17	0.22
			200	32	0.34	0.44
			300	48	0.52	0.66
18	250	350	100	27	0.29	0.35
			250	67	0.71	0.88
			350	95	1.00	1.21
24	300	400	100	49	0.51	0.51
			300	147	1.53	1.52
			400	196	2.04	2.02
36	400	600	100	115	1.22	0.80
			400	460	4.87	3.18
			600	690	7.30	4.76
48	400	600	100	220	2.33	1.97
			400	880	9.35	6.07
			600	1320	14.00	9.10
60	450	600	100	360	3.82	2.49
			450	1620	17.2	11.20
			600	2160	22.9	14.95

Belt Capacity in Tons/Hr

Belt width	Light free flowing materials	Moderately free flowing materials	Lump coal coarse stone crushed ore	Heavy sharp heavy ores lump coke
12-14	400	250	-	-
16-18	500	300	250	-
20-24	600	400	350	250
30-36	750	500	400	300
42-60	850	550	450	350

Source: Chemical Engineering Handbook, Ed. R.H. Perry & C.H. Chilton, McGraw Hill, New York, 1973.

gives a rough estimate of the belt conveyor capacities. Differences in the shape of piles on the belt are not considered, and this must be checked in specific applications. It is common practice to design conveyors with 115 percent capacity of their rated or peak capacity, whichever is lighter. The peak capacity must be calculated considering periods that the conveyor is not running (e.g., when a ship loader is being moved to another hold).

Conveyor systems are sometimes mounted on crawlers and are used to extend operational areas of crawler mounted stackers and reclaimers (see Figure VI.5.1.3).

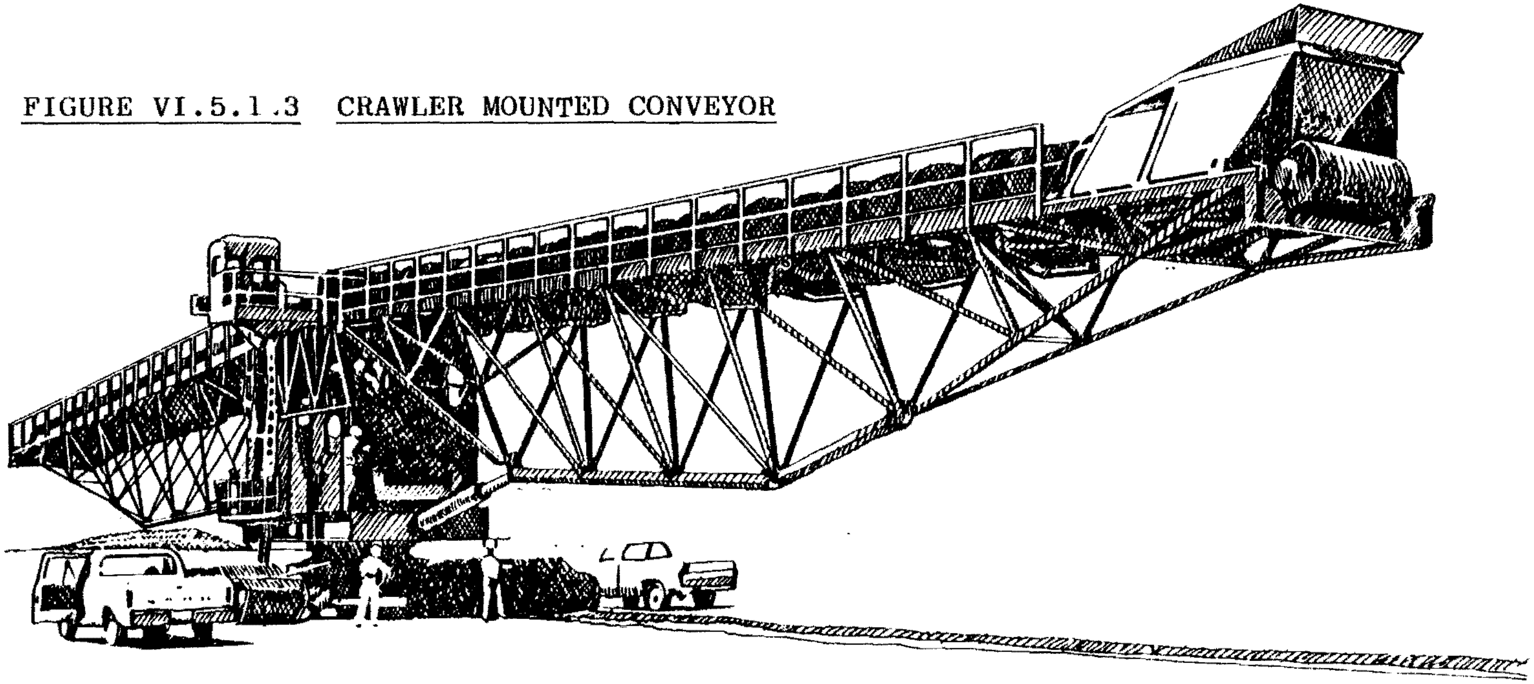
VI.5.2 Airslide Conveyors

Airslide conveyors combine translational movement with the controlled falling of the material. The conveyor itself is a box divided into two sections separated by a membrane permeable to air, but not the material being carried. The material is put into the upper chamber and compressed air is put in the lower chamber. The air passes through the membrane and partially supports the material. The device is installed on an incline and the material slides down. The air is used to reduce the angle of incline which increases the distance the material is moved with each increment of height. Other than those in the air compressor, airslide conveyors have no moving parts. Table VI.5.2.1 lists commodities which have been handled with

Table VI.5.2.1 Typical Materials Moved by Air Float Conveyors

Alumina
Bauxite
Bentonite clay
Cement
Flour
Gypsum
Kaolin clay
Plaster
Lime hydrate
Limestone
Magnesium oxide
Phosphate rock dust
Talc
Soda ash

FIGURE VI.5.1.3 CRAWLER MOUNTED CONVEYOR



Source: American Hoist and Derrick Mechanical Excavators Division.

airslide conveyors. Figure VI.5.2.1 gives design and construction details of airslide conveyors and the diagram shows their use in a ship loading installation.

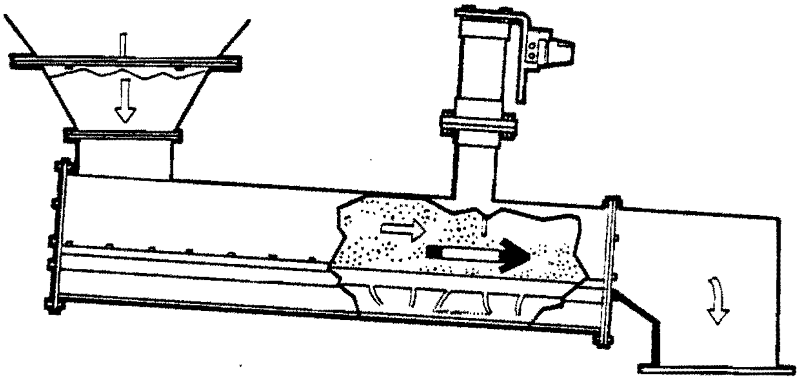
VI.5.3 Bucket Elevators

Material to be elevated can be easily processed with an inclined conveyor. However, such an approach requires a long conveyor and the space required to elevate material can be reduced by using a bucket elevator. Figure VI.5.3.1 is a typical bucket elevator. There are two kinds of bucket elevators: those that can be mounted on a rubber belt and those that can be attached to a chain. Continuous ship unloaders usually have bucket elevators and are frequently installed in grain terminals. Their capacity is the product of the bucket size times the filling efficiency times the number of bucket passes per hour. Table VI.3.2 in the section on ship unloaders provides this information in tabular form.

VI.6 Ancillary Equipment

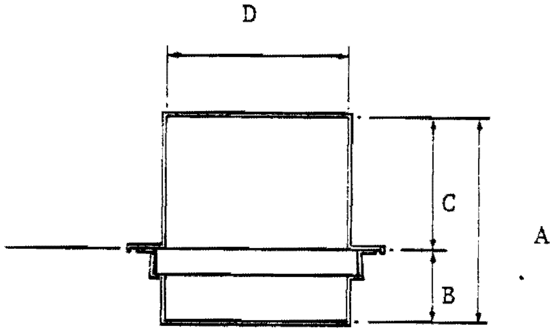
Bulk ports require many special purpose devices to perform particular functions required by each commodity. Grain, for example, requires, provision, for medium-term storage, of fumigation equipment to kill insects. A common ancillary function required is weighing and sampling. There are many systems available to do this, but the simplest and most reliable is to mount a hopper on a scale and record its weight each time it is filled. Continuous weighing systems to measure the output of conveying systems are also available. When truck and rail cars are used, the quantity moved can be determined by weighing the

FIGURE VI.5.2.1 AIR SLIDE CONVEYOR DESIGN INFORMATION

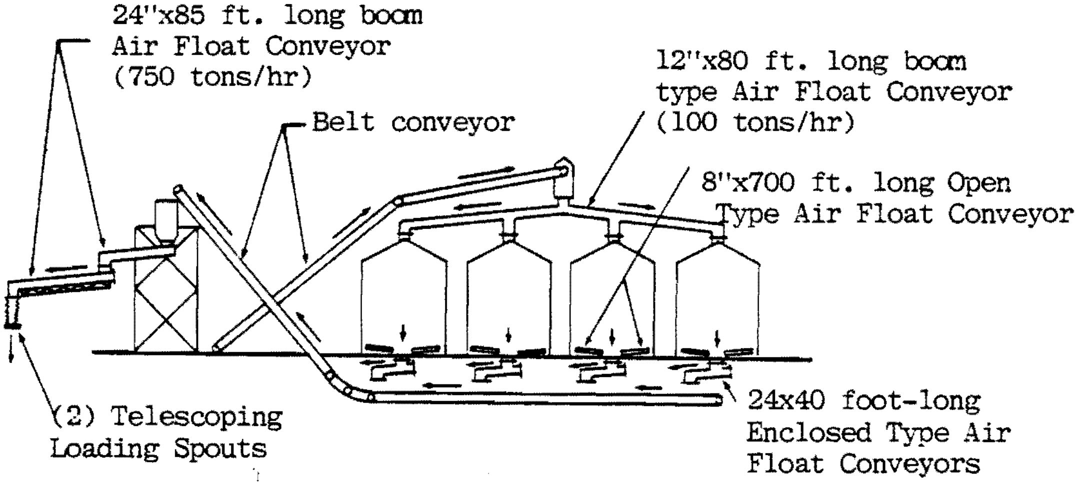


Material flow through enclosed conveyor

Conveyor	Dimensions (in)				Capacity
Size (in)	A	B	C	D	(ft³/hr)
6	9	4-1/2	4-1/2	5-1/8	1,200
8	10-3/4	4-1/2	6-1/4	7-1/8	1,800
10	10-3/4	4-1/2	6-1/4	9-1/8	3,000
12	12-3/4	4-1/2	8-1/4	11-1/8	4,500
14	12-3/4	4-1/2	8-1/4	13-1/8	6,500
16	14-3/4	4-1/2	10-1/4	15-1/8	10,000
18	14-3/4	4-1/2	10-1/4	17-1/8	14,500
20	16-3/4	4-1/2	12-1/4	19-1/8	20,000
24	22	5-3/4	16-1/4	23-1/8	26,000

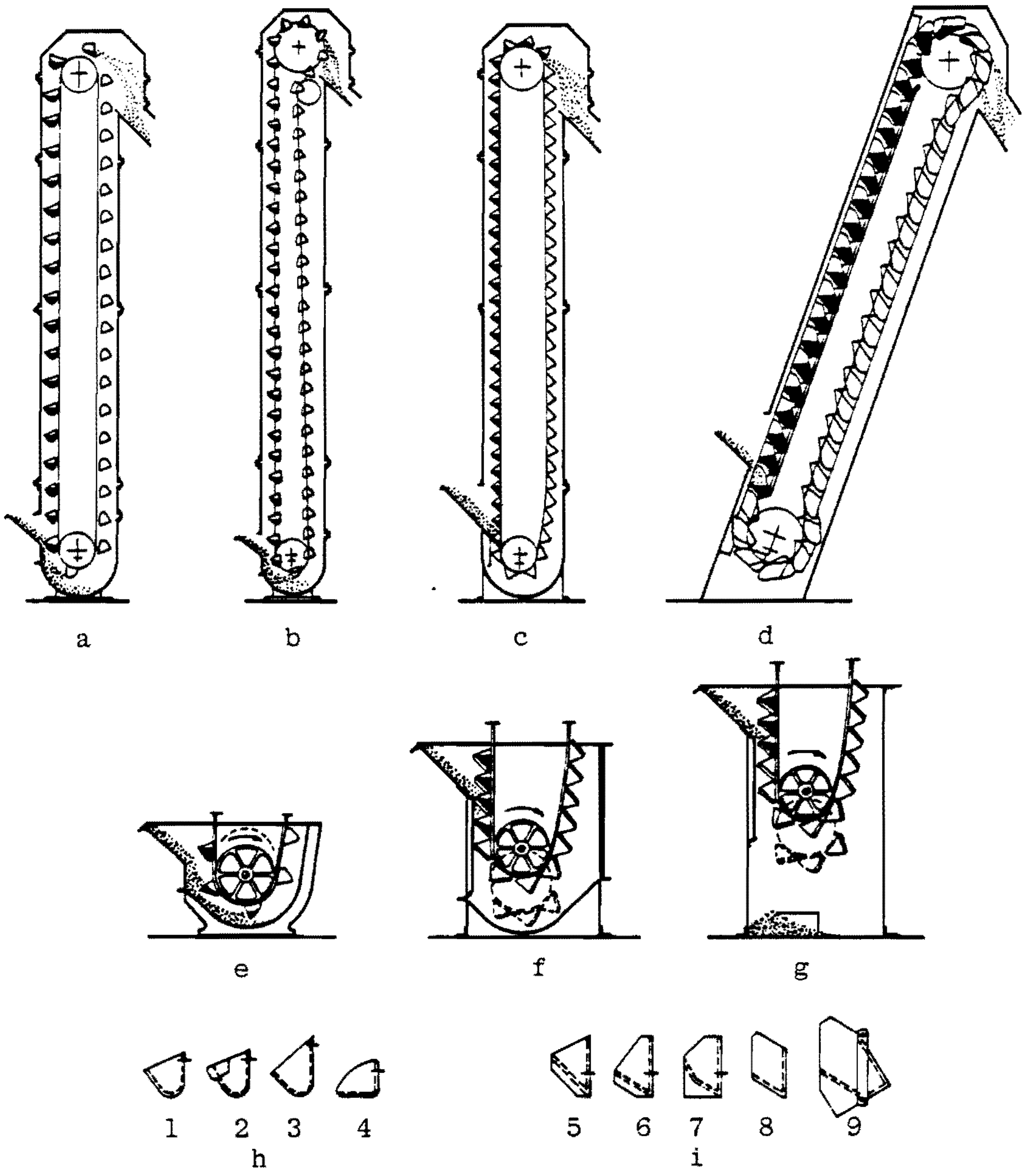


Air float conveyor sizes and capacities.



Ship loading installation (Harvey Aluminum, St. Croix, Virgin Islands.

FIGURE VI.5.3.1 BUCKET ELEVATORS



Bucket-elevator types and bucket details. (*a*) Centrifugal discharge, spaced buckets. (*b*) Positive discharge, spaced buckets (*c*) Continuous bucket. (*d*) Supercapacity continuous bucket. (*e*) Spaced buckets receive part of load direct and part by scooping from bottom. (*f*) Continuous: Buckets are filled as they pass through loading leg, with feed spout above tail wheel. (*g*) Continuous. Buckets in bottomless boot, with cleanout door. (*h*) Malleable-iron spaced buckets for centrifugal discharge. (*i*) Steel buckets for continuous-bucket elevators. (*Stephens-Adamson Mfg. Co.*)

Source: Chemical Engineering Handbook, E.D. R.H. Perry & C.H. Chilton, McGraw Hill, New York, 1973.

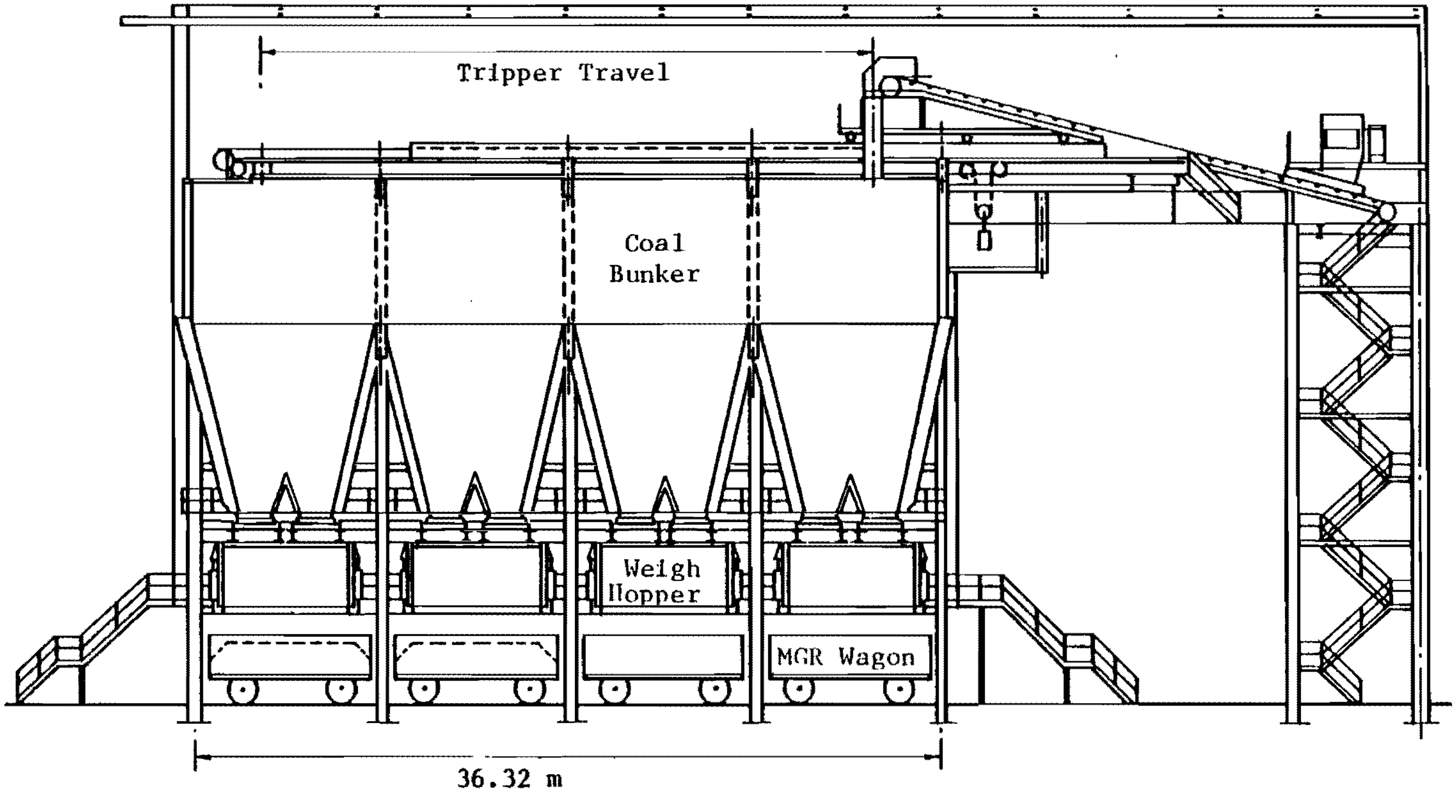
truck or rail car before and after loading or discharging. The weight of material loaded on a ship can also be determined to within 150 to 400 tons by using the vessel's draft marks as a basis for calculation.

Rail car loading and unloading is a common but important ancillary function in bulk handling. Rail car loading is easily accomplished by using conveyors to elevate the material and allowing it to fall into the car. This can be done using an intermediate hopper to allow weighing and to ensure uniform car loading. Figures VI.6.1 and VI.6.2 show two rail car loaders; Figure VI.6.3 shows a railcar unloader.

Unloading of trains can be accomplished in three ways. Hopper cars can be turned over in a rotary car dumper depositing its contents in a bin below. Car dumpers are also available to unload box cars carrying grain. Bottom dump hopper cars can be moved over a reclaim pit and their doors opened to allow the cargo to fall onto the reclaim conveyor below. Finally side dump cars can be used. Side dump rail cars cost about twice as much as bottom dump cars and their use is justified only for smaller volumes.

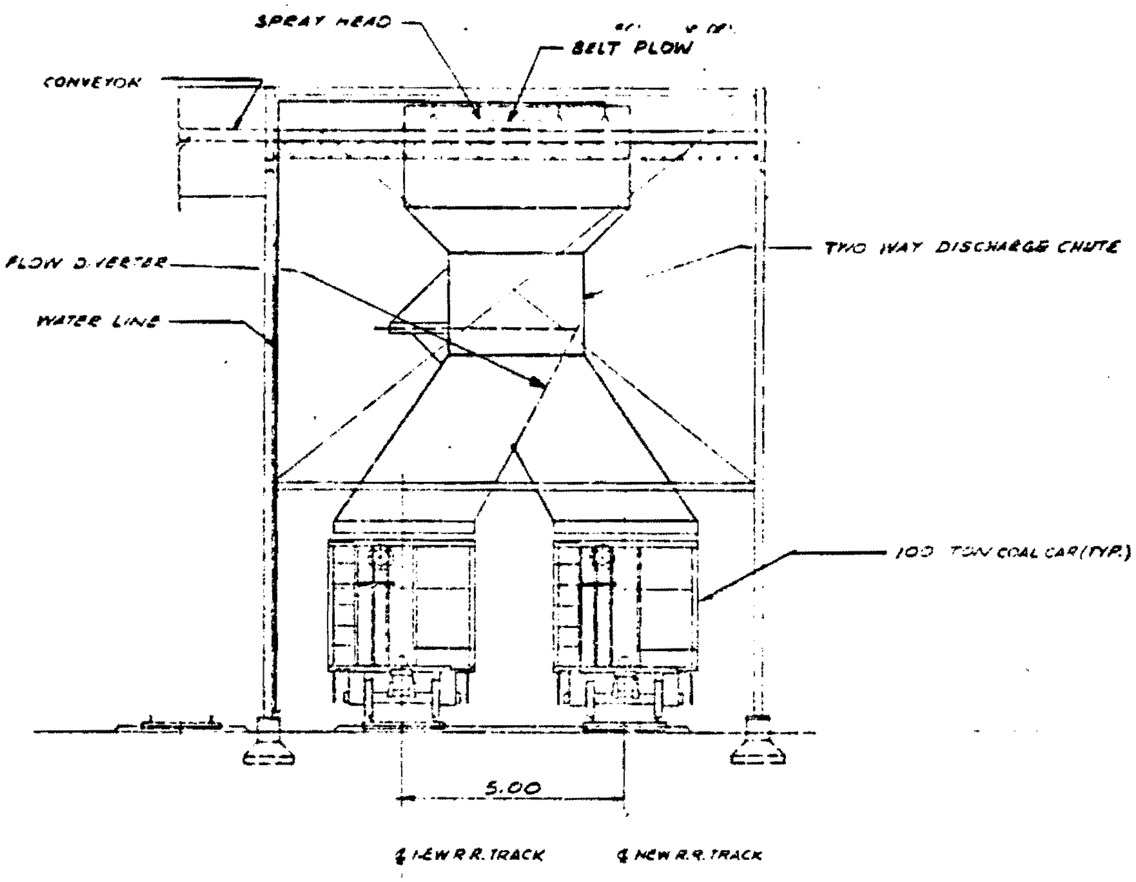
Table VI.6.1 describes typical hopper and gondola car unloading equipment. Figure VI.6.4 shows the general regions of economic application of the different modes of rail car unloading. This information is situation dependent and is for guidance only.

FIGURE VI.6.1. COAL LOADING STATION - KEY DIAGRAM



Source: World Bank.

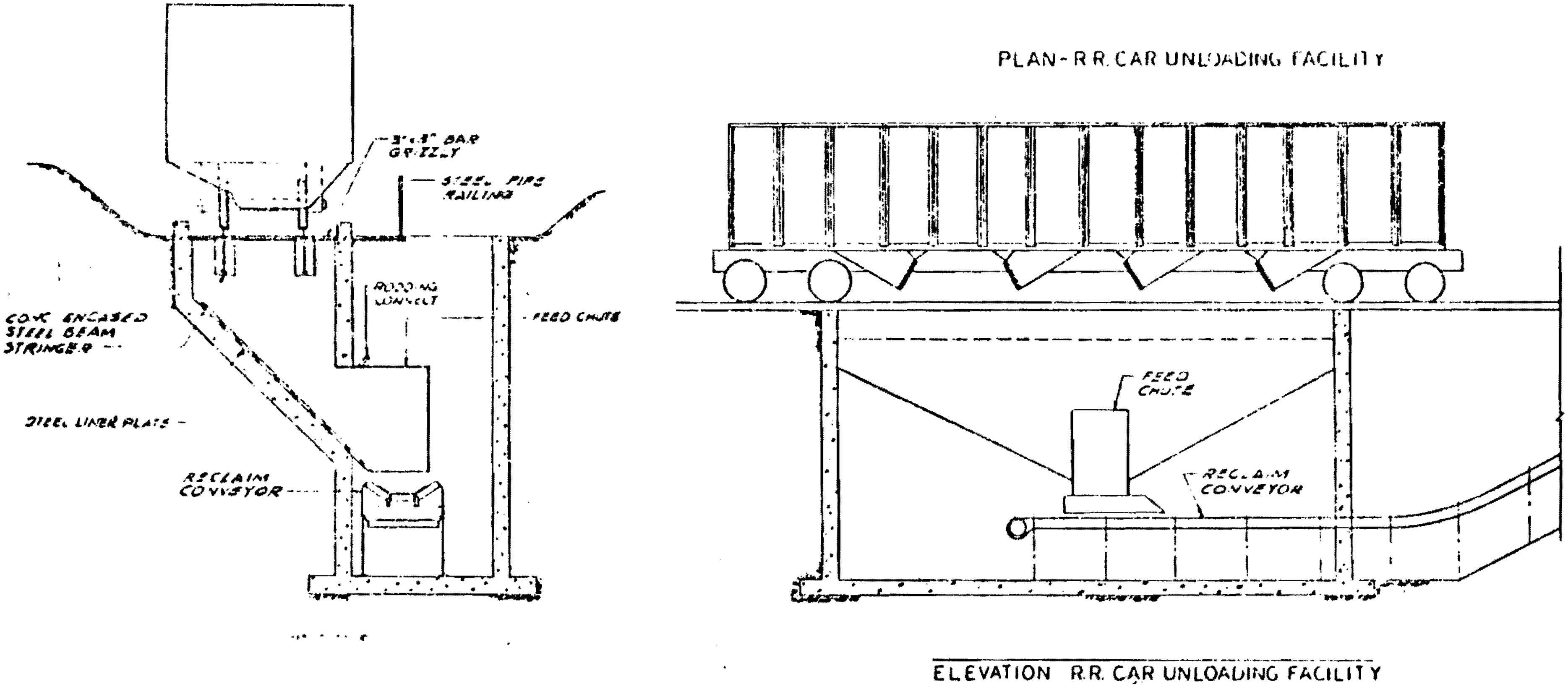
FIGURE VI.6.2 RAIL CAR LOADER



ELEVATION - RAIL CAR LOADING TOWER

Source: World Bank.

FIGURE VI.6.3 RAIL CAR UNLOADER



Source: World Bank.

Table VI.6.1 Comparison of Rail Car Unloading Equipment

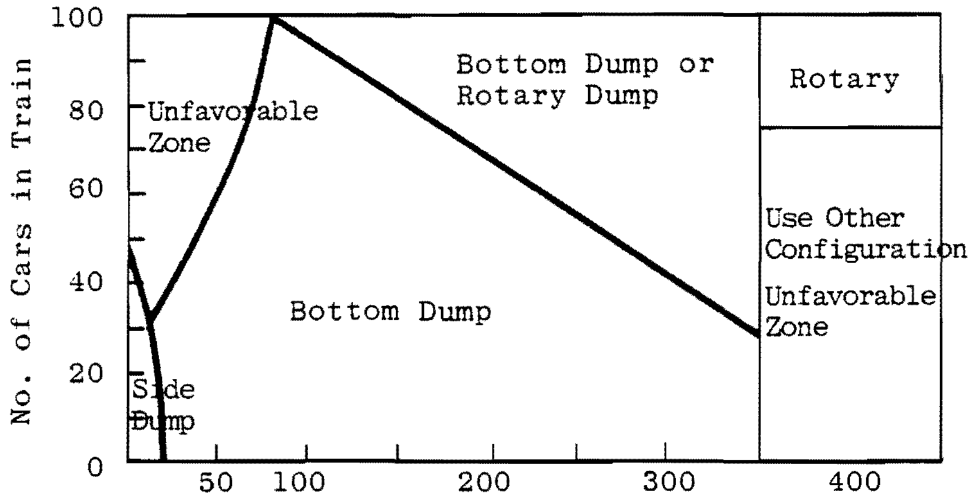
System	Rail Car	Cycle time	Manpower	Design Capacity (tons/hr)	Comments
Standard Rotary dumper	Random Lengths&sizes	3 min	4 train 3 dumper 1	2000	1
Unit train Rotary dumper	Rotary coupler equipped cars	2.5 min	3 train 2 dumper 1	2400	1
Unit train Rotary dumper Car positioner	Rotary coupler equipped cars	110 sec	2 dumper 2	3200	2
Under track Hopper with car shaker	Random hopper cars	5 min	6 opening& closing doors 4 train 2	1200	3
Under track Hopper	Mechanical cars plug in air or electric (self clearing)	2 min	3 handling air or el 1 train 2	3000	4
Under track Hopper	Automated cars (self clearing)	30 sec or less	1 observer	up to 6000	5
Trestle	Automated cars (self clearing)	30 sec or less	1 observer	unlimited	6

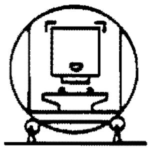
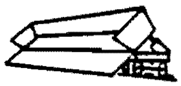
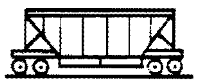
Comments:

1. Plant locomotive required as road locomotive and crew not available. Time includes switching to break into groups of 20 cars or less.
2. Road locomotives stay with train and crew rides through dumper.
3. Capacity assumes 100 ton cars. Plant locomotive required. Time includes switching to break train into groups of 20 cars or less.
4. If road locomotive can be used with radio control of starting and stopping crew can be reduced by one man.
5. Train in motion at speed dependent on takeaway capacity of under track hopper. Railroad locomotives and crew utilized.
6. The train is in motion at speeds of about 3-5 miles per hour. Railroad locomotives and crew used.

Source: World Bank.

FIGURE VI.6 .4 RAIL CAR ECONOMIC ZONES



TYPE	CAPACITY OR MATERIAL	RANGE AND NO. OF CARS	NOMINAL COST	
			CAR	DUMP
ROTARY DUMP 	Single car 5000 tph Fines to run-of-mine	75 miles and up 50-100 cars	$15,000	$500,000
SIDE DUMP 	About 40 cars maximum Fines to run-of-mine	up to 20 miles 15-40 cars	$27,000	$0
BOTTOM DUMP 	To 24,000 tph Sized free flow	20-350 miles 35-100 cars	$18,000	$300,000

Source: Design Considerations for Storage and Reclaim Systems, H. Colijn. Bulk Materials Hanlding, Vol. 1, page 360, Univeristy of Pittsburgh, 1971.

VII. TERMINAL DESIGN AND LAYOUT

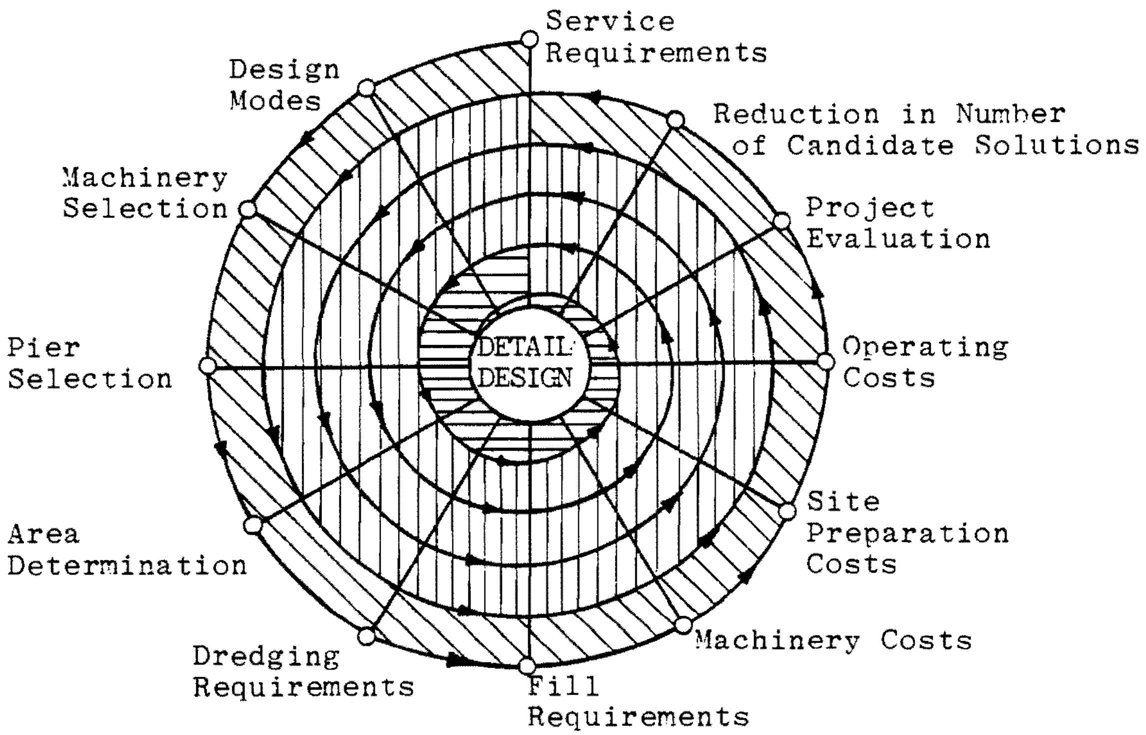
VII.1 General Design Considerations

There are a number of steps to follow when designing and constructing a bulk port facility. The initial steps are general and emphasize generating and evaluating alternatives. As the project progresses, alternatives are eliminated and the remaining ones are examined both technically and financially until, at the contracting stage, only one remains. After this commitment to one design is made, the engineering emphasis shifts to detailed construction planning.

One way to comprehend this process is to imagine it as a spiral with engineering work converging on the design as built by successive stages of refinement. This is illustrated in Figure VII.1.1. In the conceptual phase, the goal is to develop as many alternatives as possible to ensure that no feasible solutions are overlooked. These alternatives will be evaluated in successive phases. The conceptual stage requires a great deal of field experience and employs qualitative concepts. Ideas are evaluated and screened qualitatively without having to resort to quantitative analysis.

In the preliminary design phase, rough requirements for land areas, machinery types and capacities, preliminary costs and revenue estimates are made. As the design becomes more detailed with more parameters quantified, preliminary designs can be screened by using quantitative methods. However, because alternatives are still numerous, these methods are geared to a small computational investment per alternative and to the evaluation of any changes in major design parameters, such as the number of berths. Experience indicates that queueing theory fulfills many of the requirements for this stage of evaluation.

FIGURE VII.1.1 DESIGN PROCESS FOR A BULK HANDLING FACILITY



	Phase	
▧	Concept Designs (many)	20 man-days
▥	Preliminary Design (few)	300-man-days
▤	Contract Design (very few-1 or 2)	5,000-man-days
○	Detail Design	60,000-man-days

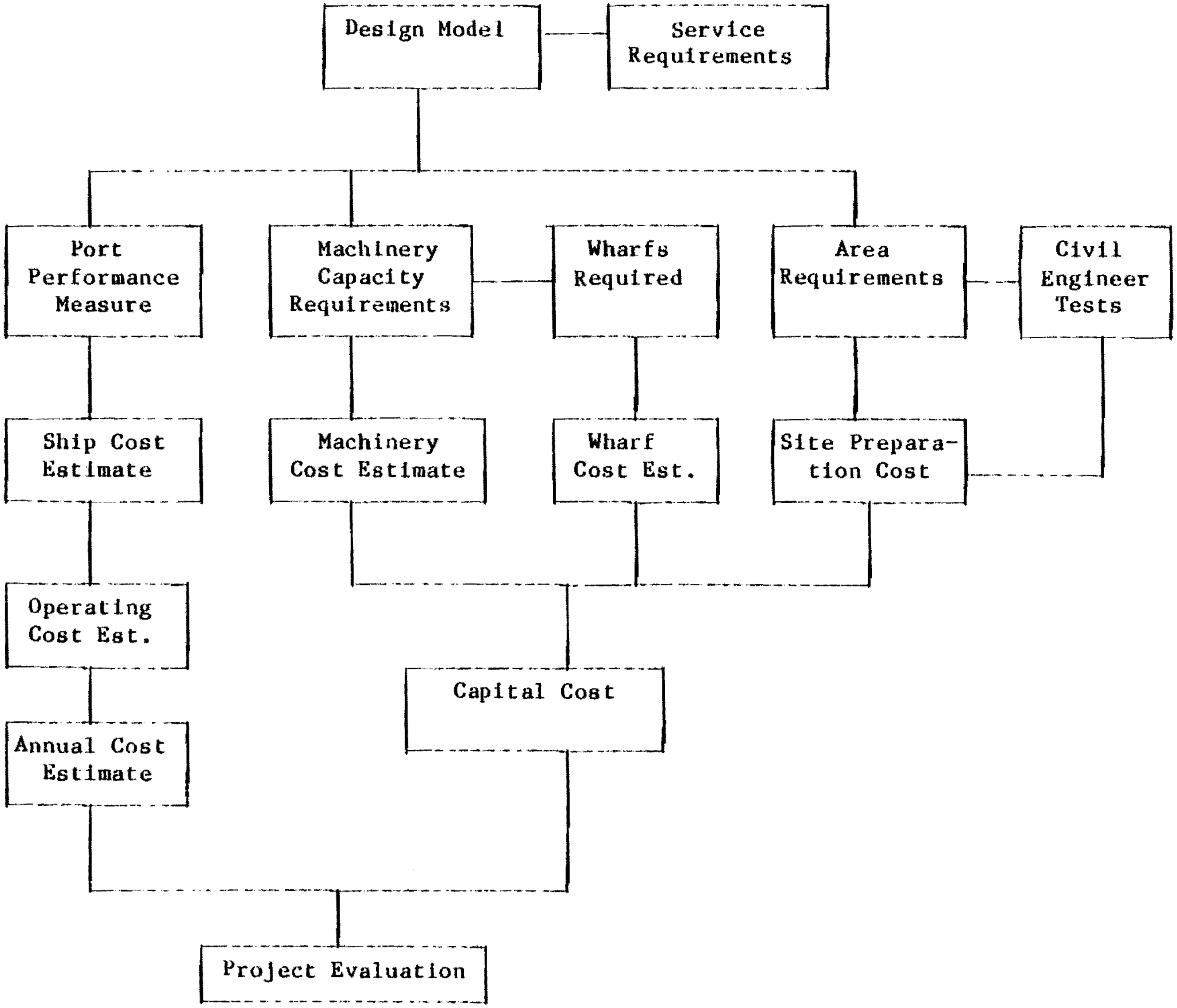
In preparing the contract design (i.e., the design used to prepare documentation for bidding), the goal is to develop a complete description of what is to be done and to provide information about the site and other factors that will allow cost estimates and construction schedules to be made by the bidding contractors and by the future owner of the port. More than one contract design can be prepared if the results of the preliminary design do not indicate a clear superiority of one concept. Actual bids are required to determine the proper course of action.

Following the bids and the award of the contracts, construction plans are made which tell individual workers and sub-contractors what to do and to order materials and services.

The conceptual design phase is the most important, as it determines the principal design parameters that will govern the completion of the entire project. It is also the time when the interactions between the project and the country's economy, commerce and infrastructure are most easily examined. Proper development of the conceptual design phase can reduce the cost of subsequent engineering steps. Often, through the detection of fatal flaws, many alternatives can be eliminated.

The principal areas covered in the conceptual design phase are the development of logistics processes that will be used and the harbor geometry each one will subsequently require. In many cases, the required geometry of the harbor (especially dredging and fill requirements) has a major impact in ranking the desirability of a design concept. Figure VII.1.2 gives some quantitative features that are considered in conceptual equipment selection. Several of these features, such as foundation requirements and cost, are susceptible to analysis in more detailed design stages. Others, such as resistance to earthquakes, are unlikely

Figure VII.1.2 Quantitative Factors for Terminal Design



to be considered further unless special reasons for concern emerge.

The requirements placed on soils to support equipment and storage piles is easily delayed until later in the project. As a result, difficult engineering problems can arise when all candidate solutions turn out to have unacceptably high site preparation costs. Initially the evaluation of soils information can only be done in a gross fashion as good test information may not be available.

At the conceptual stage, the major properties of the bulk material that must be considered are density, requirements to protect it from the elements and hazards that it may present. Many kinds of materials handling equipment, although rated in tons, actually move volumes and, varying the density of the commodity, also varies the capacity of the equipment. This is particularly true of equipment designed around buckets and grabs.

Differences between the average and maximum shipment rate must be accommodated by buffer storage within the system (sometimes called surge storage). "Surges" can be of short duration, as when a grab unloader discharges to a conveyor, requiring a hopper to provide intermediate surge capacity. They can also be of long duration, as when ships arrive infrequently, requiring a pile the size of the ship's cargo as surge storage.

It is important that the requirements for surge storage within the system be fully assessed. Otherwise the installed equipment will never be able to operate at its rated capacity for sufficient periods of time to achieve designed performance.

Figure VII.1.2 indicates a general program for the organization of the work in each stage of the design process. The advantage of this type of approach is that the initial preliminary design phase forces attention on areas where additional engineering and test information are required and on areas where existing information is sufficient and additional work is not required. The characteristics of this approach are as follows:

1. The design of the port is in levels, each subsequently more detailed. The level of detail of information in each area is balanced and to the same level.
2. Details are postponed to final stages.
3. Formalization of project status is required at the end of each stage.
4. The project is successively refined and formalized as the design progresses until easily translated into detailed design, construction plans and designs.

The above approach assumes that the goal of the port project is clear at the start and can be used to provide objectives and evaluation criteria at each stage of the design. Experience demonstrates that, from time to time, the true goals of projects are not sufficiently well-defined to provide good guidance for engineers. For example, the goal of some design projects is to demonstate that a project is not feasible or that actual alternatives are constrained politically. It is good to posit the goals of the project early in its development and to illustrate periodically the result that such goals have on the decisions made during the design. This permits non-technical personnel to see the guidance that the goals are providing.

An important general point is that the above procedure is not the only one possible for the management of port design projects. Another common, potentially successful approach is called the "systems" or "black box" approach. Here the port design project is broken down into functional areas and each is assigned to a different party to design. Detailed design specifications are worked out to ensure that the pieces operate together smoothly. This approach is required if any area of the port design is to be approached as a sub-contract. The problem with this approach is that the details of the individual areas may become firm before many of the details of the interface requirements. This can be especially true if one design group proceeds at a more rapid pace than the others. In this case, an entire area of the design can be completed with little input about the details of other areas. Hence, the efficient use of this method requires careful study of the interaction between the sub-systems of the project in order to ensure that they are well-understood. This approach can be used successfully to manage large projects and is common in the defense and aero-space industries.

A few other approaches to port design are possible. One might be called the linear approach. This consists of doing "first-things-first." The definition of the "first thing" may either be derived functionally from the cargo handling process being used or it may be the construction activity with the longest lead time. After the first item is designed, the remainder are approached in the order established by the selection of the first. This is a common way to approach the design of "simple" systems. One result of this approach is that only a single alternative for the port configuration is, in fact, developed and this as a series of pieces instead of as a complete package. Additionally, specific decisions are made about system configuration with little assurance that they are appropriate to the problem at hand.

Often it is not one's intention to approach problems in this manner. This method, however, frequently emerges when large projects are undertaken on a crash schedule. Since the engineering for a large port will require at least two years, the temptation (or necessity) arises to design long lead time items (such as breakwaters) early in the project so that their construction can proceed simultaneously with the design of the remaining areas of the port. While occasionally unavoidable, such a method should only be adopted with a defined purpose in mind and an understanding of the risks involved. Sometimes the risk can be reduced by delaying, slightly, the detailed design of the long lead time civil works until additional preliminary engineering can be performed in other areas.

A fourth method of managing a design effort is to formulate design goals, create a single preliminary design and then refine it. This reduces the number of seriously considered alternatives to a single alternative and works well only in straightforward situations. Engineering is also likely to take longer. This is primarily because the "refinements" may, in fact, be other alternatives which are being evaluated at a level of detail greater than that which is required in a demonstration of their feasibility and cost.

VII.2 Mathematical Tools

A variety of mathematical tools are available to assist in the design and evaluation of port facilities. Generally technical approaches can be described as predictive or optimizing. Predictive techniques estimate the results of selecting various design parameters, while optimizing provides suggestions for their selection. Predictive techniques can be used as part of an optimization procedure when coupled with parametric variation techniques.

Different techniques are used to examine different facets of the problem. These can lead to different conclusions, in part, because they are based on different assumptions or solution methods. Hence, even the best thought-out technique can only be a guide. Often the cost of machinery is established by purely commercial considerations, such as order cancellations, and may affect decisions in a manner which is difficult to model with mathematics.

Table VII.2.1 lists commonly used methods and their general areas of applicability. Table VII.2.2 gives some of the advantages and disadvantages of each method. A "disadvantage" of many alternatives is given as requiring a computer. Most personal computers which are available today are sufficiently powerful for use with these methodologies; the disadvantage is not that the hardware is required, but that good arrangements to provide the software and programming required are frequently not made. Instead, most good engineering time is spent writing programs rather than studying the real problems involved. Sometimes this is the brightest talent in the design effort; with little difficulty the computer can restrain rather than enhance the design project. If the programs required exist or are developed in a manner that indicates planning, then, of course, the computer approach can add tremendously to the ability of the design team to consider different alternatives and approaches.

Table VII.2.1 Various Terminal Design Methods and Their Applicable Areas

Method	Predict or Optimize	Number of Machines	Type of Machinery	Capacity of Machinery	Operational Storage Capacity	Inventory Storage Capacity	Area Required	Layout and Arrangement
Queueing Theory	P	Yes	No	Yes	Yes	No	No	NO
Flow Networks	P	Yes	No	Yes	Yes	No	No	No
Simulation	Both	Yes	Yes	Yes	Yes	Yes	No	No
Rule of Thumb	P	Some	No	Yes	Yes	Yes	Yes	No
Inventory Theory	Opt	No	No	Some	No	Yes	No	No
Search Technique	Opt	Yes	Yes	Yes	Yes	Yes	Yes	No
Pert	Both	Yes	No	Yes	No	No	No	No
Project Parameters		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Craft		No	No	No	No	No	No	Yes

Rules of Thumb

Rules of thumb are common in engineering. In the design of virtually

Table VII.2.2 Mathematical Models Available for Preliminary Design

	Advantages	Disadvantages
Rule of thumb	*Quick *Solution likely to be feasible *Easy to justify *Coordination of different groups easier	*Requires very experienced personnel *System likely to be over designed and expensive *Possibility (remote) that system under-designed and won't work
Queueing Theory	*Simple *Easy Computation *Easy parametric variation *Easy to explain and visualize	*Limited set of solutions *Restrictive sometimes unrealistic assumptions *Limited applicability to continuous systems *Complicated systems must be separated into components losing some of the systematic interaction
Flow networks-GERT-Q/GERT-V/GERT	*Complicated systems easy to model *Easy parametric evaluation *Hand solution possible (GERT) *Applicable to continuous systems	*Complicated systems require computer to solve *Large data analysis requirements
Simulation	*Easy to explain and understand *Most features of system can be modeled to detail required *Easy parametric evaluation	*Requires Computer *Large fraction of effort devoted to making computer work less to studying the problem *Random variable in answer (results frequently not repeatable)
Inventory Theory	*Stresses value of items *Stresses operational procedures as effecting facility design *Simple *Forces thought about frequently ignored issues	*Parameter Estimation difficult. *Answer very sensitive to parameter estimates *Useful at beginning stages *Personnel unwilling to make value judgements required in particular about cost and acceptable probability of stockouts
Layout algorithms-CRAFT	*Considers many alternative *Forces selection of objective evaluation criteria	*Considers few factors *Simple relations between factors

anything they play a major role. A rule of thumb is simply a standard practice whereby previously successful experiences are codified. Since it is impossible to engineer everything fully, they save considerable time and discussion. Usually they provide conservative solutions which, in practice, prove satisfactory. They provide quick answers and allow personnel to concentrate on the matters which are of real importance to the design. Another advantage to rules of thumb and standard practice is that difficult value judgements are sometimes avoided by resorting to them. Table VII.2.3 offers a few rules of thumb that are of some use in port planning.

Table VII.2.3 Generally Accepted Rules of Thumb about Port Design

*Average capacity of discontinuous machines is about 60% of their maximum performance
*Design capacity of conveyors serving discontinuous machines should equal their maximum performance
*The rated capacity of a conveyor should be 115% of the required maximum performance

Storage Capacity

1. Ship loading and unloading	1.5 to 2.5 times maximum size of vessel expected
2. Train loading and unloading	1.5 to 2 times maximum size of train
3. Barge loading	2 to 3 operating shifts
4. Truck loading	Variable-try one day's throughput
5. Overland conveyor	1.5 to 2 days supply at delivery end
6. Steel plant	1.5 to 2 month's supply
7. Coke plant	1 to 2 months supply
8. Power plant	2 to 3 months supply
9. Cement plant	1.5 to 2 months supply

They should be used, however, under the presumption that they contain no factual input from the system which is being designed. Consider the common rule of thumb, for instance, that a power plant stack should be provided initially with a two month supply of coal kept throughout its life for emergency purposes. First, this cannot be universally true of all power plants, as some are fitted to burn alternate fuels or are connected to power grids of such magnitude that temporary loss of the plant costs less than the holding cost of the coal. Second, the recommendation is made in ignorance of the price of coal and surely the correct choice must depend in some way on the value of coal. Third, it assumes that the problem causing the interruption in the supply of coal will be solved in two months and will not always be solved in a shorter period. In considering this situation, it must be noted that about ten percent of the cost of the power plant is the coal which is kept only for emergencies. This rule assumes, finally, that the acceptable risk of having a power plant, either one without fuel or one operating for extended periods at part load, is the same in situations throughout the world. Few people would be willing to address explicitly the acceptable level of risk of having a power plant without fuel; this, for fear that, no matter how unlikely it may seem, the situation could occur. The rule of thumb frees people from blame through the substitution of standard practice for judgement.

When using rules of thumb a good practice is to evaluate system performance by a more sophisticated means; this is to ensure that reasons for deviation from standard practice do not exist.

Queueing Theory

Queueing theory is the mathematical study of waiting lines (or queues). Generally it is most useful when attempting to determine the congestion that results from various levels of system use as a function of the capacity of the equipment installed. With skillful application it can also solve a variety of other problems. In port design it has almost universal application. The main advantage of queueing theory is that it offers solutions to complicated problems quickly and easily. Also it permits the expeditious evaluation of different design options. Users of the theory usually have little difficulty understanding the symbols in the formulas and, in consequence, which queueing systems are applicable to the system. In other words, it can be used by rote.

Solutions to unusual queueing problems are difficult to achieve. Unless an appropriate queueing model can be found in the literature, it can be safely assumed that no solution is available using this simple approach. As a result, other approaches, such as simulation, must be tried. Appendix C gives the solutions to some common queueing systems which are sufficient for solving most queueing applications. The real drawback of queueing theory is that even mildly complex networks of queues cannot be solved without separating them into smaller problems and eliminating much of the systematic interaction between queues. In these situations, simulation is an alternative.

Simulation

Simulation consists of making a mathematical model of a physical system and then running it to determine the behavior of the system. Systems of any practical significance in port design can only be simulated with a computer. While indispensable for complicated systems, used on simple ones simulation generally arrives at the same conclusions obtainable from a queueing model. As simulation models become complicated, "debugging" them become a difficult problem and it is not easy to determine if the results of a simulation stem from the fundamental model or from logic and coding errors in the program itself. Thus it is important to try verifying simulation models either with real data or from data derived from a queueing theory model. A severe drawback of simulation is its high cost especially if qualified personnel are limited.

Inventory Theory

Inventory theory stresses the general operation of the facility with special emphasis on the size of shipments and their frequency. The principal variables are the cost of holding inventory and of placing orders for it. The output of the method is the optimum order size and time between orders. While the ideas behind inventory theory have great importance to the design of bulk logistics systems, most of the technical work available stresses distribution systems for manufactured goods and the assumptions required for these systems reduce the value of the methodology for bulk systems. In particular, the cost of placing an order is critical to the optimum lot size. It is difficult to estimate the cost of ordering a shipload of coal. Appendix D provides a brief description of inventory theory.

Flow Graph Techniques

Flow graph techniques study materials flow as if the system were a network of rivers; They predict the flow through each one on the basis of its capacity and the demand for the system's use. The output is the total flow through the system at a given supply rate and the flow through each of the component branches. Sometimes internal inventories within the system can be estimated. Complicated flow graph models can often be solved by hand, but with much more computation than queueing theory models require. They can also model systems nearly as complex as simulation, but not in the detail a simulation model provides.

CRAFT

One interesting method available for port design is called CRAFT. The CRAFT method is used to generate and evaluate layouts of industrial facilities including ports. The computer program that does this is available in FORTRAN and works well. The user specifies the area required for each activity, the material flow and transportation costs between activities. Using this information, it produces a layout minimizing the transportation costs between activities. Conveyor centered systems conform closely to the assumptions used in the programs. Often it is the case when using CRAFT that the resulting layouts all have fatal flaws. They stimulate thought, however, and allow the manual generation of improved layouts.

There are many optimization techniques available for port planners besides those already mentioned. These range from linear programming to search techniques. Appendix E describes a few of these.

A necessary, but not sufficient condition for an optimum system is that the marginal returns from investment in any component be the same. This is not a sufficient condition since it can be true of the worst as well as of the best systems. Also it can be the case that there are local as well as global optimums and this condition is true at every optimum. All optimization methodologies try, by various means, to locate conditions where this is true and, of course, to distinguish the best from the worst and to find global not local optimums.

Because equipment purchase decisions are "lumpy" and the equipment itself is available in discrete frame sizes, this condition cannot be exactly fulfilled for most real systems. However, the systems where the returns from additional investment in any component are most nearly equal are usually the best that can be designed. Tables VII.2.4 shows equipment selection factors.

The mathematical idea has a physical illustration which is given in Figure VII.2.2. In system I, clearly overall system performance can be increased only by uniform investment in each component, while in the clearly non-optimal system II this is not true.

VII.3 Process Selection Options

The starting point of a port design is the clear delineation of the goals of the project and of the general processes available to accomplish them. This process can be organized as shown in Figure VII.3.1. It begins with the determination of goals and finishes with a description of the specific process options available to accomplish them. Work at this stage should be general with a sufficient number of options generated to ensure that no factors are overlooked and that objective standards rather than subjective means are used for evaluation.

In specific logistics problems the number of alternatives will be small at this stage because existing technology will only make available a few options for overall system evaluation. The number of options will grow only when the details of overall alternatives are considered.

Ports can be constructed with various goals or missions in mind. An increasingly common goal is industrial development which gives rise to the concept of the "industrial" port. This idea is equivalent to the

Table VII.2.4 Equipment Selection Factors

I. Requirements for foundations and suitability of site for same.

II. Allowable dimensions for equipment which is not part of the project

III. Commitment to specific ship types
  - * self unloaders
  - * specially designed ships

IV. Reliability

V. Operating costs

VI. Required operating skills

VII. Cost and risk of shipment to site

VIII. Required construction skills--especially qualified welders

IX. Effect of the environment on operations
  - * wind and rain
  - * sea conditions

X. Effect of the environment on survivability
  - * wind
  - * earthquakes
  - * seas and flooding

XI. Adverse environmental impact
  - * dust
  - * noise

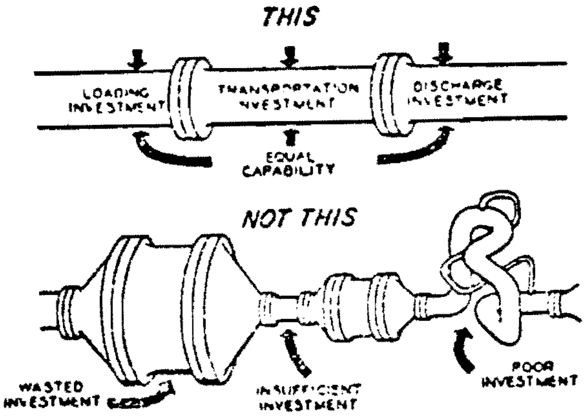
XII. Infrastructure requirements
  - * power
  - * water
  - * housing

XIII. Reversible operation

XIV. Cargo loss and damage

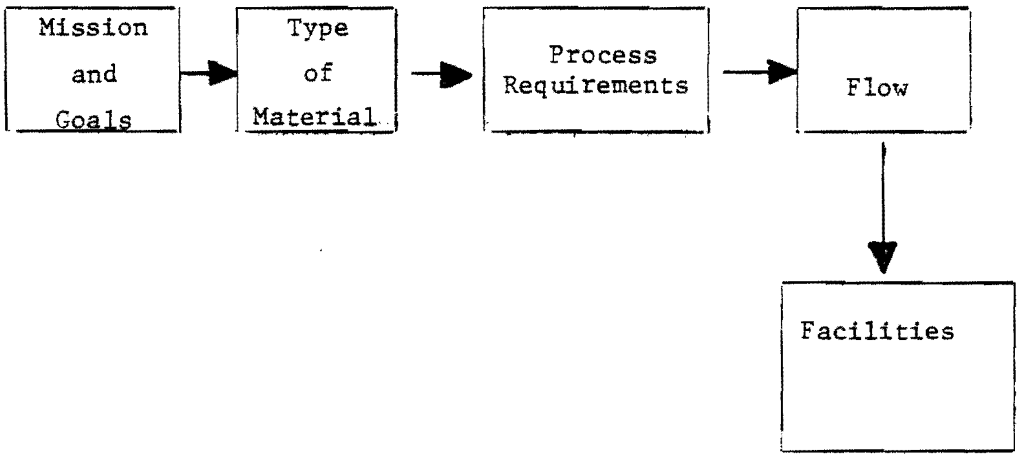
XV. Stevedoring damage to ships

FIGURE VII.2.2 PIPELINE ANALOGY OF TRANSPORTATION PLANNING



Source: The Total Transportation Concept, P.J. Maddex
Bulk Materials Handling, Vol. 2.
University of Pittsburgh, 1973

FIGURE VII.3.1 STEPS IN INITIAL PRELIMINARY DESIGN



American idea of the industrial park - the idea being to stimulate the development of factories and industrial facilities through the provision of high quality logistics and usable industrial land. A second similar idea is to create a regional port to handle the logistics requirements of a large area. The EUROPORT complex in Rotterdam is an example of a port developed along the regional port concept. Planning a successful port along either line is difficult, as most, if not all, of the demand for the port's service will be generated by the port itself. Planning for a port is, in large part, market research to determine the types of industry that will be attracted, and the types of logistics services that should be provided to assist in the placement of industry. Until this market research is done, little can reasonably be said about the goals for the development of actual port facilities.

On the other side of the spectrum is the bulk port to be integrated into a specific industrial development project, such as a steel mill or coal mine. Here the goal is to support the development of the industrial project and the goals of the port element should follow in a straightforward manner from the plans for the industrial project. It is useful to structure the goals of the port development as performance specifications expressed primarily in monetary and throughput capacity terms. These will establish at an early date the feasibility of the marine development.

The goals should stress the market for the commodity in order to determine, among other things, the best estimate of shipment sizes resulting from commercial transactions rather than the optimum shipment size resulting from a cost minimization viewpoint. While effective project management and marketing may make the two the same, they need not be. Investment in ports to serve optimum ships that do not arrive is wasted. In the context of an export terminal, this will determine the maximum draft required to attain a given level of product sales.

The analysis of the commercial sales implications for the product also establishes the maximum allowable cost for the export operation. The maximum and minimum production volumes of the industrial facility establish the throughput levels at which the performance of the ports must be evaluated. Table VII.3.1 gives what might be an initial performance specification for a steam coal export project.

This can be expanded into somewhat greater detail by estimating the size distribution of the vessels which actually use the port as shown in Table VII.3.2.

While it is of no use in determining the performance specification, the physical properties of the material should be assembled at this time since they are used in all subsequent steps in design. Table VII.3.3 gives the properties of coal.

The general processes available for coal export are shown in the flow diagram Figure VII.3.2. Each can then be developed in greater detail as in Figures VII.3.3 and VII.3.4. One process table should be prepared for every alternative available.

A preliminary design for the storage reclaim and shiploading sector of this system using rail transport from the coal mine to the port illustrates the procedure. In an actual study a preliminary design for competing approaches, including slurry and conveyor transport from the mine, would also be prepared.

The questions having the largest effect on the terminals cost are the following:

Table VII.3.1 Initial Performance Specification for Coal Logistics System (1982 $/ton)

Throughput		5,000,000 tons annually	2,000,000 tons annually
Delivered price coal at customer pier	$35.00	$35.00	$35.00
Estimated cost at minehead		$12.50	$17.00
Maximum logistics cost allowable		$22.50	$18.00
Maximum ship size customer pier	150,000 DWT		
Estimated maximum marine freight		$12.00	$12.00
Estimated minimum marine freight		$5.00	$5.00
Possible range combined inland and port costs		$10.50-17.50	$6.00-13.00

Source: World Bank staff.

Table VII.3.2 Ship Performance Specification for Coal Logistics System

	5,000,000 tons annually	2,000,000 tons annually
Average ship size 95,000 DWT Maximum ship size 150,000 DWT Minimum ship size 60,000 DWT		
Number ship calls annually (average ship size)	53	22
Mean intership arrival time	6.9 days	16.6 days

Source: World Bank staff.

Table VII.3.3 - Important Physical Properties of Coal

* Angle of repose	35-40 degrees
* Material strength	High
* Density	48 pounds/cubic foot
* Flow factor	.63 m-tons/m^3
* Material protection requirements	None
* Hazards imposed by material	Fire, dust

Source: World Bank staff.

FIGURE VII.3.2 FLOW DIAGRAM FOR LARGE SCALE MINERAL EXPORT

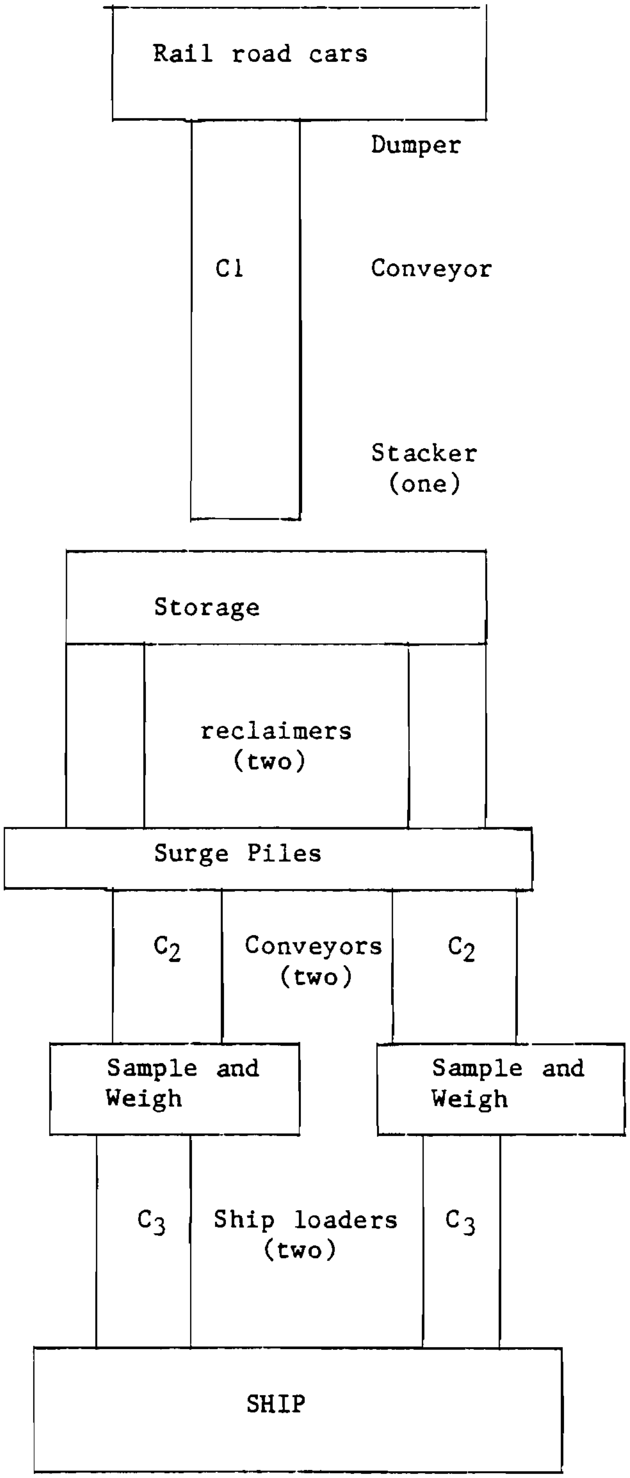
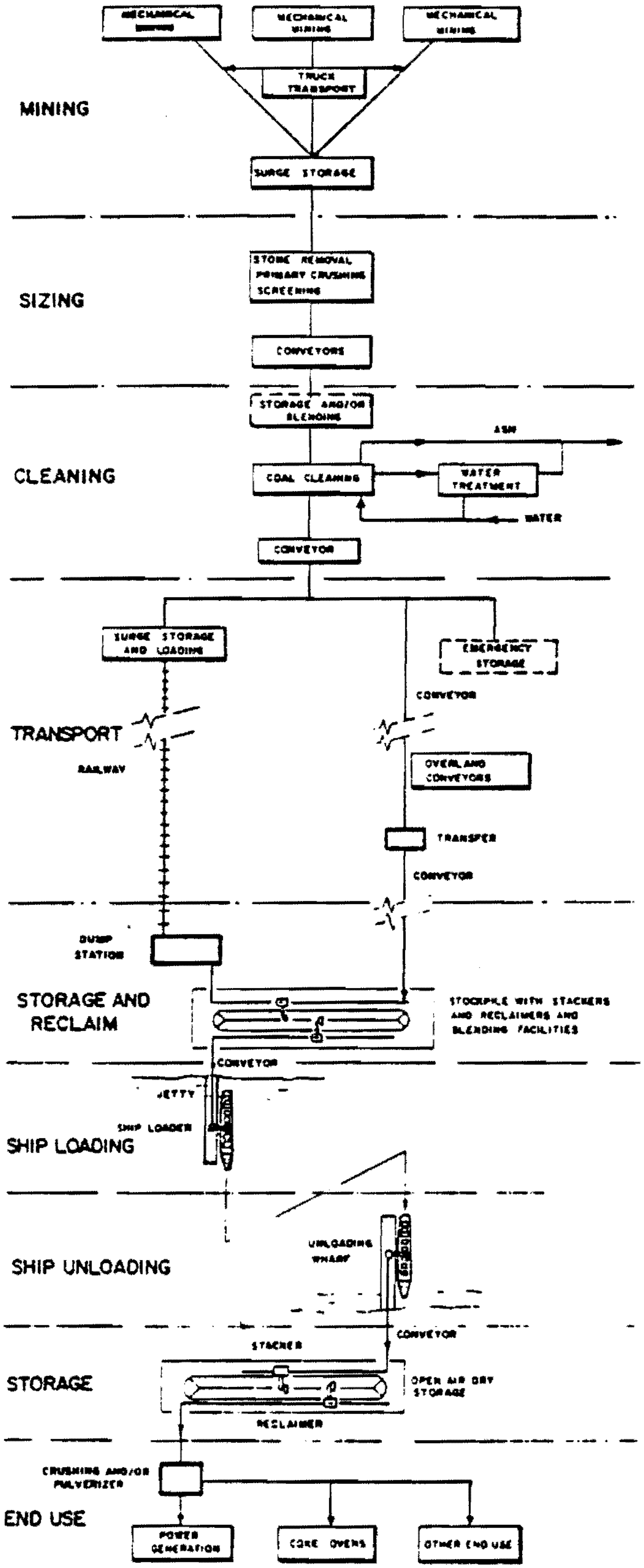
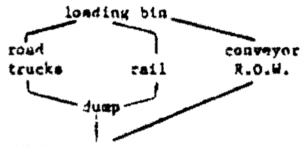
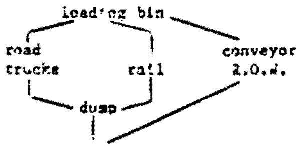


FIGURE VII.3.3 COAL HANDLING USING RAILWAYS OR CONVEYOR TRANSPORT SYSTEM



Source: "The Growing Viability of Continuous Systems in The Transport of Coal", E.R. Kennett, Coal Trade Transport and Handling, C.S. Publications, Surrey, England, 1981

FIGURE VII.3.4 SYSTEM FACILITIES COMPARISON

MODE		RAIL		CONVEYOR		PIPELINE	
Operation		Facilities	Environ Aspects	Facilities	Environ Aspects	Facilities	Environ Aspects
MINING SITE	Winning	Truck loading		Truck loading		Trucks Coarse slurry prepn. pumps	Noise
	Transport	Trucks - haul roads Dump station	Traffic Density Noise Dust	Trucks - haul roads Dump station	Traffic Density Noise Dust	Haul roads Pipelines	
	Storage	Open air surge/emergency	Visual Dust Noise	Open air surge/emergency	Visual Dust Noise	Surge & emergency storage Surge/emergency slurry storage	
	Prepn. Cleaning Storage	Crushing screening Surge storage Cleaning plant - water - mineral matter Conveyors	Noise Visual Dust Waste	Crushing screening Surge storage Cleaning plant - water - mineral matter	Noise Visual Dust Waste	Grinding slurry preparation, H. C. injection Automatic in line coal clearing Pumps - water - mineral matter	Waste Waste
	Storage	Open air storage - stackers Capacity - depends train size train frequency Reclam. - reclamer - gullet feeder	Visual Dust	Surge or emergency only Small surge		Surge storage	
OVERLAND TRANSPORT		Rail loading bin Balloon loop - service siding - workshops Right of way cleaning fencing bridges (heavy) overpass underpass	Dust Noise Land use Noise Spil'ge Visual	In line main feed Right of way cleaning fencing bridges (light) overpass underpass	Land use Noise Spil'ge Visual	Pump station Right of way none pipeline u/g route returned to original use	Noise
		Access occasional track		Access road - full length - transfer houses		Access to pump houses	
		Material handling Rolling stock (Locos wagon) Ballast track maintenance Controls signalling Communications Dump station Conveyors - sampling		Material handling Conveyors - fire service Transfer points-power supply Maintenance spares & equip Controls Communications Sampling		Slurry handling Pipeline Pump houses - power supply Controls & communication Sampling	
PORT STORAGE & MATERIALS HANDLING		Storage area - open air Stacking machines Reclaim machines Conveyors - sampling dust	Visual Dust Noise Fire	Storage area - open air Stacking machines Reclaim machines Conveyors - sampling	Visual Dust Noise Fire	Storage ponds - under water storage - water usage Pump reclaim Pipeline	
SHIPLOADING		Harbour - protection - dredging Wharf - fendering - services-power supply Conveyors - fire ⌉ dust ⌋ protection Mechanical loader	Seashr' use Recrea. Dust Noise Fire	Harbour - protection - dredging Wharf - fendering - services-power supply Conveyors - fire ⌉ dust ⌋ protection Mechanical loader	Seashr' use Recrea. Dust Noise Fire	None Undersea pipeline to buoy	
SHIPPING		60,000 - 160,000 D.W.T.		60,000 - 160,000 D.W.T.		250,000 - 300,000 D.W.T.	
SHIP UNLOADING		Harbour - protection - dredging Wharf - fendering - services-power supply Mechanical unloaders - batch Conveyors	Seashr' use Recrea. Dust Noise Fire	Harbour - protection - dredging Wharf - fendering - services-power supply Mechanical loaders - batch Conveyors	Seashr' use Recrea. Dust Noise Fire	None Offshore buoy Undersea pipeline to buoy	
STORAGE		Storage area - open air Mech. stacker Mech. reclaimer Conveyors - fire ⌉ dust ⌋ protection	Visual Dust Noise Fire	Storage area - open air Mech. stacker Mech. reclaimer Conveyors - fire ⌉ dust ⌋ protection	Visual Dust Noise Fire	Pond storage - water storage	
DISTRIBUTION			Traffic density Noise Dust		Traffic density Noise Dust	Pump reclaim Pipeline	
USER		Open air storage - fire ⌉ dust ⌋ protect Grinding Use	Noise Visual Dust Fire	Open air storage - fire ⌉ dust ⌋ protect Grinding Use	Noise Visual Dust Fire	Pond storage de Water Use	

Source: "The Growing Viability of Continuous Systems in The Transport of Coal", E.R. Bennett, Coal Trade Transport and Handling, C.S. Publications, Surrey, England, 1981.

1. Number of ship loaders
2. The use of conveyor c-2 intended to allow direct loading of coal without stacking and reclaiming
3. The use of the surge storage pile
4. The number of stackers and reclaimers installed

Table VII.3.4 identifies the types of decisions necessary during preliminary design.

Table VII.3.4 - Major Decision Variables for Coal Port Design

Variable	Install or not	Type	Number	Size
Number of Berths	X		X	
Ship loader		X	X	X
Conveyor (C-2)	X			
Reclaimers	X	X	X	X
Stackers	X	X	X	X
Surge Storage (S-1)	X			X
Storage (S-2)				X

VII.4. Terminal Design Optimization

VII.4.1 Number of Berths

It is impossible to precisely schedule ship arrivals at a port, because a vessel's average speed is heavily dependent on the weather. The variance in over the ground speed accounted for by the weather is easily ±1.5 knots which indicates that the arrival time of a bulk carrier on a 5,000 mile voyage will not be known in advance to an accuracy greater than three days. In addition, for heavily laden vessels requirements to wait for tides create additional random delays expected to be hours long in duration.

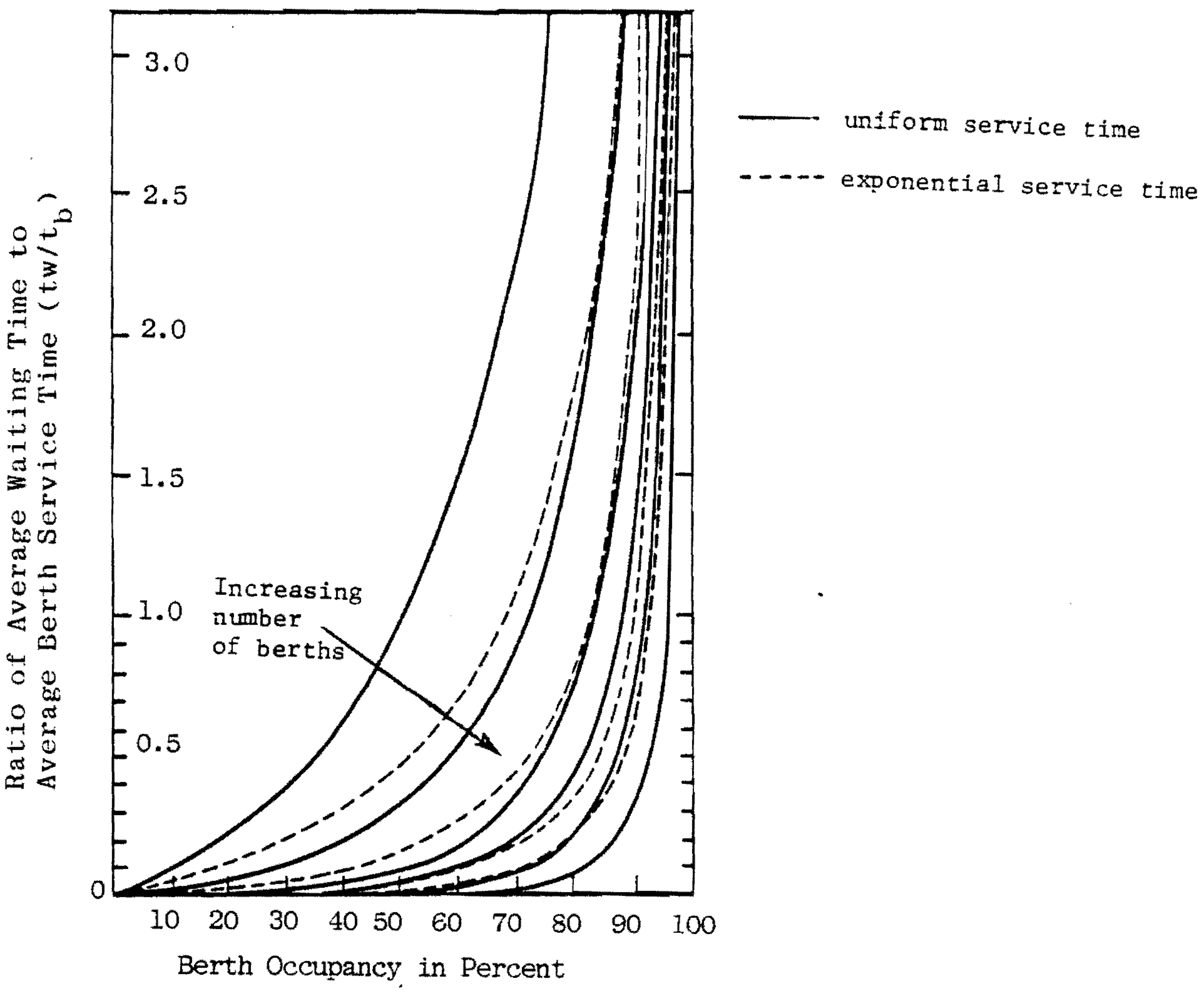
However, the average occurrences of winds, waves, and currents on the various portions of a route are known by season and can be included in the calculations of the voyage time. Deviations from the average always occur and, therefore, off-schedule arrival is a normal phenomenon. When taking the arrival of all vessels at a terminal facility into account, it is obvious that this phenomenon of early or late arrivals will create a pattern that rather closely fits that of a random distribution.

The selection of the number of berths required for a particular alternative will be based on Mettam's ship queueing theory. This theory establishes the relation between berth occupancy and the waiting time ratio. This relation is graphically shown in Figure VII.4.1.1. The broken lines present the case of uniform service time, whereas the full lines present the case of varying service time (the variation is exponential).

An important consideration is the manner in which ships are procedurally entered in the queue. As the days remaining in a voyage decrease, the ship's arrival time becomes increasingly more certain. During the last four days of the voyage some flexibility exists to advance or retard the physical arrival time by changing the vessel's speed. In the last stages insufficient time exists to allow a substantial advancement of the vessel's arrival time, and only delaying arrival through slow steaming is possible.

Ports differ in the way they deal with this. One philosophy is that entrance to the berth should be on a first come, first served queue with entry to the port being the same as entry into the queue. Other ports allow entry into the queue to be made while the vessel is

FIGURE VII.4.1.1 QUEUEING ANALYSIS OF WAITING TIMES FOR SHIPS IN PORT



Source: Forecasting Delays to Ships in Port, J. D. Mettam, The Dock and Harbor Authority, London, England, April 1967.

at sea allowing it to wait in the queue while underway, enabling it to wait in the queue at no financial cost. Systems using this approach grant "preferential" days to vessels on the basis of their planned arrival schedules with the ship losing its place if late. Systems such as this allow higher berth utilization for a given wait than the first arrival discipline.

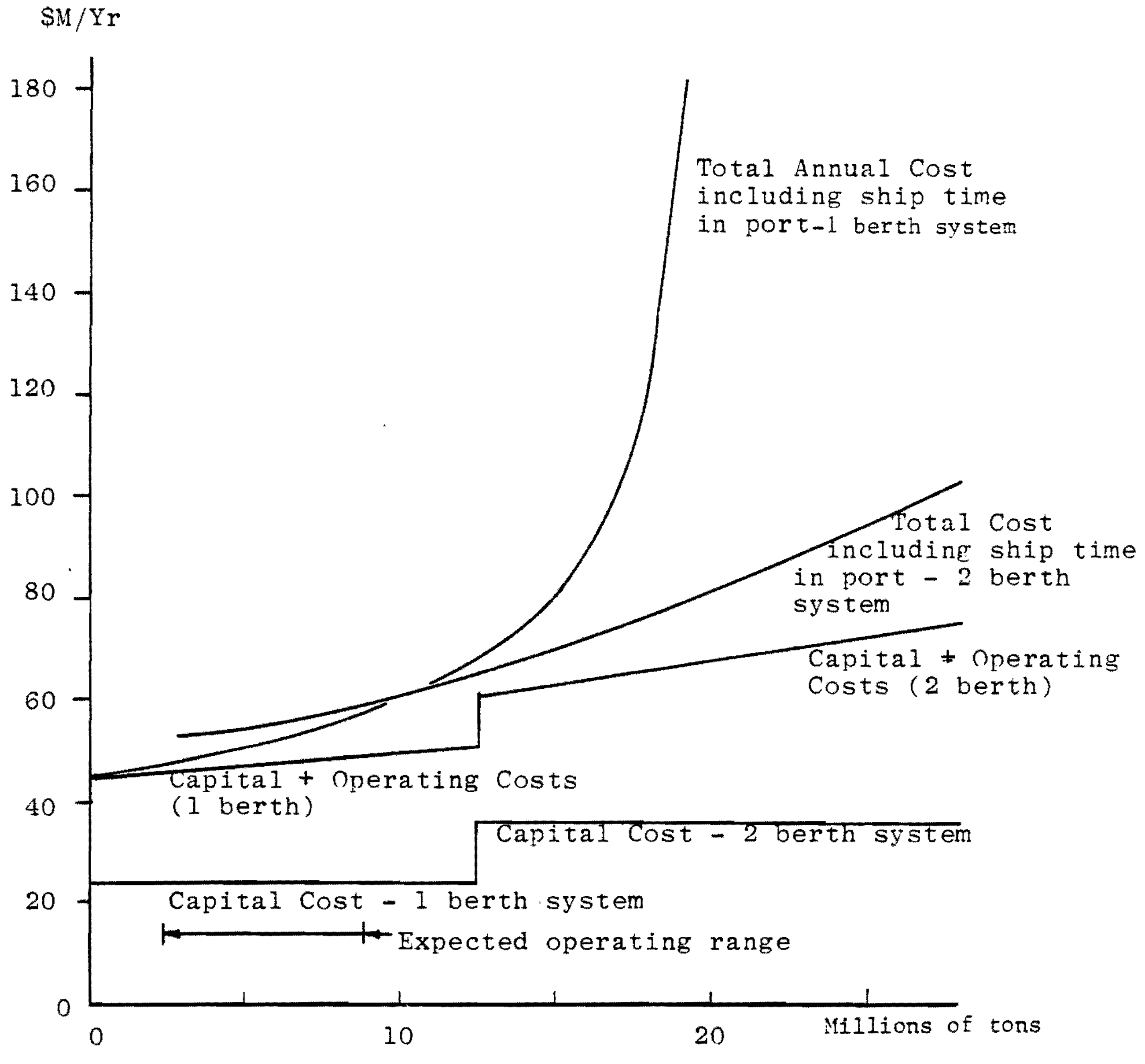
Utilizing the results of the queueing model together with rough estimates of the marginal costs of additional berths, a graph similar to Figure VII.4.1.2 can be developed.

In the case of the given example, a single berth is adequate for the high production figure of 5,000,000 tons and the low of 2,000,000.

VII.4.2 Capacity of Shiploader

The required capacity of the shiploader can be calculated using queueing theory as shown in an example in Table VII.4.2.1. The service time of the system is modeled with an Erlang distribution which allows the shape of the distributions of service times to be varied (see Figure VII.4.2.1). The value of K ranging from 1 (if the service time is exponentially distributed) to 0 (if the service time is constant). In this case, the difference in service times caused by the differing ship sizes is critical. The maximum ship sizes is critical. The maximum ship size is 150,000 dwt, the smallest 60,000 and the mean 95,000. To fit the Erlang distribution, the standard deviation of the ship sizes arriving at the loader must be estimated. This can be achieved either by setting policies for ship procurement or by taking the information available and estimating the standard deviation using the beta distribution. The constant, K, for Erlang distribution is then calculated

FIGURE VII.4.1.2 QUEUEING THEORY IN PRELIMINARY PLANNING



Note: In practice stockpile capacity, rail capacity, etc. would limit the ultimate throughput.

- 10,000 tph reclaim and loading system
- maximum ship 150,000 DWT

Table VII.4.2.1 Example of Estimation of Number of Berths and Optimum Size of Ship Loader

A. Estimate Arrival Distribution

Largest Ship = 150,000 DWT
Smallest Ship= 60,000 DWT
Mean Ship = 95,000 DWT

To get the standard deviation, simply use the Beta distribution

$$\sigma^2 = \frac{[150,000 - 60,000]^2}{6}$$

$$\sigma^2 = 15,000^2$$

calculate K for Erlang Distribution

$$K = \frac{95,000^2}{15,000^2} = 40.11$$

$$\lambda = \frac{5,000,000}{95,000} = 52.6 \text{ ships/year} = .14 \text{ ships/day}$$

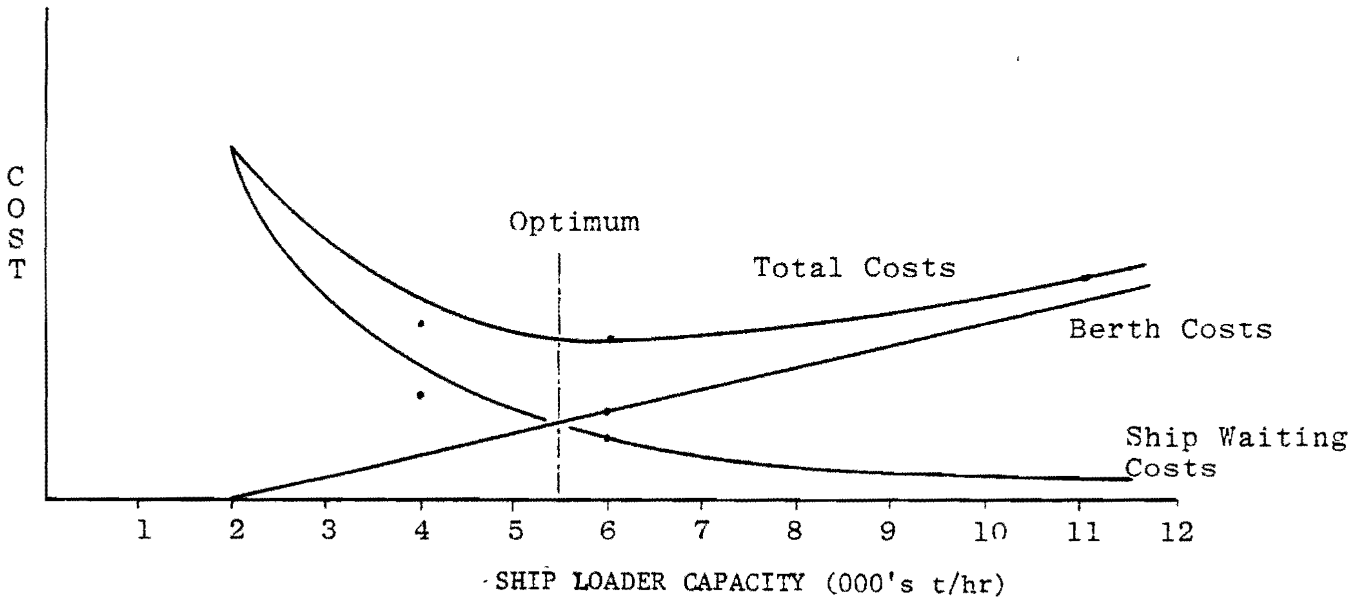
Loader Capacity (tons/hr)			Unloading Time (hours)	μ (ships/day)
2000	47.5 + 12	=	59.5	.4
4000	23.8 + 12	=	35.8	.67
6000	15.8 + 12	=	27.8	.86
10000	9.5 + 12	=	21.5	1.12
12000	7.9 + 12	=	19.9	1.21

$$\text{Mean waiting} = \frac{K + 1}{2K} \times \frac{\lambda}{\mu(\mu - \lambda)} \text{ days}$$

Loader Capacity	Ship waiting cost ($20,000/ship-day)
2000	.68 days x 20,000 x 52 = 707,000
4000	.20 days x 20,000 x 52 = 208,000
6000	.115 days x 20,000 x 52 = 119,000
10000	.06 days x 20,000 x 52 = 62,000
12000	.055 days x 20,000 x 52 = 57,000

Source: World Bank staff.

FIGURE VII.4.2.1 TOTAL COSTS VS. SHIP LOADER CAPACITY



Source: World Bank staff.

and the formulas given in Appendix C are used to calculate the waiting time and total system cost as shown in Figure VII.4.2.1. Minimum total cost is achieved with shiploading capacity in the region of 5500 tons/hour on the average.

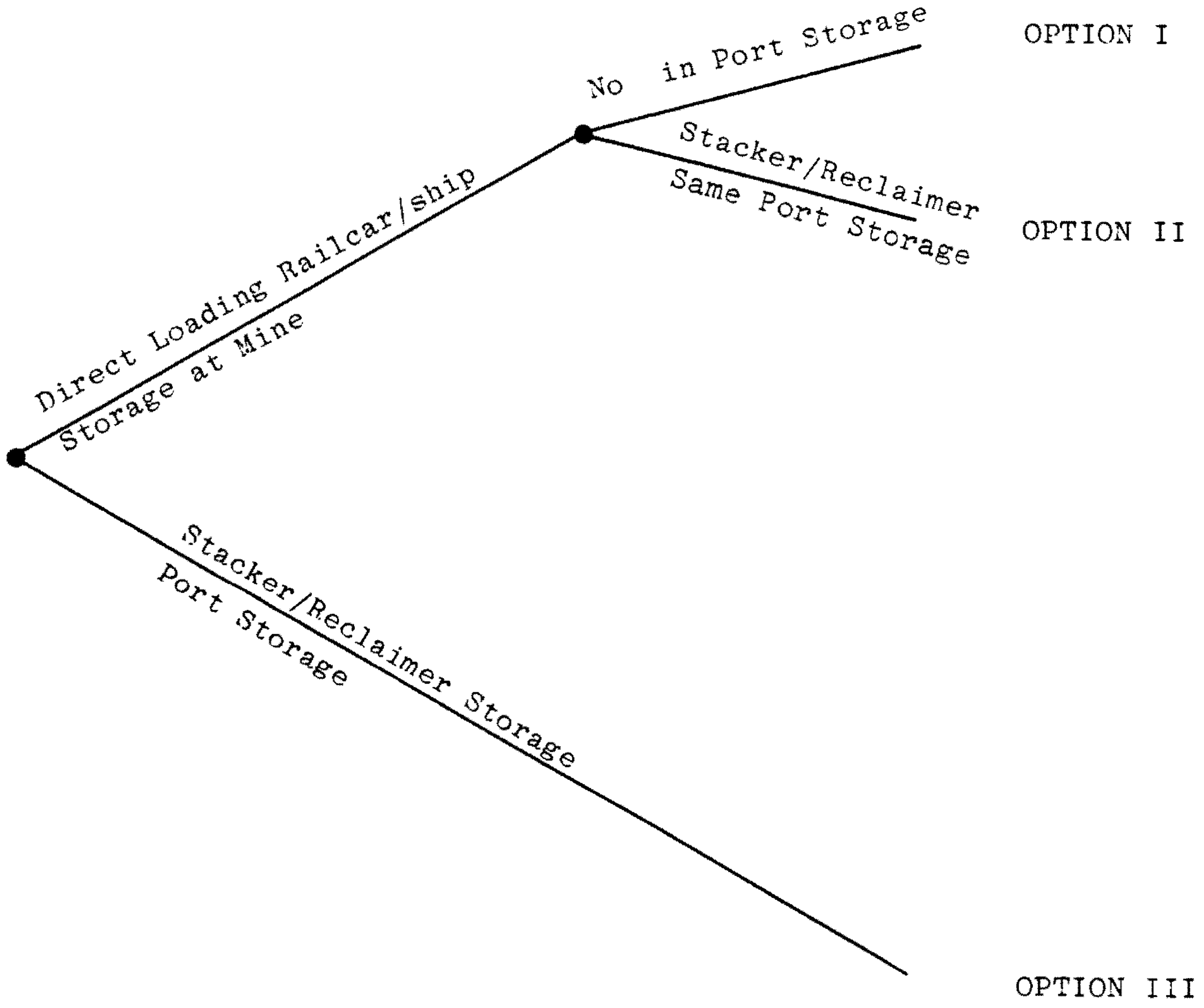
Assuming the vessel has eight holds of 15,000 tons, 2.73 hours are allowed per hold and half an hour is required to move the loader to the next hold. This leaves 2.2 hours for the actual loading operation. Thus, the rated capacity of the loader must be 6,818 or 7,000 tons per hour, in order to achieve an average rate of 5500 tons/hr.

The size of the vessel which is being loaded allows either one slewing loader on a finger pier, one quadrant loader (if the ship is moved during loading) or two quadrant loaders (if the ship is not to be moved). For the same loading time, it is found from the results of a comparative analysis of the three alternatives, two quadrant loaders of 4,000 tons per hour capacity each is the best choice.

VII.4.3 Storage System Selection

The coal waiting for shipments can either be stored at the mine and loaded directly aboard the ship after rail car unloading via the bypass conveyor, or it can be stored in a stacking reclaim yard. A third alternative of combining the two, that is, storing only a portion in the reclaim yard, also exists. The option of silo storage would be worth considering were land at a premium and annual volumes small. Storage in parked rail cars is not required, because blending requirements are not substantial. Since this system will be at least twice as expensive as the other alternatives, it will not be considered. The basic options available are shown in Figure VII.4.3.1.

FIGURE VII.4.3.1 STORAGE OPTIONS



. Table VII.4.3.1 presents the equipment and equipment utilization as a function of the number and size of the reclaiming capacity installed. The direct loading option with no in-port storage is for the system with no reclaiming capacity installed. Only costs and information not common between options are presented.

Table VII.4.3.1 Equipment Capacities as Function of Reclaimer Capacity

Reclaimer Average Production (tons/hr)	# of Reclaimers	Yard Production (tons/hr)	Yard Surge (tons)	Max Dump (tons)	Average Car Dump (tons)	# of Dumpers	Dumper Storage (tons)	Surge Size
2,000	1	2,000	0	5,000	3,500	2 x 2,400	1100	
	2	4,000	0	3,000	1,500	1 x 2,400	0	
	3	6,000	1,500	0	0	1 x 1,700 1/	0	
	4	8,000	0	0	0	1 x 1,700 1/	0	
3,000	1	3,000	0	4,000	2,500	1 x 4,000	1100	
	2	6,000	1,500	0	0	1 x 1,700 1/	0	
	3	9,000	0	0	0	1 x 1,700 1/	0	
None	0	—	—	7,000	5,500	2 x 3,200	3300	

Source: World Bank staff.

Table VII.4.3.2 Storage System Costs (1000's USD)

Capacity (tons/hr)		Stackers	Reclaimers	Yard	Cars	Dump Pit	Sw Pit		Total
2,000	1	800	2,750	0	10,227	1,200 2/	330 3/		15,300
	2	1400	5,500	0	7,404	600	0		14,900
	3	2000	8,250	550	4,500	400	0		15,700
	4	2000	11,000	0	4,500	400	0		17,900
3,000	1	1000	3,500	0	8,590	1,500	330		14,920
	2	2,000	7,000	550	4,500	400	0	0	14,450
	3	2,000	10,500	0	4,500	400	0	0	17,400
None	0	-	-	-	13,500	3,000	660		17,160

1/ Dump train in 4 hours 2 trains = 1 shift
2/ Estimated from dump pit costs at Puertode Haina
3/ Estimated from Surge storage pit cost Puerto de Haina

Source: World Bank staff.

From the calculations of the shiploader capacity, the maximum requirement will be for 7,000 tons/hr of material and average 5,500 tons/hr. For systems which have a delivery capacity in excess of 7,000 tons per hour, no surge capacity is required. For systems with delivery capacities between 5,500 and 7,000 tons/hr surge storage is required at some point in the system. When the option utilizes direct loading from rail cars this surge storage is most cheaply incorporated into the railcar unloader. For other systems this surge storage is incorporated at the output of the reclaimers.

As the contents of the surge storage goes to zero just prior to the completion of the loading of the hold, its size is determined by the time required to load each hold and the difference between the capacity of the system and the peak of 7,000 tons per hour. This means that the maximum hold size of vessels calling is an important parameter which should be verified.

The costs of the options are given in Table VII.4.3.2. of the previous page. Note that the direct loading and the purely port storage option are very close in cost. In a real situation, additional factors would have to be considered. Among these are the following:

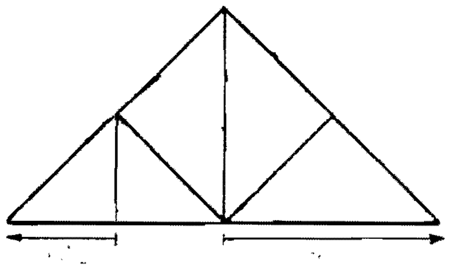
1. The probable higher cost of stock pile site preparation when the site is located near the water rather than at the mine.
2. The cost of the direct loading option is not burdened with the cost of additional coal storage facilities at the mine. These will cost at least $5 million (U.S.) and should indicate that the best choice is Option III.

As the design with two surge piles at the discharge is the cheapest, it will be selected for further development.

The surge pile must have a size sufficient to hold the production of the reclaimers for the period required to move the ship loader from one hold to the next. This was estimated to be one-half hour. The piles must then hold 1,500 tons each, the production of a single reclaimer for half an hour. A simple conical pile with tunnel reclaim is chosen. Because of the large throughput utilization of materials, the dead-storage area in the pile is not possible, and the pile must be made larger. The pile itself is described in Table VII.4.3.3 below.

Table VI.4.3.3 Stockpile Size and Volume

Size of surge storage pile
capacity of pile = 1,500 tons



density of coal 45 lbs/cubic/foot
angle repose 40^{o}

$$\text{Volume Live Storage} = \frac{1{,}500 \times 2{,}280}{45} = 76{,}000 \text{ cubic feet}$$

$$\text{Volume Cone} = \frac{\pi r^2 H}{3} = \frac{\pi r^3 \tan \alpha}{3} = .28\, \pi r^3$$

$$\text{Dead Storage Section Area} = 1/2 \cdot \frac{r}{2} \cdot \frac{r}{2} \cdot \tan \alpha \cdot 2 = \frac{0.74 r^2}{4}$$

$\text{Length} = \pi r$

$\text{Live Storage Volume} = r^3 \pi (0.28 - 0.185)$

$76{,}000 = 0.095 \pi r^3$

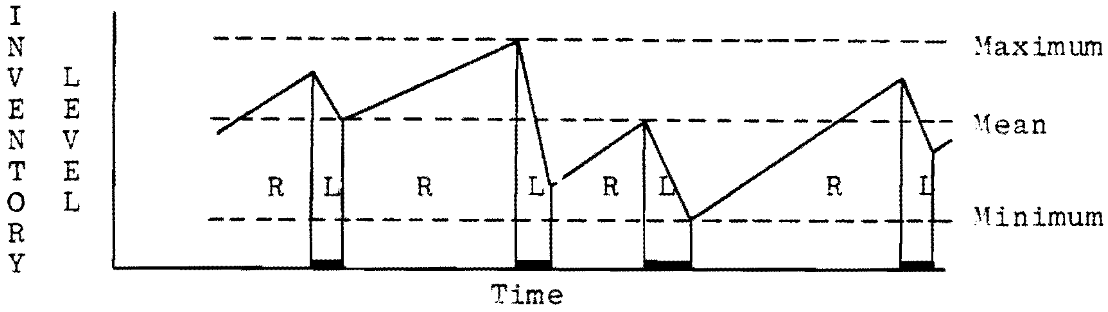
$r^3 =$ 253,000
$r =$ 63 feet
$h =$ 63 x 0.84 = 53 ft

Source: World Bank staff.

The last storage area to design is the attached reclaim stock yard. The inventory carried in the stock pile follows a pattern shown in Figure VII.4.3.2. The minimum level of inventory in the yard is such that, if a ship should arrive perchance at more frequent intervals than the mean, then there would be sufficient ability to load it. The maximum level is set by a desire not to be forced to shut down the production of coal at the mine should the ship arrive late.

FIGURE VII.4.3.2 TYPICAL VARIATION IN DRY BULK CARGO TERMINAL INVENTORY LEVEL

EXPORT STOCKPILE



L = Shiploading period

R = Replenishment period

Source: World Bank staff.

To do this, acceptable levels of risk must be established for each event. The early arrival of a ship at port has a higher acceptable level of risk because of the following:

1. The railroad supplying coal was designed for operation on a single shift and has a larger capacity if operated for longer periods.
2. The loss, if sufficient coal is unavailable, is demurrage for the longer period required to load the vessel (about $10,000/day).

On the other hand, the loss from a ship which is late is the value of the coal which could have been produced; this amounts to about $80,000 per day. In addition, relations with customers are sometimes jeopardized if production schedules cannot be met. Finally, as this maximum inventory level is only the capacity, not the actual inventory level, there is no holding cost associated with it, only the additional capital investment required to install the larger storage capacity.

To estimate the minimum level of coal inventory, one must calculate the probability that the time between vessels will be less than a given value. Storage must then be equal to the amount that would be supplied during the interval between the early and expected arrival of the ship, since this is the position of the replenishment cycle not available for uninterrupted loading of the ship.

The minimum time between ships is, of course, zero, as it is always possible that one will be loaded immediately after the completion of the loading of the first. The maximum time between vessels is probably close to the case where a ship was lost at sea or delayed for service mechanical problems. Thus, the maximum time between ships is probably twice the mean. With this information, it is possible to estimate the standard deviation of the inter-arrival times using the beta distribution.

For this distribution:

Standard deviation = (Maximum time - Minimum time)/6

This can then be used with the cumulative normal distribution to determine the probability that the time between ships is under a given value. This is used next to estimate the stock required, as shown in Table VII.4.3.4.

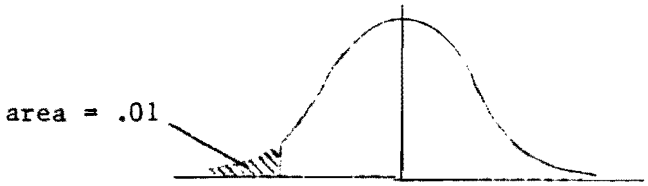
Table VII.4.3.4 Safety Stock Calculation

Minimum Time Between Arrivals = 0
Mean Time Between Arrivals = 6.9 days
Maximum Time Between Arrivals = 13.8 days

Standard deviation = (13.8 - 0)/6 = 2.3 days

It is decided that a probability of 0.99 that shiploading is not delayed for lack of stock is acceptable. This is equivalent to a time between stockouts of 2 years.

Using the normal distribution



k = 2.33 when the shaded area is .01.

The time period is then 2.33 x 2.3 = 5.36 days

The production during this period is 72,800 tons which is the minimum safety stock.

minimum safety stock = 72,800

Source: World Bank staff.

The matter of late ship arrival requires a more stringent view. It is important to protect the system from becoming inoperable because of excess stocks so that such will be the case only once in twenty years.

This occurs when the probability of the inter-arrival time being greater than the mean is .9991. When this is the case K=3.1, the number of days is 3.1 x 2.3 or 7.13 days. The required stock to meet this criterion is 7.13 times the railroad's mean delivery rate or 98,400 tons.

The mean level of material in the stockyard is 95,000 tons or the average ship size.

In a real problem more scrutiny should be given to the assumptions behind this analysis. In particular, the probabilities of a stock-out or being full should be treated as parameters and the costs of varying levels of protection estimated.

On the basis of this analysis, the maximum capacity of the stockyard should be 95,000 tons to load one ship and 98,400 tons for protection against late ship arrival or 193,400 tons, say 200,000 tons. 72,800 tons will be "permanently" stored in the facility to protect against early ship arrivals and the inventory level will fluctuate by 95,000 tons as a result of ship loading operations.

General options for the layout of the yard are given in Figure VII. 4.3.3. These arrangements derive directly from increasing the number of stackers serving the two reclaimers from the minimum of one to the maximum of 3.

The capacity of the storage yard is given in the following formula:

$$\text{capacity} = L \times A \times H \times K \times N$$

where,

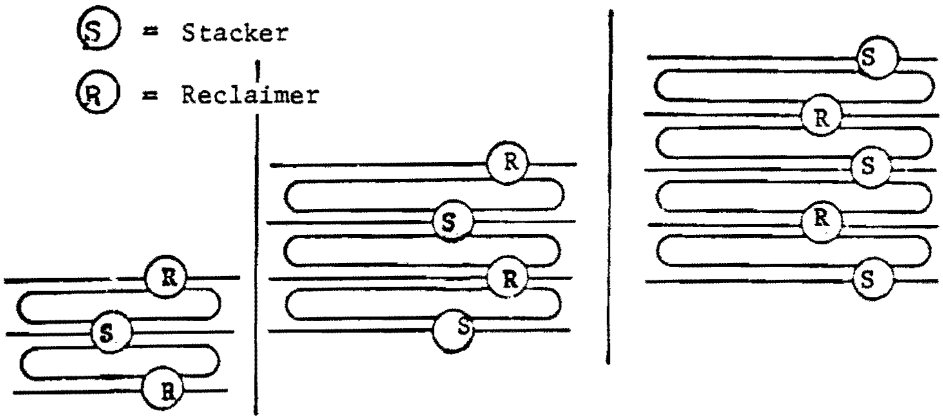
L = Length of piles

A = Width of piles

H = Height of piles

K = factor depending on the angle of repose to account for the shape of piles

FIGURE VII.4.3.3 OPTIONS FOR STOCKYARD LAYOUT



Source: World Bank staff.

TABLE VII.4.3.5 GEOMETRIES OF PILES

Width (m)	Height (m)	Cross Section Area (m3)	Capacity for Coal Storage (m.tons/m)	Total Length of Pile Required (m)	3 Piles Length 1 Pile (m)	4 Piles Length 1 Pile (m)
35	13.2	254	160	1,650	550	412
40	15.0	332	209	956	318	239
45	16.0	415	261	766	255	191

Source: World Bank staff.

N = Number of piles.

This formula neglects the semi-conical shaped portion on the end of the stacks. This is a small error at the initial design stages. Table VII.4.3.5 of the previous page, gives the geometry of the pile system required by stackers and reclaimers of various widths. The basic geometries of the piles are given in Table VII.4.3.6.

This information was then used to estimate the costs of each alternative. This comparative cost is given in Table VII.4.3.7. Note that the land development cost is an important parameter in bulk ports as much or all of the stockyard may be built on filled land and the alternatives differ greatly in land requirements. If the land cost is $50 a square meter, the lowest cost solution is for one stacker and two reclaimers.

An effective method for pile capacity computation is described here. Volume of material that can be stockpiled in elongated form in an area of 115 feet wide and 415 feet long is calculated as follows:

a) Assuming that the material has 35° angle of repose, the ends volume of the conical pile is 5050 yd^3 .

b) The volume of prism in yd^3 is

$$V = \frac{(\text{length})(\text{width})(\text{height})}{2 \times 27\ ft^3/yd^3} = \frac{(415 - 115)(115)(40)}{2 \times 27}$$

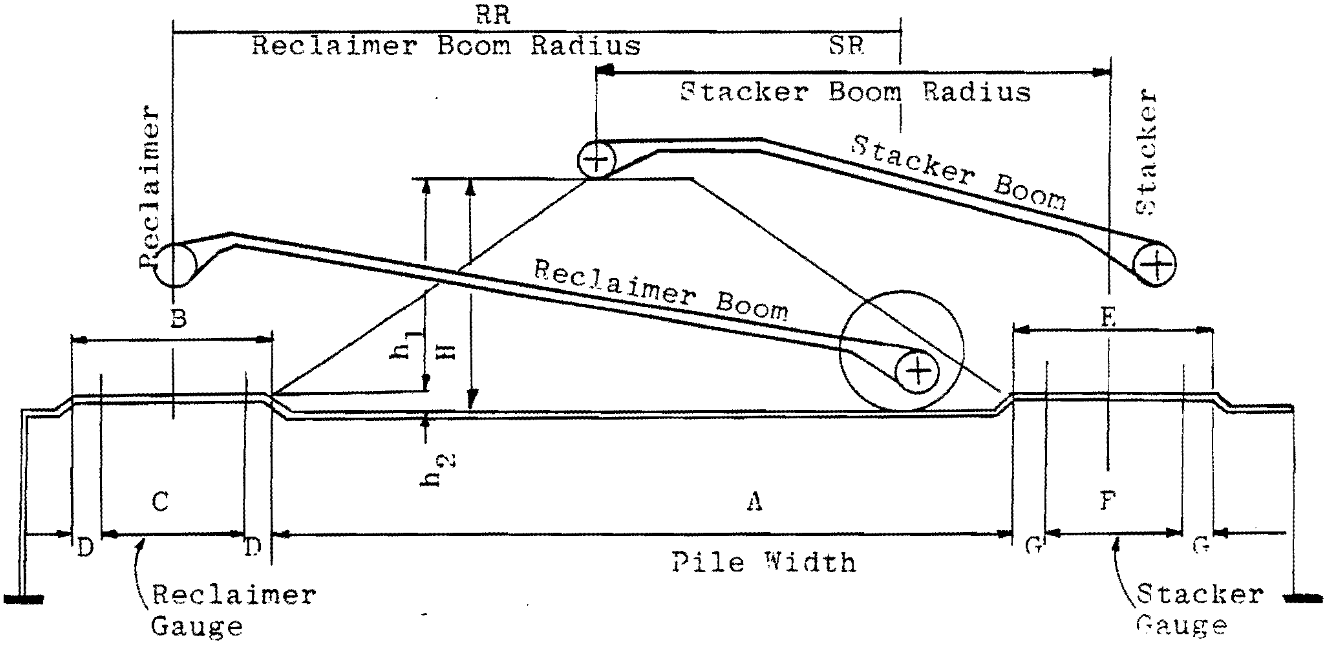
$$= 22{,}550\ yd^3$$

c) Total Volume = 5050 + 22,550 = 27,600

The method of computing radial stockpile volume can be readily compared with that of elongated stockpiles. A computation method for the amount of bulk material that can be withdrawn from a conical stockpile, is similarly easily developed.

TABLE VII.4.3.6 GEOMETRY OF PILE SYSTEM

PILE WIDTH A	B	RECLAIMER GAUGE C	D	E	STACKER GAUGE F	G	H	h_1	h_2	RECLAIMER ROOM RADIUS RR	STACKER BOOM RADIUS SR
30	10.0	7.0	1.5	8.0	6.0	1.0	11.5	10.5	1.0	30	20
35	10.0	7.0	1.5	8.0	6.0	1.0	13.2	12.2	1.0	35	22.5
40	11.0	8.0	1.5	10.0	7.0	1.5	15.0	14.0	1.0	40	25
45	11.0	8.0	1.5	10.0	7.0	1.5	16.0	15.0	1.0	45	27.5
50	14.0	10.0	2.0	10.0	7.0	1.5	16.0	15.0	1.0	50	35
55	14.0	10.0	2.0	11.0	8.0	1.5	16.0	15.0	1.0	55	40



Source: World Bank staff.

Table VII.4.3.7 Comparative Costs for Stockpile Alternatives

COST OF LAND DEVELOPMENT $25 PER SQUARE METER

PILE WIDTH 35 AREA OF STOCKYARD 70,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	2,475	1	2	15,987.5
3	2,200	2	2	18,850
4	2,062.5	3	2	21,781.25

PILE WIDTH 40 AREA OF STOCKYARD 45,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	1,434	1	2	16,042
3	1,274.667	2	2	19,362.33
4	1,195	3	2	22,722.5

PILE WIDTH 45 AREA OF STOCKYARD 40,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	1,149	1	2	18,774.5
3	1,021.333	2	2	23,110.67
4	957.5	3	2	27,478.75

COST OF LAND DEVELOPMENT $50 PER SQUARE METER

PILE WIDTH 35 AREA OF STOCKYARD 70,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	2,475	1	2	17,737.5
3	2,200	2	2	20,600
4	2,062	3	2	23,531.25

PILE WIDTH 40 AREA OF STOCKYARD 45,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	1,434	1	2	17,167
3	1,274.667	2	2	20,487.33
4	1,195	3	2	23,847.5

PILE WIDTH 45 AREA OF STOCKYARD 40,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	1,149	1	2	19,774.5
3	1,021.333	2	2	24,110.67
4	957.5	3	2	28,478.75

(Table continues on the following page)

Table VII.4.3.7 Comparative Costs for Stockpile Alternatives (cont'd)

COST OF LAND DEVELOPMENT $75 PER SQUARE METER

PILE WIDTH 35 AREA OF STOCKYARD 70,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	2,475	1	2	19,487.5
3	2,200	2	2	22,350
4	2,062.5	3	2	25,281.25

PILE WIDTH 40 AREA OF STOCKYARD 45,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMERS	COST
2	1,434	1	2	18,292
3	1,274.667	2	2	21,612.34
4	1,195	3	2	24,972.5

PILE WIDTH 45 AREA OF STOCKYARD 40,000

NUMBER PILES	LENGTH TRACK	# STACKERS	# RECLAIMETS	COST
2	1,149	1	2	20,774.5
3	1,021.333	2	2	25,110.67
4	957.5	3	2	29,478.75

Source: World Bank staff.

The stacker's average production is 1,725 tons per hour when 13.8 tons of coal are unloaded from trains in an 8 hour shift. Thus, the rated capacity of the stacker should be 1.15 x 1,725 = 1,983 or about 2,000 tons per hour.

The rail car dumper must be able to dump cars at a rate of 1,800 tons per hour.

The conveyor C-1 must have a capacity of 2,000 tons per hour. The conveyors C-2 and C-3 must be sized to accept the maximum digging output of 3,000 ton per hour average per reclaimer. This maximum digging output is about 3,000 tons per hour.

The conveyor loaded by the reclaim tunnel must be of sufficient capacity to supply the shiploader. This is 4,000 tons per hour.

The belts in the system are selected on the basis of Table VII.4.3.8. The rest of the equipment installed is listed in Table VII.4.3.9.

A cost estimate is then prepared; a model is shown in Table VII.4.3.10. Given the gross nature of the design and failure to consider dredging and other costs in any detail, the contingency portion of this cost estimate is large. As the design progresses to the center of the design spiral, this contingency is replaced with estimates for specifications.

Prior to the refinement of this design there are several areas where improvements may be possible. First, it would be desirable to reduce the speed of operation of Belts C-2 and C-3, and to eliminate the surge piles at their discharge. This could be done by installing 3-3,000 ton per hour reclaimers instead of 2. The evaluation of this option would be done in a manner similar to the example used in this text. Figures VII.4.3.4 and 5 show examples of bulk loading and unloading systems.

TABLE VII.4.3.8. Guide to Belt Selection

Belt	Capacity* (tons/hr)	Speed (ft/min)	Width (inches)
C-1	2,000	500	60"
C-2EC-3	6,000	900	72"
C-3EC-5	4,000	700	72"

*Assuming 40 lbs/ft^2 belt loading

Source: World Bank.

TABLE VII.4.3.9 Other Terminal Equipment Installed

Berths	One Dredged to 55 feet to accept 150,000 ton ship
Ship Loaders	Two - quadrant type Required cream capacity 3,500 tons/hour Rated capacity 3,500 x 1.15 = 4,000 tons/hour Outreach of boom 45 meters
Reclaimers	Two - pile width 40 meters Required rated capacity 3,000 tons/hour Theoretical capacity - 6,000 cubic meters/hour
Stackers	One - pile width 40 meters Rated capacity 2,000 tons/hour
Rail Car Dumper	One Rated Capacity 1,800 tons/hour

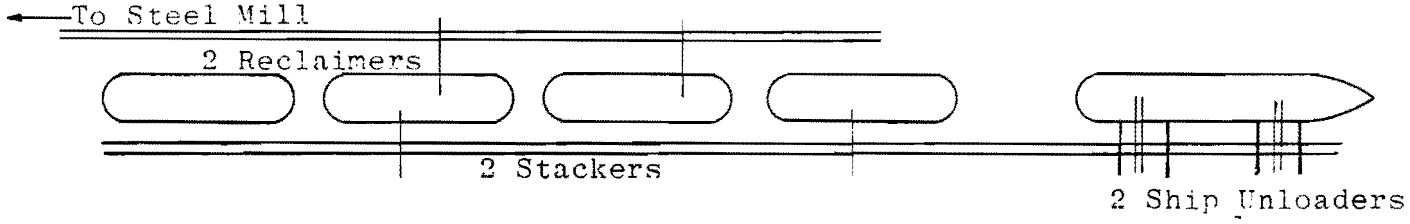
Source: World Bank.

TABLE VII.4.3.10 Initial Coal Port Estimate (USD)

Berth	5,000,000
Shiploader	12,000,000
Stacking/reclaim yard	17,167,000
Rail dumper	3,200,000
Misc. and contingency (70% of above)	26,160,000
Initial Estimate Port Cost	63,520,000

Source: World Bank.

FIGURE VII.4.3.4 IRON PELLET IMPORTS



Design Capacity 3,200,000 tons/year

Equipment

2 1000 ton/hour grab unloaders
2 3000 ton/hour belt conveyors

Subtotal (ship unloading)

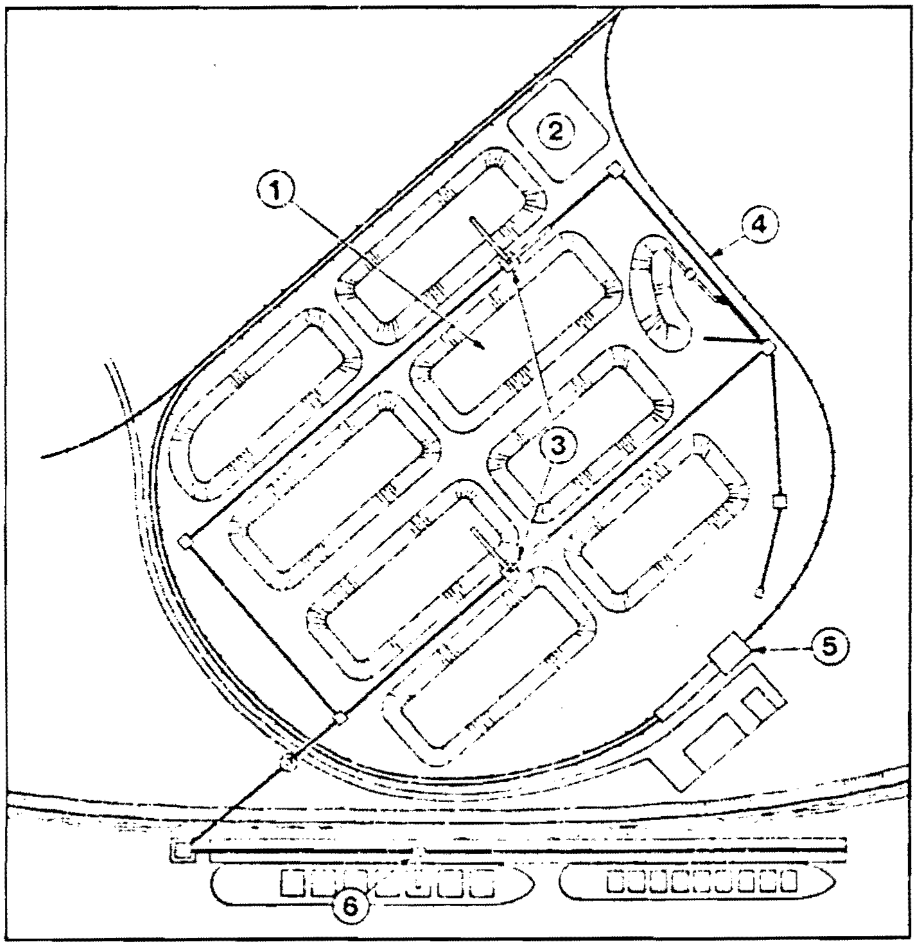
2 3000 ton/hour stackers
2 500 ton/hour reclaimers
Stacking belt conveyor
Reclaiming belt conveyor

Subtotal (storage and reclaim)

Dredging and quay construction

Source: World Bank Project Files

FIGURE VII.4.3.5 COAL EXPORT TERMINAL



Layout of Pacific Coal Corp's Portland, Oregon, coal terminal showing: (1) total storage capacity of 1.7 mt; (2) 3.8 million gallon retention pond; (3) stacker/reclaimers (the second unit will be added in the event of a Phase 2 expansion); (4) rail loop serving Burlington Northern and Union Pacific unit trains; (5) wagon dumper shed; (6) 6600 travelling shiploader.

Source: Bulk Systems International, Sept. 1982.

VIII. TERMINAL COST ESTIMATION

VIII.1 Introduction

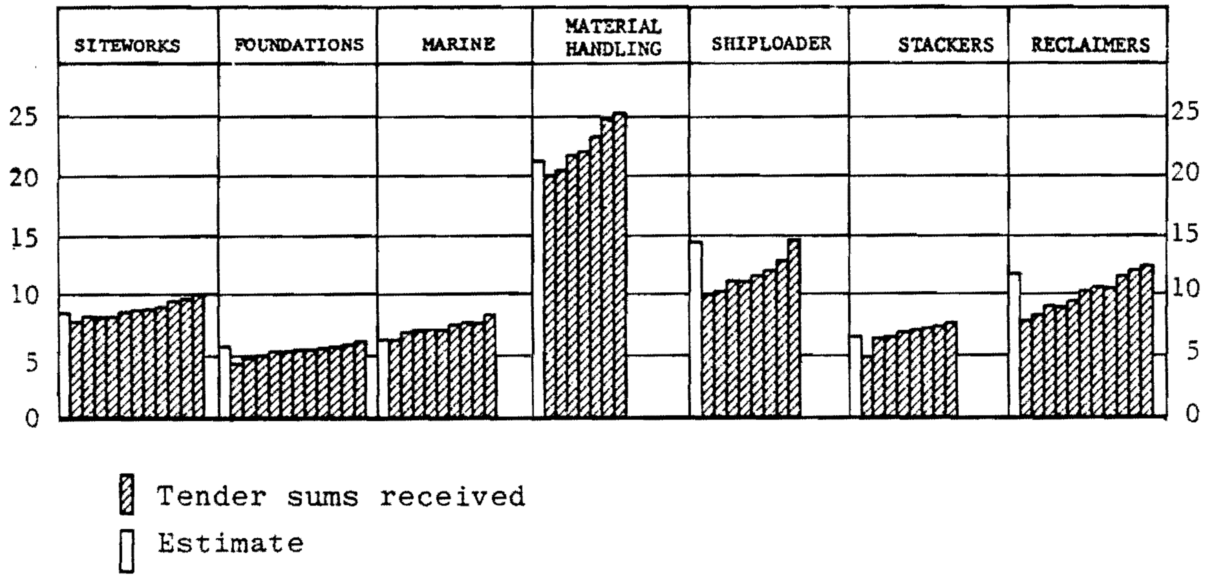
To estimate the cost of bulk terminals, one should proceed by refining initial comparative prices to decision prices, then to contract prices, and finally, to actual costs. Comparative prices are used to judge the relative desirability of alternatives and to evaluate the feasibility of a project at the initial stages. In later stages, one needs more accurate information to arrange for contracts, equipment purchases, and financing. Costs, other than the initial comparative costs, must be obtained by quotations and bids. Real world prices vary continuosly with business conditions, currency exchange rates, and work loads at particular factories. Most bulk port equipment must be custom-designed for specific situations, and that which is not, is available with many optional features. Factors, such as the power source (on board or external electrical supply) and a sophisticated control system easily can account for 30% of the variations in equipment cost.

The initial comparative costs have to be only accurate enough to guide designers. While a high degree of accuracy is in itself desirable, too great an emphasis on the accuracy of costs in the initial stages can force design decisions to be made that are better postponed to later stages of the design. Port development costs can be divided into site preparation and development costs, and equipment costs, although further division within these groups is possible. Figure VIII.1.1 shows a break down of the costs for the Port Kembla coal loader. The figure provides the initial cost estimate for the port, and the results of an analysis of bids for the project by construction companies. For this new port, about seventy percent of the cost is for equipment and equipment installation (excluding foundation construction which is accounted for separately).

The exact proportion of construction costs in each group varies among projects. Some port development projects re-use existing berths, channels, and other portions of existing ports, and others require complete turnkey development. Table VIII.1.1-VIII.1.3 analyze cost estimates from the engineering feasibility studies of three ports. The tables give the percentage of groups of major project costs and shows the wide divergence in the break down between equipment and sitework. Non-equipment related costs vary from a low of 12 percent to a high of 52 percent.

FIGURE VIII.1.1 PORT KEMBLA COAL LOADER ESTIMATES AND TENDER RESPONSES

(Figures in Millions of Australian Dollars)



Source: Planning, Layout and Design of Bulk Terminals, N. J. Ferguson, XXV International Navigation Conference. 10-16 May, 1981, Edinburgh, Scotland, U.K. Permanent International Association of Navigation Congresses.

Table VIII.1.1 Cost Breakdown--Port 1

Equipment	% Total
2-1000 ton/hour grab unloaders	22
2-3000 ton/hour belt conveyors	13
2-3000 ton/hour stackers	8
2-5000 ton/hour reclaimers	9
stack in between conveyor	17
reclaiming belt conveyor	19
Sitework	
dredging and quay construction	12
	100

Table VIII.1.2 Cost Breakdown--Port 2

Equipment	% Total
Shiploader	20
Stackers	9
Reclaimers	16
Conveyors	27
Sitework	
Sitework	11
Foundations	8
Marine	9
Subtotal sitework	100

Table VIII.1.3 Cost Breakdown--Port 3

Equipment	% Total
Coal unloader	16
Electricity	5
Conveyors & transfer towers	27
Sitework	
Pier construction	16
Conveyor foundations	9
Miscellaneous	
Land	4
Contingency	14
Coal pile	9
	100

Source: For Tables VIII.1 1-3
World Bank project files.

VIII.2 Civil Engineering Costs

Civil engineering costs include dredging, pier and foundation construction, land fill, road building and other construction activities. In the initial design phases of a project, one should estimate unit construction costs at the site(s) in question with each alternative port using the same costs. In estimating these costs, it is important to consider the cost of construction materials, such as rock and cement at the site, mobilization, and construction costs per unit of work done.

A good way to estimate dredging costs is to use dredging cost figures from similar, already-existing ports, but the cost of moving the dredging equipment to the port and differences in the cost of removing the spoils (the material removed by the dredge) must be considered on a case by case basis. The cost of removing the spoils usually cannot be estimated from previous dredging work, because the distances the spoils must be transported before they are dumped vary.

Bottom soils to be dredged can be grouped into four categories:

Type 1 - Loose soils, such as lagoon deposits and sand

Type 2 - Somewhat cemented soils, which can be dredged with a suction dredge, cutter dredge or bucket ladder dredge

Type 3 - Hard soils, that require a powerful cutter dredge

Type 4 - Very hard ground, which requires loosening, usually with explosives, before it can be dredged.

Most port projects involve some of each type of dredging.

A recent port project, financed by the World Bank established the following unit costs (in 1983) for dredging:

Type 1 - Loose soils	$1.67 per cubic meter
Type 2 - Somewhat cement soils	$5.00 per cubic meter
Type 3 - Hard soil	$11.97 per cubic meter
Type 4 - Very hard ground	not estimated

These costs illustrate only the order of magnitude of the dredging costs. Unit costs, for example, vary depending on the volume dredged (they fall as more is dredged). Thus, if the amounts vary significantly among port alternatives, it could result in different project costs. Site exploratory work is required before dependable estimates can be made.

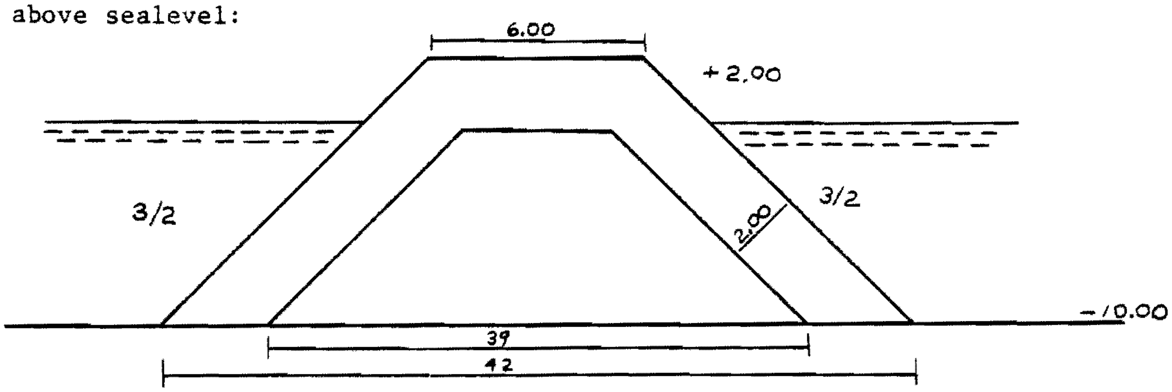
Land fill is, in a sense, the opposite of dredging. After the fill is deposited, another layer of fill, called a surcharge, is usually required to be put over the original fill to compact it. It may be several years before the surcharge can be removed and the land used. Frequently, the dredged spoils are not suitable for land fill, and filling material must be brought to the site. As a result, cost estimates for land fill are even more site-sensitive than dredging estimates. When earth fill is obtained dry, transported by truck and put into place with a bulldozer, a figure of $1.67 per cubic meter was used to estimate the cost in the project above. The cost to compact the fill, remove the surcharge, pave, and pay for utilities was assumed to be $25.00 per square meter.

The construction costs of breakwaters can be estimated from the costs of delivering and installing rock on the site. Breakwaters are usually constructed of an internal rubble fill with an exterior facing to protect the interior. Figure VIII.2.1 shows the cost estimate for such a breakwater.

FIGURE VIII.2.1 BREAKWATER COST ESTIMATION

- Quarry run 0 to 500 kg for breakwater	laid from land	7	$/m^3
- Quarry run 0 to 500 kg for breakwater	laid by sea	12	$/m^3
- Quarry run 50 to 1000 kg for breakwater	laid by sea	13	$/m^3
- Rock material 20 to 200 kg or 50 to 1000 kg	laid by sea	30	$/m^3
- Rock material 1 to 3 ton		25	$/m^3

For example, for a breakwater -10,00 m deep rising to + 2.00 above sealevel:



Quarry run core cost per meter:

$$\$13 \times \frac{(6{,}00 + 39)}{2} \times 11 = 247.50\ m^3 \times 13 = \$\ 3{,}217$$

Facing of natural blocks cost per meter:

Total volume

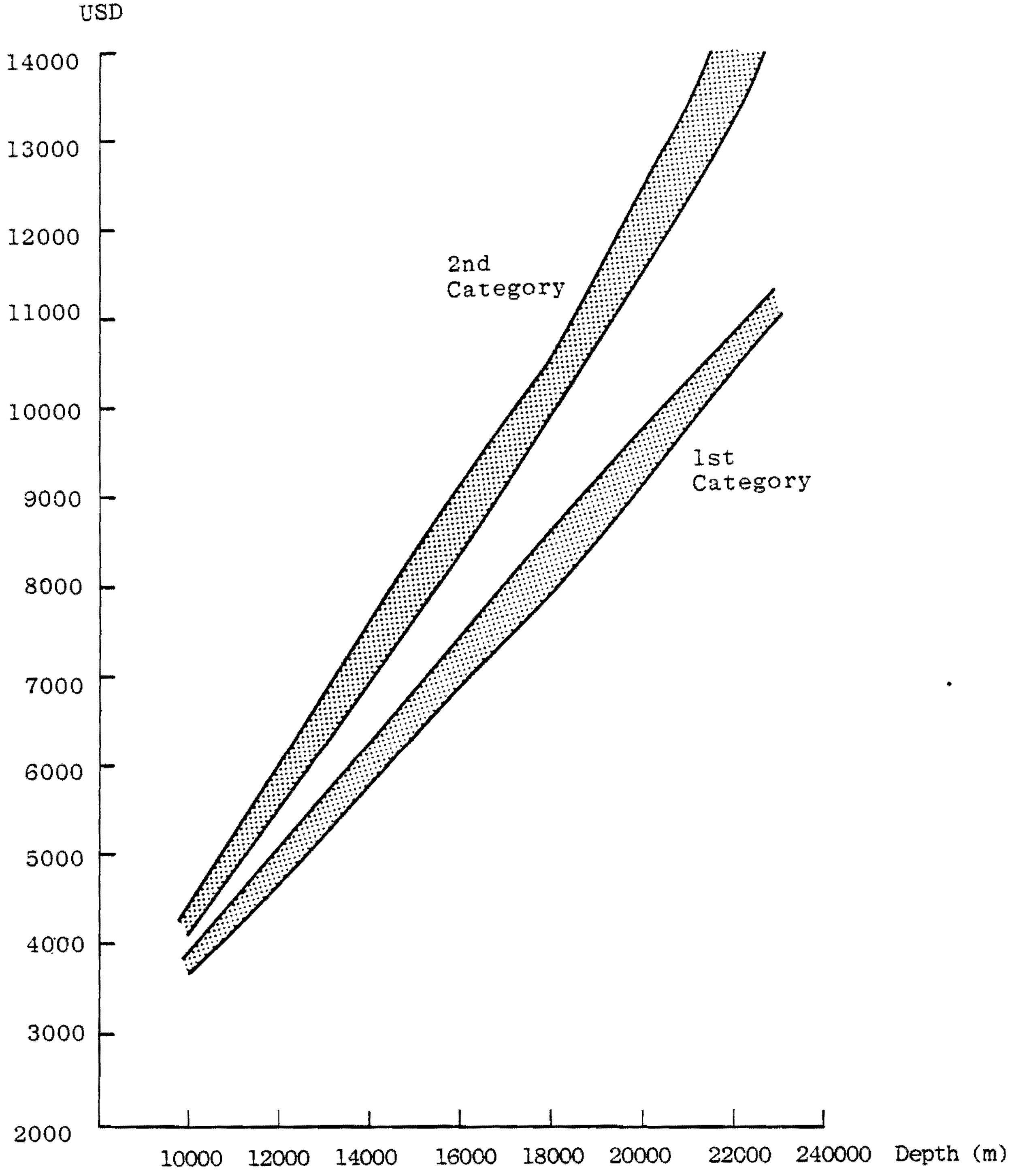
$$\frac{(6 + 42)}{2} \times 12 - 247.5 = 288.00 - 247.5 = 40.5\ m^3$$

Cost per meter = 40.5 x \$25 = \$1,012

giving an average price per m^3 of : \$14.7/m^3 approx.

FIGURE VIII.2.2 QUAY COSTS PER LINEAR METER

(1983 USD)



Source: World Bank staff.

The cost of both breakwaters and quays are highly dependent on the type of support provided by the bottom. In some cases, the bottom is too hard, which requires special provisions to anchor the breakwater or quay to the hard bottom.

Pavement construction costs for container yards vary with type of construction. Table VIII.2.1 shows costs per square meter for asphalt and gravel construction in various countries.

For a recent project financed by the World Bank, cost data has been obtained for bulk terminal construction. Table VIII.2.2 shows civil engineering costs for this project.

Table VIII.2.1 Unit Construction Costs for Pavement

(1982 USD)

Country	USD/m^2 of 10 cm asphalt, with 20 cm base and 15 cm sub-base	USD/m^2 of 40 cm gravel bed
Cyprus	11	3.5
Greece	9	3.0
Malaysia	11.5	4
U. K.	20	8.2
Indonesia	17.3	7.7
Oman	17	8.4
Netherlands	18.3	9.8
Saudi Arabia	17	8.2
U.A.E.	16.5	9

Source: World Bank staff.

Table VIII.2.2 Bulk Terminal Civil Works Costs
(USD 1983)

	Depth Alongside	Width	USD/m
Bulk Berth (Piled) for heavy shiploaders/unloaders including rails, etc.	10m	12m	28,719
	12m	14m	32,724
	14m	16m	40,920
Approach Causeway (Piled) for conveyors, roadway, etc.	12m	6m	10,370
	12m	8m	11,200
	10m	6m	8,700
	10m	8m	9,400
	8m	6m	7,667
	8m	8m	8,280

Source: World Bank project files.

Table VIII.2.3 Bulk Terminal Storage Construction Costs
(USD 1983)

	Size	Unit Cost
Storage shed (top conveyor feed) with load capacity 2-4 ton/m^2	100,000 m^2	\$150/m^2
Paving for open storage	-	\$ 10.8/m^2
Silo (High rise)	100,000 m^3	\$180/m^3

Source: World Bank project files.

VIII.3 Equipment Costs

A number of manufacturers were surveyed to develop price ranges on bulk handling equipment. Figures VIII.3.1 to VIII.3.5 graph the responses. Prices do not include shipping costs. Prices, not displayed as a range, are for equipment built to an "economical" standard. We note that these price ranges are based on budgetary estimates.

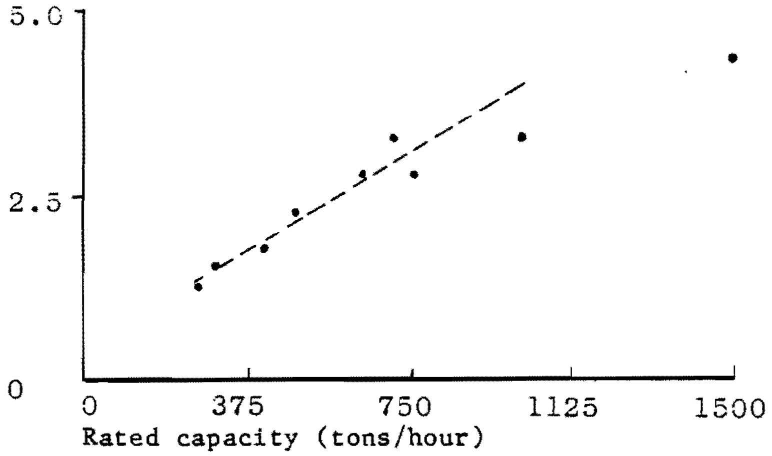
For the World Bank project mentioned in the last section, the equipment costs are summarized in Table VIII.3.1. A compilation of some additional bulk handling equipment data is provided in Table VIII.3.2. This is a sampling of data being gathered as part of an ongoing effort to create a database of port project costs.

Table VIII.3.1 Bulk Terminal Equipment Costs
(1983 USD)

		Capacity	Cost
Ship unloaders	25 t. grab	500 tph	$4.92 million
	50 t. grab	800 tph	$7.15 million
	Continuous	800 tph	$4.39 million
Conveyors including support Frames, Drives, Etc.		300 tph	$780/m
		500 tph	$960/m
		800 tph	$1200/m
		1000 tph	$1420/m
Scraping/reclaimers			$1 million each
Bagging machines			$100,000 each
Bag stacker/reclaimer			$700,000 each
Bag loaders/unloaders			$108,000 each

Source: World Bank project files.

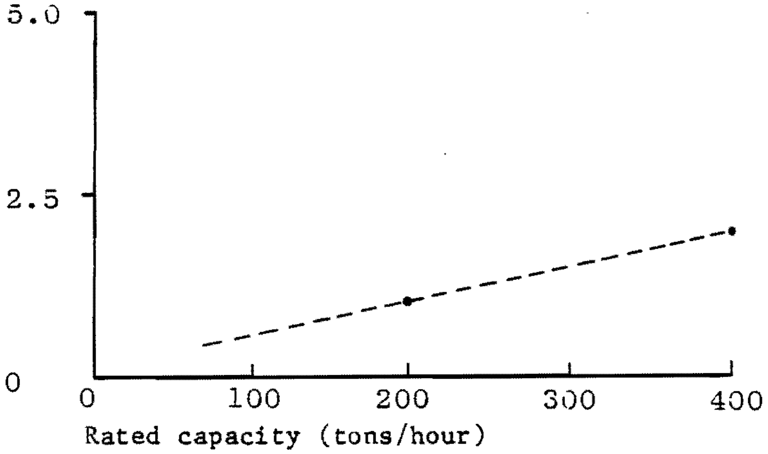
FIGURE VIII.3.1 SHIP UNLOADER COSTS (1983)



Note: Costs are in millions of US dollars per unloader converted from quotation in yen at rate of 239 per $

Source: Mitsubishi Heavy Industries

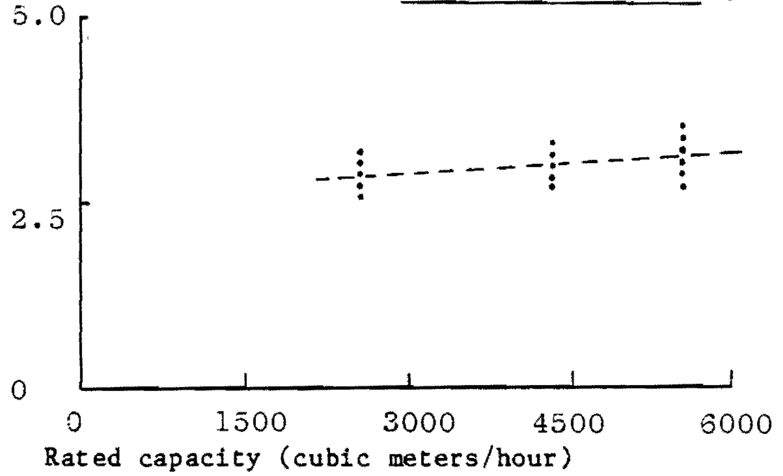
FIGURE VIII.3.2 COST OF RAIL MOUNTED PNEUMATIC GRAIN UNLOADERS (1983)



Note: Costs are in millions of US dollars per unit converted from a quotation in yen at rate of 239 per $

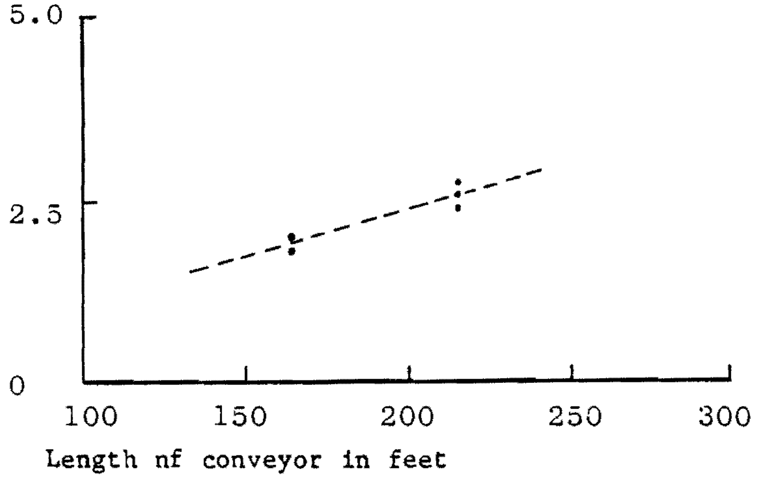
Source: Mitsubishi Heavy Industries

FIGURE VIII.3.3 PRICE OF CRAWLER MOUNTED BUCKET WHEEL EXCAVATORS (1983)



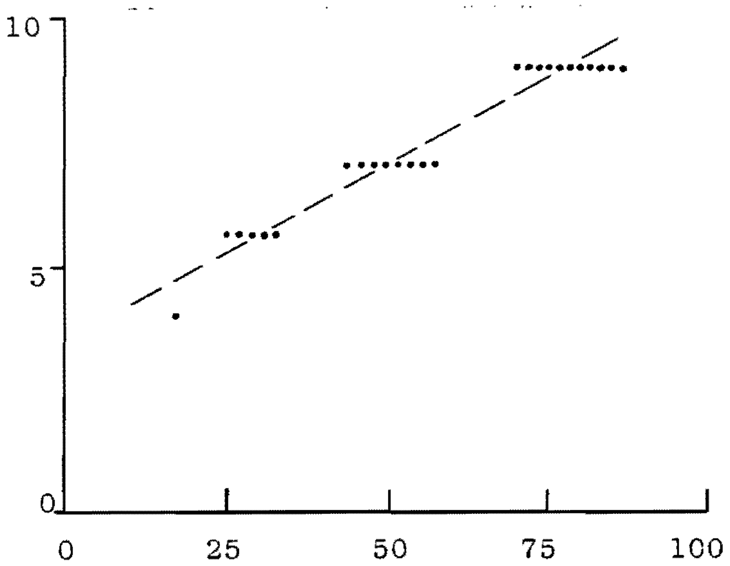
Note: Quotation in millions of US dollars per unit
Source: American Hoist and Derrick-Mechanical Excavators Division

FIGURE VIII.3.4 COST OF CRAWLER MOUNTED CONVEYORS (1983)



Note: Cost in millions of dollars per unit
Source: American Chain and Hoist-Mechanical Excavators Division

FIGURE VIII.3.5 BELT CONVEYOR PRICES (1983)



Width conveyor in inches

Note: Cost in thousands of US dollars per foot including gallery and installation-excluding land costs

Source: Louis Berger Inc.

Table VIII.3.2 Selected Bulk Equipment Project Cost Data

Description	Capacity	Unit	Cost(USD)	Year
Ship Unloaders	600 tph	each	1.6 million	1979
"	540 tph	each	2.0 million	1981
"	1000 tph	each	2.24 million	1979
"	1800 tph	each	3.47 million	1979
Ship Loaders	500 tph	each	0.54 million	1981
"	1000 tph	each	0.90 million	1981
Conveyors	300 tph	metre	816	1979
"	600 tph	"	1,122	1979
"	600 tph	"	2,000	1981
"	1000 tph	"	1,530	1979
"	1200 tph	"	1,735	1979
"	1500 tph	"	2,040	1979
"	1200 tph	"	2,200	1981
"	1500 tph	"	2,500	1981
"	1800 tph	"	2,347	1979
"	2000 tph	"	2,551	1979
Stackers	600 tph	each	0.61 million	1979
"	1000 tph	each	0.73 million	1979
"	1800 tph	each	0.97 million	1979
Reclaimers	600 tph	each	1.22 million	1979
"	1000 tph	each	1.53 million	1979
"	1800 tph	each	2.14 million	1979
Stacker/Reclaimer (Rec. Cap)	1000 tph	each	1.8 million	1981
Tripper Cars	-	each	0.13 million	1979
Wagon Loading Station	-	each	0.35 million	1979
Truck Loading Station	-	each	0.30 million	1979
Major Surge Bin	-	each	0.31 million	1979
Minor Surge Bin	-	each	0.09 million	1979
Transfer Cars	-	each	0.27 million	1979
Rail Weigh Bridge	-	each	0.055 million	1982
Road Weigh Bridge	-	each	0.055 million	1981
Electronic Scales	-	each	0.011 million	1981

Source: World Bank Project Files

VIII.4 Bid Invitation and Evaluation

This section provides some general guidelines for procurement of port equipment. Some common conditions and evaluation factors are highlighted and can serve as a check-list in organizing procurement activities.

The following factors must be covered by the purchasing department in evaluating bids:

1. Comparison of net price
2. Comparison of payment terms
3. Comparison of transportation charges
4. Existence of escalation terms and the probable impact of final cost
5. Charges for optional items including:
   - spares requirements
   - service and erection engineers fees
   - prices of additional work options
6. Availability of spares with respect to:
   - extent to which locally available
   - factory stocking policy of manufacturer
   - need to order for factory production and lead time
7. Comparison of rights to manufacturing drawings and ability to purchase locally
8. Equipment delivery and erection schedules
9. Manufacturer's shop loading and capacity available for this project
10. Extent of warranties and engineering responsibility
    - scope of coverage
    - manufacturers liability in event of failures or performance inadequacies
11. Financial responsibility of bidders.

At times evaluation procedures may eliminate a manufacturer who is normally competitive, reputable and qualified. The purchasing department should review the specifications for lack of clarity or ambiguity when such a manufacturer fails to make the competitive range.

Invitations for bids on material handling equipment should comprise three sections broken down as follows:

1. General Project Description:
    a. Outline of the material handling requirements;
    b. Location with applicable environmental condition and site limitation;
    c. Arrangement drawings;
    d. Statement defining responsibilities of supplier for engineering, schedule, and financial aspects.
2. Equipment Specifications:
    a. performance or insistence on specific types or features;
    b. minimum acceptable design conditions;
    c. component performance;
    d. requirement to provide drawings and technical descriptions;
    e. equipment evaluation criteria.
3. Commercial Specifications:
    a. procedure and timing for proposed submission;
    b. requirements to be satisfied before contract award and procedure for award;
    c. estimate of project implementation schedule;
    d. special requirements.

The purchase contract must cover the following provisions.

1. Engineering Provisions
    - a. requirements for successful handling of material and interface with other systems;
    - b. limits of engineering responsibility of supplier;
    - c. list of drawings to be provided;
    - d. requirements for engineering coordination;
    - e. safety features to be provided;
    - f. installation and testing responsibility
        - obtaining permits and certification;
        - site preparation, excavation and laying of foundations;
        - provision for storage and safekeeping of delivered equipment;
        - temporary power and wiring provisions;
        - procedures for examination, testing and acceptance;
        - requirements for clean-up and operational start-up;
    - g. responsibility to train operators and provide training materials.

2. Equipment Provisions
    - a. detailed specifications of material handling equipment and accessories;
    - b. references to control drawings;
    - c. listing of buyer furnished equipment and their specifications;
    - d. specifications of painting, protective coatings, and corrosion control equipment;
    - e. provisions for acceptance of substitute equipment and materials.

3. Commercial & Legal Provisions

   a. Identification of supplier and buyer, and individual points of contact for technical and contractual matters;

   b. summary of work description and location of work identifying all applicable specifications;

   c. delivery and erection schedules;

   d. applicable penalties for delays and failure to complete;

   e. provision if supplier is delayed by buyer;

   f. price and payment schedule including withholding and final payment;

   g. assessment of transportation charges;

   h. insurance requirements;

   i. responsibility for person and property;

   j. procedures for negotiating work deletions, additions or change orders;

   k. provision for buyer approval of sub-contracts;

   l. inspection of work in progress by buyer and correction of deficiencies;

   m. responsibility for work in progress and associated equipment;

   n. procedure for buyer's acceptance of work and transfer of ownership;

   o. liability for taxes including payroll, sales, excise and other taxes;

   p. provision for payment of Workmen's Compensation, social security, unemployment contribution, and employee insurance;

   q. responsibility for permits, licenses, certificates, and payments for same;

   r. definition of warranty terms, including provisions for correcting inadequacies;

   s. responsibility for use of patents and copyrights;

   t. buyer's use of supplier drawings and rights to data;

Organizing for a project requires careful delineation of functions between the various groups involved. The breakdown of activities among the groups are as follows:

1. Buyer's Engineering Department Functions:
    a. complete definition of material handling problem (could include preliminary arrangement drawings);
    b. develop detailed specifications;
    c. evaluate bids for technical parameters;
    d. coordinate engineering activities;
    e. supervise installation and fine tuning of equipment;
    f. implement training programs for operating and maintenance personnel.
2. Buyer's Purchasing Department Functions:
    a. handle all commercial aspects;
    b. send inquiries and receive proposals;
    c. make commercial evaluations of bids integrating technical evaluations made by engineering;
    d. select supplier and award contract;
    e. monitor progress and take expediting actions.
3. Equipment Manufacturer Functions:
    a. prepare and submit bid, coordinating with buyer's technical group to ensure responsiveness;
    b. refine preliminary engineering - review and correct as necessary
    c. design equipment and accessories for fabrication;
    d. coordinate engineering with other engineering contractors;
    e. purchase necessary equipment;
    f. schedule fabrication and shipment;
    g. fabricate, install and turn over equipment;

   - h. train operators and provide operating manuals;
   - i. stock spares inventory;

4. Consulting Engineer Functions:
   - a. provide expert personnel on temporary basis;
   - b. engineering services;
   - c. procurement services;
   - d. installation and training services.

Quality and performance of material handling equipment will depend on a number of factors. Even very tightly written specifications can be variously interpreted by vendors. Consequently, bids on identical specifications can vary a good deal. Evaluation of bids on first cost alone is usually not desirable; equally important are the life cycle costs which will be incurred. The life cycle costs will depend on inherent design features as well as the application in which the equipment is used.

APPENDIX A. REGIONAL DEVELOPMENT ANALYSIS

As mentioned in Chapter V.6, it is in the national interest to balance regional development by increasing the income of depressed regions. Development of a new port in a region will generate a new source of income for the region and can thus contribute to the objective of balancing regional development.

Therefore, it should be emphasized that, when deciding on a port site, planners should consider a broader aspect of balancing regional development. This can be achieved by undertaking such regional development analysis as the one described below while trying to minimize the necessary total investment costs.

Parameters Used in the Analysis

R_n = Regions (1 to n).

a_{ij} = the marginal average propensity of region i to spend its income in region j.

(Note that $\sum_{j=1}^{n} a_{ij} = 1$).

$$A = \text{Exchange Matrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Y_i = Total income of Region i

$= \sum_{j=1}^{n} a_{ij} Y_j$ = Sum of income of region i spent in i and incomes of other regions spent in i.

Y = Equilibrium income vector of regions which satisfies the equation $A'Y = Y$.

Methodology

The following simple example based on a Markov chain analysis with three regions will illustrate the method of computing the equilibrium incomes of regions relative to others.

Assume that we have the exchange matrix of

$$A = \begin{bmatrix} 0.5 & 0.2 & 0.3 \\ 0 & 0.6 & 0.4 \\ 0.2 & 0 & 0.8 \end{bmatrix}$$

The above system of homogeneous linear equations can be solved by writing it into A'Y = Y formulation as below:

$$\begin{aligned} 0.5Y_1 \phantom{{}+0.6Y_2} &+ 0.2Y_3 = Y_1 \\ 0.2Y_1 + 0.6Y_2 \phantom{{}+0.8Y_3} &= Y_2 \\ 0.3Y_1 + 0.4Y_2 &+ 0.8Y_3 = Y_3 \end{aligned}$$

and we get the equilibrium income vector of

$$Y = (Y_1 , 0.5Y_1 , 2.5Y_1)$$

in terms of Y_1.

Interpretation

The resulting equilibrium income vector shows that, with given propensities to spend and using the income of region 1 as the basis, the equilibrium income of region 2 is half of the income of region 1 and the income of region 3 is 2.5 times the income of region 1.

From the equilibrium income vector, one can see that region 2 is the most depressed region in terms of the total income and, to increase the absolute amount of its income, the incomes of region 1 and 3 should be increased by an even greater amount to maintain the equilibrium conditions.

The equilibrium growth can take place in this model as long as the growth rate is the same for each region, but this will increase the relative income difference among regions further.

Dynamic Regional Growth

In order to increase the income of a depressed region, it is necessary to inject one period or continuous income into the region and the development of a port in a region can provide a continuous source of increased income for the region.

The following analysis, based on a Markov chain solution method, will indicate the effect of this new investment on the total equilibrium income of the region and on that of others.

By introducing index t to represent different time periods the following results:

$V_{ij}(t)$ = element of the row i in the exchange matrix in time period t

which satisfies the condition of

$$\sum_{j=1}^{n} V_{ij}(t) = 1$$

and,

$$V_{ij}(t + 1) = \sum_{j=1}^{n} V_{ij}(t)a_{ij}$$

Then, the equilibrium income vector becomes

$$\begin{aligned} Y(1) &= Y(0)A \\ Y(2) &= Y(1)A = Y(0)A^2 \\ Y(3) &= Y(2)A = Y(0)A^3 \\ &\vdots \end{aligned}$$

which are generalized into

$$Y(t) = Y(t-1)A = Y(0)A^t.$$

As an example, consider a simple two regions case with the following exchange matrix

$$A = \left\{ \begin{matrix} p, & 1-p \\ q, & 1-q \end{matrix} \right\},$$

and by performing Markov's chain analysis, the equilibrium income vector becomes.

$$Y = \left\{ Y_1 , \frac{(1-p)}{q} Y_1 \right\}$$

If a capital investment, such as the development of a port, is put into a region so that its income increases by an amount equal to x in period 1 and all following periods, the region's relative income will be increased. Following are the resulting equilibrium income vectors for each time period.

$$Y(0) = [Y_1 , \frac{(1-p)}{q} Y_1]$$
$$Y(1) = [(Y_1 + x), \frac{(1 - p)}{q} Y_1]$$
$$Y(2) = [(Y_1 + x (1 + p)), \frac{((1 - p)}{q} (Y_1 + x))]$$
$$\vdots$$

Summary

The method of analysis presented so far assumes that the propensities to spend remain constant throughout the periods. From the static analysis of the equilibrium income for regions, one can determine the most relatively depressed region. From the dynamic growth analysis, the effect of continuous additional income on the equilibrium income distribution among regions in each time period resulting from capital investment to a depressed area, can also be determined.

Methodology summarized from:
Smith, Paul E., "Markov Chains, Exchange Matrices, and Regional Development," in Regional Analysis and Development (Chapter 9), edited by John Blunden and others, The Open University Press, Harper & Row, Publishers, New York, 1973.

APPENDIX B. TECHNIQUES FOR PORT DEVELOPMENT ANALYSIS

In this appendix a number of computer-based optimization techniques are briefly described. Then, simple linear programming models are developed which will support the decision-making process of choosing a port site from available alternatives (see Chapter V) and the desired inland transportation modes from the site to the demand centers.

B.1 Description of Available Optimization Techniques

Linear programming and dynamic programming methods, which are two of the most widely used computer-based optimization techniques, are described below along with the simulation method, which does not produce optimum solutions, but compares alternative solutions.

In applying the above mathematical methods to real world problems, such as port logistics problems, the users should bear in mind that these methods are to be used only as guidelines to support human judgement in their decision-making process.

Linear Programming (LP)

Linear Programming is a powerful optimization method developed which can be applied to a wide variety of problems. By optimally allocating constrained resources among activities, it maximizes profit or minimizes the cost. Although the objective function is restricted to being linear, non-linear functions can be linearized through piecewise linear approximation.

Due to the development of an efficient simplex algorithm and the availability of high-speed digital computers, LP problems can be solved quickly and inexpensively when compared to other methods.

Another major advantage of LP is the ability to perform sensitivity analysis. It gives ranges on the objective function coefficients and in the righthand side values of constraints for which the optimum solution remains unchanged.

It also calculates shadow price (or opportunity cost) of a constraint which is defined as the amount of change in the optimal objective function value per one unit increase in the righthand side value of that constraint, given all others remain constant. This is valuable information since, by pricing out an activity with shadow prices, one can tell whether the activity is worth undertaking.

Dynamic Programming (DP)

Dynamic Programming is an optimization technique that simplifies a complex problem into a series of multi-stage, more easily analyzable problems. The stages are treated as independent of each other.

For each stage optimal value for different states is calculated using a recursive relationship that is applicable to every stage. Subsequently when the optimal solution is found at the final stage, one can track back to the beginning for the states of each stage that constitute the optimal solution.

Simulation

When a given problem for which mathematical programming models cannot be formulated, such as LP or DP, the simulation approach is resorted to. The difference is that simulation models do not generate alternatives or produce an optimum answer to the problem under study. Rather, it merely evaluates alternatives developed by the decision-maker.

Simulation computer programs are usually a series of logical arithmetic operations which are arranged and executed in a sequence closely resembling the actual operation of the system. Thus, it usually requires extra time and effort to develop simulation models and it may be more difficult to track back to the source of the error.

The formulation of simulation models is very flexible and it can be made as realistic as needed by incorporating conditions which can be expressed in logical arithmetic expressions.

One disadvantage of simulation is that decision-makers are required to provide flexible alternatives to be evaluated by the model. The decision-makers should also have a good understanding of the optimal solution for the problem under study in order to judge the accuracy of the model.

B.2 Analysis for the Optimum Choice of the Inland Transportation Model

In the general methodology for bulk terminal logistics described in Chapter V.2, the information on the total inland transportation costs from each prospective port site to demand centers are required in order to choose a minimum cost port site.

A method of determining the minimum cost inland transportation mode from each port site using a Linear Programming (LP) model is illustrated by the following simple example. More detailed LP description is presented in Appendix B.3.

Example

Assume that there exist the following prospective port sites of A, B and C and demand centers of 1,2 and 3 in a region and that they are located as in Figure B-1.

Assume also that the available alternate inland transportation modes are road, rail and barges with transportation cost per ton as in Figure B-2.

Figure B-1 Alternate Port Sites and Demand Centers

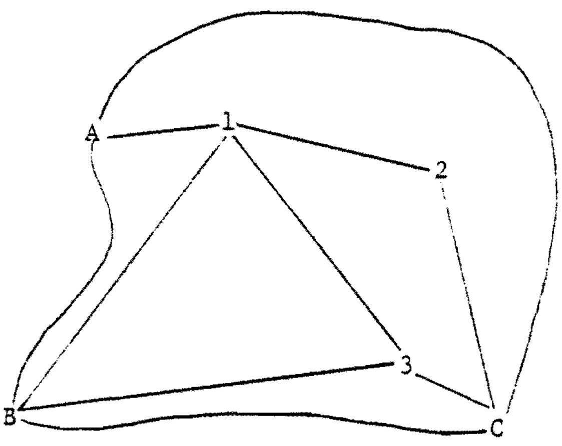


Figure B-2 Inland Transportation Costs/ton for Commodity 1

Demand Centers

		1	2	3	= j
	A		C_{jkl}		road) rail)=k barges)
Ports	B				road rail barges
	C				road rail barges

Objective: The objective is to determine the minimum cost transportation mode from each prospective port site to demand centers.

Methodology: The optimal way to solve the above transportation problem is to set up a simple LP model that minimizes total inland transportation cost subject to constraints on the capacities of each transportation mode for each link, and the demand sufficiency condition for each demand center.

LP Formulation: By utilizing cost and capacity information, LP model is formulated for each prospective port site of A, B and C.

Minimize $\sum_{j}\sum_{k}\sum_{l} C_{jkl}X_{jkl}$

Subject to (1) $\sum_{k} X_{jkl} = d_{jl}$ for all j and l

(2) $\sum_{jk} X_{jkl} \leq CAP_l$ for all l

all $X_{jkl} \geq 0$

Where subscripts j refers to demand centers,

k refers to transportation modes, and

l refers to commodities,

and

C_{jkl} = transportation cost from a site to demand center j through inland transportation mode k for commodity l.

X_{jkl} = amount of bulk flow from and to demand center j through mode k for commodity l.

d_{jl} = amount of bulk handling (inflow and outflow) required at j for commodity l.

CAP_l = capacity of a port for handling commodity l.

The constraint (1) states that bulk handling requirement at demand center has to be satisfied for all commodities and the constraint (2) states that the total amount of bulk flow from/to a port for commodity 1 cannot exceed the port's handling capacity for that commodity. If $x_{jkl} = 0$, it means that the mode k is not used in transporting commodity 1 from a terminal site to j.

This LP model determines the minimum total inland transportation cost from each port site and the resulting choice of inland transportation mode for each transportation link. This model assumes that the transportation costs are linear and different for each commodity. In addition to the total inland transportation cost, initial investment costs for port and inland transportation facilities have to be considered in making the final choice of the port site and the inland transportation mode from it.

B.3 Detailed LP Formulation for Bulk Terminal Logistics

In Appendix B.2 a simple LP model was developed to determine the minimum cost inland transportation mode. This is a simple LP formulation because it only considers demand and capacity constraints. In this Appendix the usefulness and power of the LP method is illustrated by presenting a more detailed formulation for solving bulk port logistics problems using the same example as in Appendix B.2.

Define the subscripts and variables as follows:

Subscripts i = prospective port sites

j = demand centers or regions

k = modes of inland transportation. (Depending on the quality of a mode, they can be subdivided further - e.g. gravel road, paved road, highway)

l = commodities

t = time period

Variables

$COST_{ijklt}$ and VOL_{ijklt} = Inland transportation cost per unit volume and amount of volume transported respectively, from port i to demand center j through transportation mode k for commodity l in time period t.

$PEXCAP_{i,l,t}$ and $PNEWCAP_{i,l,t}$ = existing and new additional handling capacity, respectively, in port i for commodity l during time period t.

$DEMAND_{j,l,t}$ = required bulk handling (from/to) in a demand center j for commodity l during time period t.

$BUDGET_t$ = available financial resource for port expansion during time period t.

$INVCOST_{i,l,t}$ = investment cost per unit capacity increase in port i for commodity l during time period t.

$ICAP_{i,j,k,t}$ = inland transportation capacity of mode k from port i to demand center j during time period t.

The LP formulation is as follows:

Objective Function

$$\text{Minimize} \quad \sum_{i}\sum_{j}\sum_{k}\sum_{l}\sum_{t} (\text{COST}_{ijklt} \times \text{VOL}_{ijklt})$$

This objective function minimizes the total inland transportation costs.

Constraints

(1) Demand Constraints

$$\sum_{i}\sum_{k} \text{VOL}_{ijklt} = \text{DEMAND}_{j,l,t} \text{ for all } j,l,t$$

These constraints assure that the total amount of bulk volume transported from all ports (i) to demand center j through all transportation modes (k) for commodity l during time period t should be equal to $\text{DEMAND}_{j,l,t}$.

(2) Port Capacity Sufficiency Conditions

$$\sum_j \sum_k VOL_{ijklt} \leq PNEWCAP_{i,l,t} + PEXCAP_{i,l,t}$$

for all i,l,t

These constraints prevent the total amount of bulk volume transported from exceeding the available (existing plus new) capacity for handling commodity l in port i during time period t. Here, we assumed that new capacity become available instantly.

(3) Updating the Port Capacity

$$PEXCAP_{i,l,t} + PNEWCAP_{i,l,t} = PEXCAP_{i,l,t+1}$$

for all i,l,t

Existing port capacity during time period t+l for handling commodity l in port i is updated by adding new capacity, which is to be determined by the LP model, to the existing capacity in time period t.

(4) Budget Constraint for Port Capacity Expansion

$$\sum_{i} \sum_{l} (\mathrm{PNEWCAP}_{i,l,t} \times \mathrm{INVCOST}_{i,l,t}) \leq \mathrm{BUDGET}_{t}$$

for all t.

These constraints prevent the total investment for expanding bulk material handling capacity of all commodities (l) in all ports (i) from exceeding the available financial resource during time period t.

(5) Inland Transportation Capacity Sufficiency Conditions

$$\sum_{l} \mathrm{VOL}_{ijklt} \leq \mathrm{ICAP}_{i,j,k,t} \qquad \text{for all } i\ j\ k\ t$$

These constraints prevent the total amount of bulk volume transported from port i to demand center j through mode k during time period t from exceeding the available transportation capacity of mode k from port i to demand center j during time period t.

The inland transportation capacities can be updated, and the required investment costs for inland transportation capacity expansion are added to the left hand side of constraint (4).

Output

The output of this LP formulation is somewhat different from the output of the general methodology for bulk terminal logistics presented in Chapter V.2. The general methodology selects one port site among several alternatives and the minimum cost inland transportation mode from that port site.

The LP model formulated in Appendix B-3 does not just select one port site, but may select a number of port sites, which may already exist or which should be newly developed. This is done in order to achieve the minimum total port investment and inland distribution costs.

This model can also determine the timing and the amount of port and inland transportation capacity expansions subject to budget constraints.

More importantly, by incorporating the time period into the model it is possible to evaluate the proposal for its entire project life and the availability of efficient LP packages in most computers is a great advantage for other similar applications.

Shortfall

One shortfall of this LP formulation is in constraint (2). This constraint assumes that new capacity can be added whenever the required bulk handling demand exceeds the available handling capacity in the ports. But, as pointed out in Step 4 of the methodology for bulk terminal logistics in Chapter V.2, this may not be the optimal port capacity expansion strategy. Due to inflation, fixed cost involved in starting port expansion project and economies of scale, it may be better to expand the capacity so that it can satisfy the bulk handling demand for several years into the future rather than expanding the capacity every one or two years.

A dynamic programming approach can solve this expansion problem most efficiently. It essentially considers all the available expansion strategies and selects the one which results in the minimum total investment cost over the project life. The optimum expansion strategy obtained from a dynamic programming model specifies when and by what amount the port capacity should be expanded subject to demand requirement and budget constraints.

APPENDIX C. QUEUEING THEORY

This appendix is intended to provide a summary of the more common queueing theory models. The cases selected are sufficient renderings of ballpark estimates of the utilization and waiting times experienced for most queues commonly encountered in facility design.

By using this information a rough evaluation of a system is possible with a few minutes' work. It is not intended as an exposition of the mathematics behind the queueing process, but merely as a presentation of summary formulae actually used. Readers wishing to learn more about the subject should consult a book such as, Elements of Queueing Theory, by T.L. Saaty.

Four classes of queues are considered:

1. Single channel-exponential interarrival time and exponential service rate.

   Here there is a single waiting line for a single service facility. The time between arrivals in the queue and the time required to service them are both assumed to be exponentially distributed. The exponential distribution assumes that any service time is possible, both very long and very short (although very long times are unlikely as the probability of a service which requires a great time falls rapidly as the time increases). For the exponential distribution the mean is equal to the variance.

2. Single channel-exponential arrival arbitrary service.

   This queue is similar to the simple queue above except that any service time distribution can be used. This includes a fixed service time. The parameter varied to model the arbitrary service time affects standard deviation. When this is zero a constant service time results, when one, an exponentially distributed time, etc.

3. Limited queue length.

   This is a single channel queue similar to the first, where waiting line can only accommodate a maximum number of units. When the queue is full, additional arrivals are lost and never pass through the system. An example of this would be the departure of patrons at a cinema when a very long line is present. In many situations the results from a queue of limited length approach that of unlimited for a small maximum queue length.

4. Limited number of customers for a single queue

   This system can be used to model systems for machinery repair. Here a few machines break down randomly and are repaired by a single repairman. Other interesting applications are possible.

5. Multiple servers serving a single queue

   Here one line feeds a number of services as is common at highway toll booths and other situations.

6. Single server-Erlang arrivals Poisson service

   This is similar to case 2 except the distribution of inter-arrival times is the parameter rather than the service time. The Erlang distribution has two parameters, the mean and "K "; when K is one, the Erlang distribution is identical to the exponential. As "K" increases the variability in the inter-arrival time is reduced. For large values of "K," the time between arrivals is nearly constant. Table C.1 gives the procedure to calculate "K".

The meaning of symbols used in the table is given below:

L_s = Mean number of units in the system including those being served

L_q = Mean length of the queue. This is the mean number in the system L_s minus the mean number being served

P(0) = Probability there are no units in the system (counting those being served)

N = Number of units in the system (counting those being served)

P(N) = Probability there are N units in the system (counting those being served)

λ = mean interarrival rate

μ = mean service time

σ = standard deviation, in case 2 that of the arbitrary service time

M = maximum length of queue, case 3 or maximum number of customers, case 4

S = number of servers in a multi-channel queue

K = coefficient of Erlang distribution

$$K = \frac{\text{mean}^2}{\text{variance}}$$

TABLE C.1 - QUEUEING FORMULAE

	Mean Number in System L_s	Mean Number in Queue L_q	Probability All Busy	Mean Waiting Time	Mean Time in System	Probability None in System P(0)	Probability N in System P(N)
Single Channel Exponential Arrivals Poisson Service	$\frac{\lambda}{\mu-\lambda}$	$\frac{\lambda^2}{(\mu-\lambda)}$	$\frac{\lambda}{\mu}$	$\frac{\lambda}{\mu(\mu-\lambda}$	$\frac{1}{\mu-\lambda}$	$1-\frac{\lambda}{\mu}$	$(\frac{\lambda}{\mu})^N(1-\frac{\lambda}{\mu})$
Single Channel Exponential Arrival Arbitrary Service	$\frac{\lambda}{\mu}\ \frac{\lambda\sigma^2+(\frac{\lambda}{\mu})^2}{2(1-\frac{\lambda}{\mu})}$	$L_s-\frac{\lambda}{\mu}$	$\frac{\lambda}{\mu}$	$\frac{L_q}{\lambda}$	$\frac{L_s}{\lambda}$	$1-\frac{\lambda}{\mu}$	$(\frac{\lambda}{\mu})^N(1-\frac{\lambda}{\mu})$
Limited Queue of Length M $\lambda < \mu$	$\frac{\lambda}{\mu}\ \frac{\lambda\sigma^2+(\frac{\lambda}{\mu})^2}{2(1-\frac{\lambda}{\mu})}$	$L_s-(1-P(0))$	$(1-P(0))$	$\frac{L_q}{\lambda(1-P_M)}$	$\frac{L_s}{\lambda(1-P_M)}$	$\frac{1-\frac{\lambda}{\mu}}{1-(\frac{\lambda}{\mu})^{M+1}}$	$(\frac{\lambda}{\mu})\cdot\frac{1-\frac{\lambda}{\mu}}{1-(\frac{\lambda}{\mu})^{M+1}}$
$\lambda > \mu$	$\frac{M}{2}$	$L_s-(1-P(0))$		$\frac{L_q}{\lambda(1-P_M)}$	$\frac{L_s}{\lambda(1-P_M)}$	$\frac{1}{M+1}$	$\frac{1}{M+1}$
Limited Number of Customers M = # Customers	$M-(\frac{\mu}{\lambda})(1-P(0))$	$M-\frac{\lambda+\mu}{\lambda}(1-P(0))$	$1-P(0)$	$\frac{L_s}{\lambda(M-L_s)}$	$\frac{L_s}{\lambda(M-L_s)}$	$\frac{1}{\sum_{n=0}^{M}\{\frac{M!}{(M-N)!}(\frac{\lambda}{\mu})^N\}}$	$\frac{M!}{(M-N)!}(\frac{\lambda}{\mu})^N P(0)$
Multiple Servers S = Number Servers Exponential Arrival Poisson Service	$L_q+\frac{\lambda}{\mu}$	$\frac{(\frac{\lambda}{\mu})^S(\frac{\lambda}{S\mu})}{S!(1-\frac{\lambda}{S\mu})^2}$	$\frac{(\frac{\lambda}{\mu})}{S!(1-(\frac{\lambda}{S\mu})^2)}P(0)$	$T_s-\frac{1}{\mu}$	$\frac{L_q}{\lambda}+\frac{1}{\mu}$	$\frac{1}{\sum_{N=0}^{S-1}\frac{(\frac{\lambda}{\mu})^N}{N!}(\frac{\lambda}{\mu})^S\frac{1}{1-(\frac{\lambda}{S\mu})}}$	$\frac{(\frac{\lambda}{\mu})^N}{N!}P(0)\quad 0\le N\le S$ $\frac{(\frac{\lambda}{\mu})}{S!-S^{N-S}}P(0)\quad N\ge S$
Single Channel Erlang Arrivals Poisson Service $K=\frac{\text{Mean}^2}{\text{Variance}}$	$\frac{K+1}{2K}\cdot\frac{\lambda^2}{\mu(\mu-\lambda)}+\frac{\lambda}{\mu}$	$\frac{K+1}{2K}\cdot\frac{\lambda^2}{\mu(\mu-\lambda)}$	$\frac{\lambda}{\mu}$	$\frac{K+1}{2K}\cdot\frac{\lambda}{\mu(\mu-\lambda)}$	$\frac{K+1}{2K}\cdot\frac{\lambda}{\mu(\mu-\lambda)}+\frac{1}{\mu}$	$1-\frac{\lambda}{\mu}$	

Table C.1 gives the formulae describing the principle parameters of these queues.

It is sometimes required to perform queueing calculations when good estimates of the mean and standard deviations are not available. Estimates of these can be obtained using the Beta distribution. This distribution provides an estimate of the mean and standard deviation if the fastest time, "most" likely time, and slowest time can be estimated. The formulae to do this are given in Figure C.2. While this way of estimating mean and standard deviations is not completely justified in theory, it can give useful results in most situations.

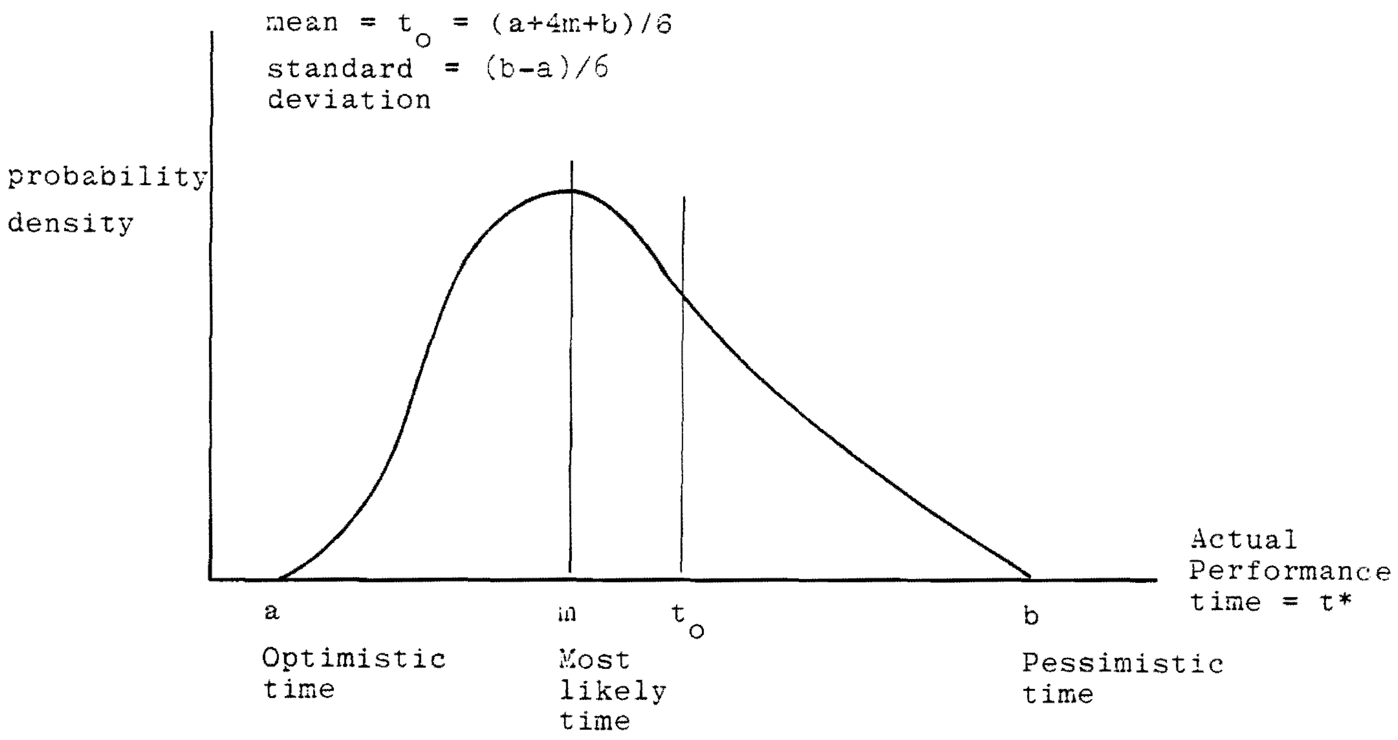
The Beta Probability Density Function originated from making PERT computations. The review of Beta distribution will facilitate our calculations of means and standard deviations for such parameter as ship inter-arrival time.

A Beta-PDF looks as in Figure C.2 and by estimating:

a = Optimistic time
b = Pessimistic time
m = Most likely time

The mean and the standard deviation of the activity can be calculated by using the formulas shown in this figure.

FIGURE C.2 BETA DISTRIBUTIONS



APPENDIX D. INVENTORY MANAGEMENT

It is important to keep enough inventory of raw materials to ensure smooth and continuous production activities. However, keeping excessive amounts of inventory is costly and it should be avoided to keep much needed capital from sitting idle in the form of raw materials inventory. Part of the success of many Japanese manufacturing industries is the result of efficient production planning, which required very small amounts of inventory. The inventory management also affects the facilities that will be required, such as storage area and transportation requirements.

In this appendix some inventory management techniques, based on the detailed examination of demand patterns and other related costs, are reviewed. The port planner should consider these techniques in their designing effort rather than make arbitrary inventory management decisions.

In general there are four functional classifications of inventory. They are as follows:

Cycle stock	Due to economies of scale or technology requirements, orders are placed in batches and the resulting inventory is called cycle stock.
Safety stock	To account for the variability in demand and delivery schedule of raw materials, a certain amount of inventory is kept in each time period as safety stock.
Anticipation stock	As with peaks in sales, when situations, such as strikes or wars, are expected, anticipation inventory is built up.
Pipeline stock	Work in process and in transit inventories

The simplest inventory management model is the Economic Order Quantity (EOQ) model, which is also known as Wilson's lot size formula.

The assumptions are the following:

1. Demand is continous at a constant rate.
2. Process continues infinitely.
3. Replenishment is instantaneous.
4. All costs are time invariant.
5. No shortage or quantity discounts allowed.

Based on the above assumptions, the total ordering and inventory holding cost is:

$$TC = A \cdot \frac{D}{Q} + r \cdot c \cdot \frac{Q}{2} = \text{(Annual Ordering Cost)} + \text{(Annual Inventory Holding Cost)}$$

where A = ordering cost
D = amount of annual demand
Q = order quantity
r = inventory carrying charge per year per unit
c = unit price of the item
$\frac{Q}{2}$ = average inventory

By differentiating the above total cost equation with respect to Q and setting it equal to zero, we get Q*, the optimal order quantity, to be

$$Q^* = \sqrt{\frac{2A \cdot D}{r \cdot c}}$$

Essentially, this EOQ formula is obtained by trading off the annual ordering cost with the annual Inventory holding cost.

As an example, for

A = \$10/order
D = 10,000 units/year
r = 10%/year/unit
c = \$100/unit

$$\text{then, } Q^* = \frac{2 \times 10 \times 10{,}000}{0.1 \times 100} = 141$$

The EOQ formula can be modified in order to apply it to cases where demand varies, supply rate is finite and backlogging and quantity discount is allowed. (See "Decision Systems for Inventory Management and Production Planning" by R. Peterson and E. Silver). Table D.1 is a summary of those cases.

This EOQ scheme is represented as follows.

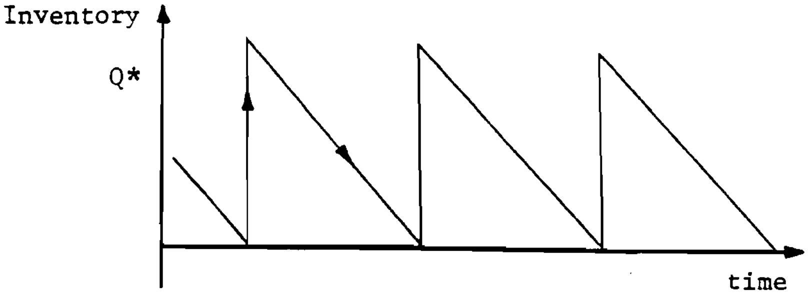
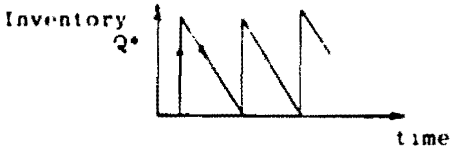


TABLE D-1 SUMMARY OF INVENTORY CONTROL CASES

1. EOQ System

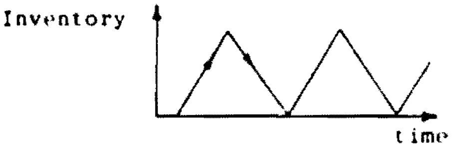
$$Q^* = \sqrt{\frac{2A \cdot D}{r \cdot c}}$$



2. Finite Supply Rate

$$Q^* = \sqrt{\frac{2A \cdot D}{r \cdot c(1-\frac{D}{P})}}$$

P = supply rate/year



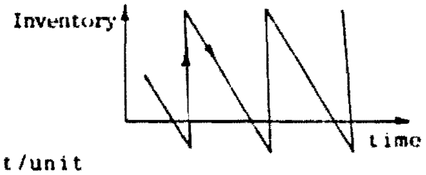
3. Backlogging Allowed

$$Q^* = \sqrt{\frac{2A \cdot D}{r \cdot c}} \sqrt{\frac{r \cdot c+b}{b}}$$

$$B^* = \frac{r \cdot c \cdot Q^*}{r \cdot c+b}$$

b = annual backorder cost/unit

B* = optimal amount of backorder



4. EOQ with Varying Demand (Silver - Meal

a. Find $T^2\, d(T) = \frac{2A}{r \cdot c}$

b. Find T_i^*, where $T_i^2 d(T_i) \geq \frac{2A}{r \cdot c}$

c. Solve $T = \sqrt{\frac{2A}{r\ c\ d(T_i)}}$

T = Length of time period that the current replenishment should last

$d(T_i)$ = demand rate in period i

5. Quantity Discounts for all Units

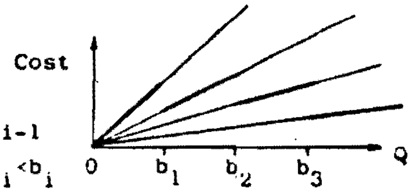
a. Compute

$$Q_i = \sqrt{\frac{2AD}{rc}}$$

b. $Q_i^* = b_{i-1}$ if $Q_i < b_{i-1}$

Q_i if $b_{i-1} < Q_i < b_i$

b_i if $b_i < Q_i$



c. Compute $TC(Q_i^*) = C_k D + \frac{AD}{Q_i} + r \cdot C_k \cdot \frac{Q_i}{2}$

d. Minimum $TC(Q_i^*)$ gives Q*

C_k = unit cost at discount rate K.

APPENDIX E. METHODS OF MAKING PILE CAPACITY COMPUTATIONS

Figure E-1 illustrates a computation method for the amount of bulk material that can be withdrawn from a conical stockpile.

The amount of material that can be stockpiled (in elongated form) in an area of 115 feet wide and 415 feet long is calculated as follows:

(a) Assuming that the material has a 35 degree angle of repose, the conical pile volume is 5,050 yd^3 .(see Figure E-2_.

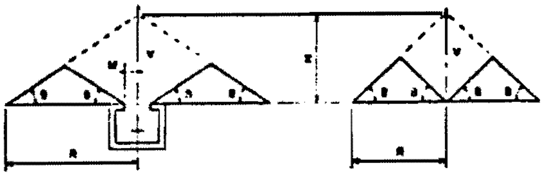
(b) The prism volume in cubic yards is as follows:

$$V = \frac{\text{(length)(width)(height)}}{2 \times 27 \ ft^3/yd^3} = \frac{(415 - 115)(115)(40)}{2 \times 27} = 22,550 \ yd^3$$

(c) Total volume = 5,050 + 22,550 = 27,600 yd^3

Figure E-2 provides a simple means for correcting for the conical ends of the pile when calculating pile volume.

Figure E.1 Method of Determining the Amount of Material which can be Withdrawn from a Conical Pile



V = volume which can be drawn from pile (ft^3)

R = radius, base of conical pile (ft)

For left illustration:

$$V = \frac{4}{9}(R + M)^3 \text{ Tan } B - 2RM^3 \text{ Tan } B$$

B = angle of repose of material

H = height of pile (ft)

For right illustration:

$$V = \frac{4}{9} \times \frac{H^3}{\text{Tan}^2 \ B} \text{ in terms of height of pile}$$

Source: Bulk Materials Handling Vol. 1, p. 461
Funnel Reclaim, by F.O. Snow

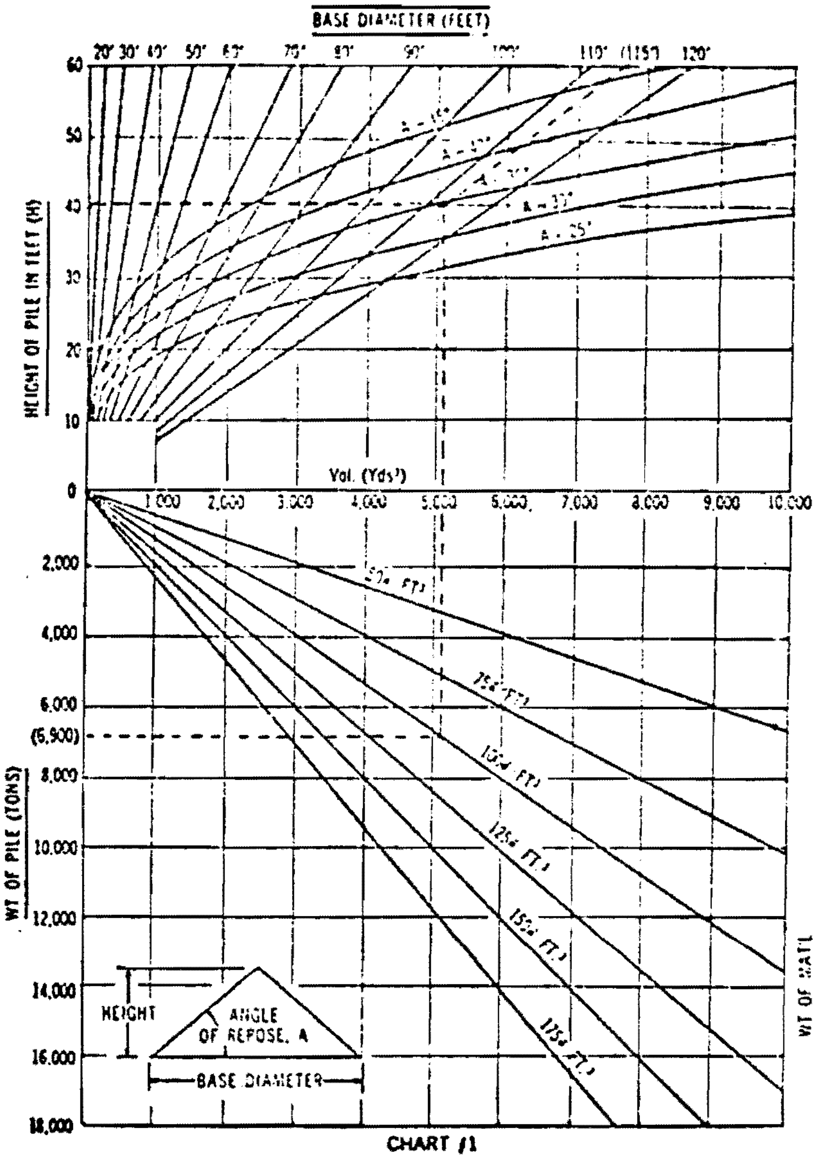


FIGURE E.2 Figuring conical stockpile capacities (from Barber-Green Co.) Bulk Materials Handling, Vol. 1, p. 361, Univ. of Pittsburgh, 1971 Design Consideration for Storage and Reclaim Systems, H. Colijn.