Chapter III

CONTAINER TERMINALS

A. Container ship development

105. Container ships are generally classified into "generations", that is, as having characteristics typical of certain stages in container development and container shipbuilding. The main characteristics of each "generation" are shown in table 1. The term TEU (twenty-foot equivalent unit or equivalent in goods to a container of 20 feet) is a useful standard term for defining the carrying capacity of a container vessel: a 40-foot container therefore counts as two TEUs. The principal dimensions of 20-foot and 40-foot steel containers are given in table 2. The R-foot high 20-foot container has been largely replaced by the X-foot 6-inch unit. and for the 40-foot container the trend is towards units of 9 feet to 9 feet 6 inches.

TABLE 1

Physical characteristics of container ships

	Container capacity (TEUs)	*Dwt*	*Overall length (metres)*	*Overall width (metres)*	*Draught (metres)*
"First-generation" container ships	750	14 000	180	25	9.0
"Second generation" container ships	1 500	30 000	225	29	11.5
"Third generation" container ships	2 500–3 000	40 000	275	32	12.5

106. To keep operating costs to a minimum, the maximum utilization of these large modern vessels must be achieved. Thus there has been a move to reduce the number of ports of call of the mother ships and to introduce feeder vessel services to the ports with smaller volumes of trade. The feeder ships have the task of relieving the long-haul container ships from making the extra calls which greatly increase the total time they spend in ports. Feeder ships vary in size from capacities of 50 to 75 TEUs up to 300 TEUs.

107. The rapid spread of container operations has been very fully documented. A detailed discussion of containerization and its impact on ports in developing countries is given in the UNCTAD publication on the subject[2] and in a series of reports prepared by the UNCTAD secretariat on the subject of technological change in shipping and its effects on ports.[3] The last major trade routes between highly industrialized countries have been containerized. At the same time, there is an increasing trend towards containerization of certain specific services linking developing and developed countries.

[2] *Unitization of Cargo* (United Nations publication, Sales No. E.71.11.D.2).

[3] "Technological change in shipping and its effects on ports" (TD/B/C 4/129 and Supp.1–6).

TABLE 2

Principal dimensions of typical steel containers

	20 ft × 8 ft × 8 ft		*20 ft × 8 ft × 8 ft 6 in.*		*40 ft × 8 ft × 8 ft 6 in.*	
	Corrugated roof	*Flat roof*	*Corrugated roof*	*Flat roof*	*Corrugated roof*	*Flat roof*
Inside (*in millimetres*)						
Length	5 897	5 897	5 897	5 897	12 022	12 022
Width	2 352	2 352	2 352	2 352	2 352	2 352
Height	2 246	2 221.5	2 395.5	2 371	2 395.5	2 371
Door opening (*in millimetres*)						
Width	2 340	2 340	2 340	2 340	2 340	2 340
Height	2 137	2 137	2 280	2 280	2 280	2 280
Inside cubic capacity (in *cubic metres*)	31.5	30.8	33.2	32.9	67.7	67.0
Tare weight (*in kilograms*)	2 230	2 260	2 300	2 330	4 050	4 100
Stacking capacity	9 high	9 high	9 high	9 high	9 high	9 high

108. Examples of this trend are services between Europe and the Caribbean, between Europe and the Middle East, between Europe and West Africa, between Europe and the Far East, between Europe and South America, between North America and the Far East, between North America and South America and between North America and Central America. Generally the vessels involved are of the first generation or, on the shorter runs, feeder vessels. The basic problems with these services are the imbalance of trade and the labour problems caused by the reduced damage for manpower.

109. At present these and similar container services carry a fraction of the general cargo liner traffic between developed and developing countries, but in developed countries' ports container services already handle between 70 and 80 per cent of the cargo. Therefore port authorities in developing countries must consider the development towards containerization of their countries' trade, and the profound changes in port planning, management and operations which such development brings with it. Thus it is not a question of whether or not to containerize, but rather when to containerize.

110. Both the break-bulk berth group and the multi-purpose terminal must be capable of handling containers-even if, in the former case, only a small number of units are carried (mainly on deck) in a liner operation. This chapter is concerned with the specialized container terminal needed to handle the cellular container ships.

111. These large ships will not normally call at a port without a specialized container terminal offering a specified level of service. By investing in a specialized terminal a port can make calls by container ships possible, but such an investment cannot be financially justified until a satisfactory level of use is guaranteed. The container throughput must be around 50,000 TEUs per year if the investment is to be justified. Below this level, the port should either provide limited facilities for container feeder ships or adopt the transitional multi-purpose terminal described in the next chapter.

B. Planning and organization

112. It is wrong to imagine that the planning, organization and running of a container terminal is a straightforward task. Figure 16 gives an indication of the main factors which have to be taken into consideration in planning a container terminal and can be used as a checklist in order to ensure that none of the most important issues have been overlooked. The complexity of this type of terminal coupled with its newness necessitates a comprehensive training programme of the senior operating staff, often in a well-organized and efficient container terminal.

C. Productivity

113. There has been considerable inaccuracy in predicting container terminal productivity. In the course of its investigations into technological change in shipping and its effects on ports. the UNCTAD secretariat found that the average throughput for a sample of 21 ports was 442 containers per 24 hours in port,[4] a figure significantly below figures which are often quoted.

114. The average productivity per hour per vessel, even averaged over a long period, varies considerably from one terminal to another. from about 10 to 50 containers per hour, even on the same cellular ship operated by two gantries, averaged over a 24-hour period. This figure refers to single units either loaded or discharged and includes any idle time within a working period. The early operating objective of lifting one container off and one container on in a combined cycle is now rarely achieved or even attempted for any significant period.

115. The gross productivity per hour can be converted to a daily figure by using the ratio of working time to berth time. The working time includes any idle time within a working period, such as that due to equipment breakdown, and therefore for ports operating around the clock the ratio could be 100 per cent. A number of reasons prevent ports from achieving this 24-hour per day operation, however, and the ratios usually vary between a peak of 95 per cent and a low of 40 per cent. Clearly this variation in the intensity of working can have a significant effect on the annual throughput of the terminal.

116. The figures for throughput per 24 hours in the sample referred to above varied from a high of approximately 750 containers to a low of approximately 225 containers. The average throughput for these terminals was nearly 450 containers per 24 hours in port, Given that at most terminals 24-hour operation seven days a week is standard practice, the typical throughput was calculated as follows in the early 1970s:

Average output per gantry-crane 20 units per hour
Average number of gantry-cranes allocated to each vessel: 2
Working time/berth time ratio: 0.80

Thus, according to this earlier method,

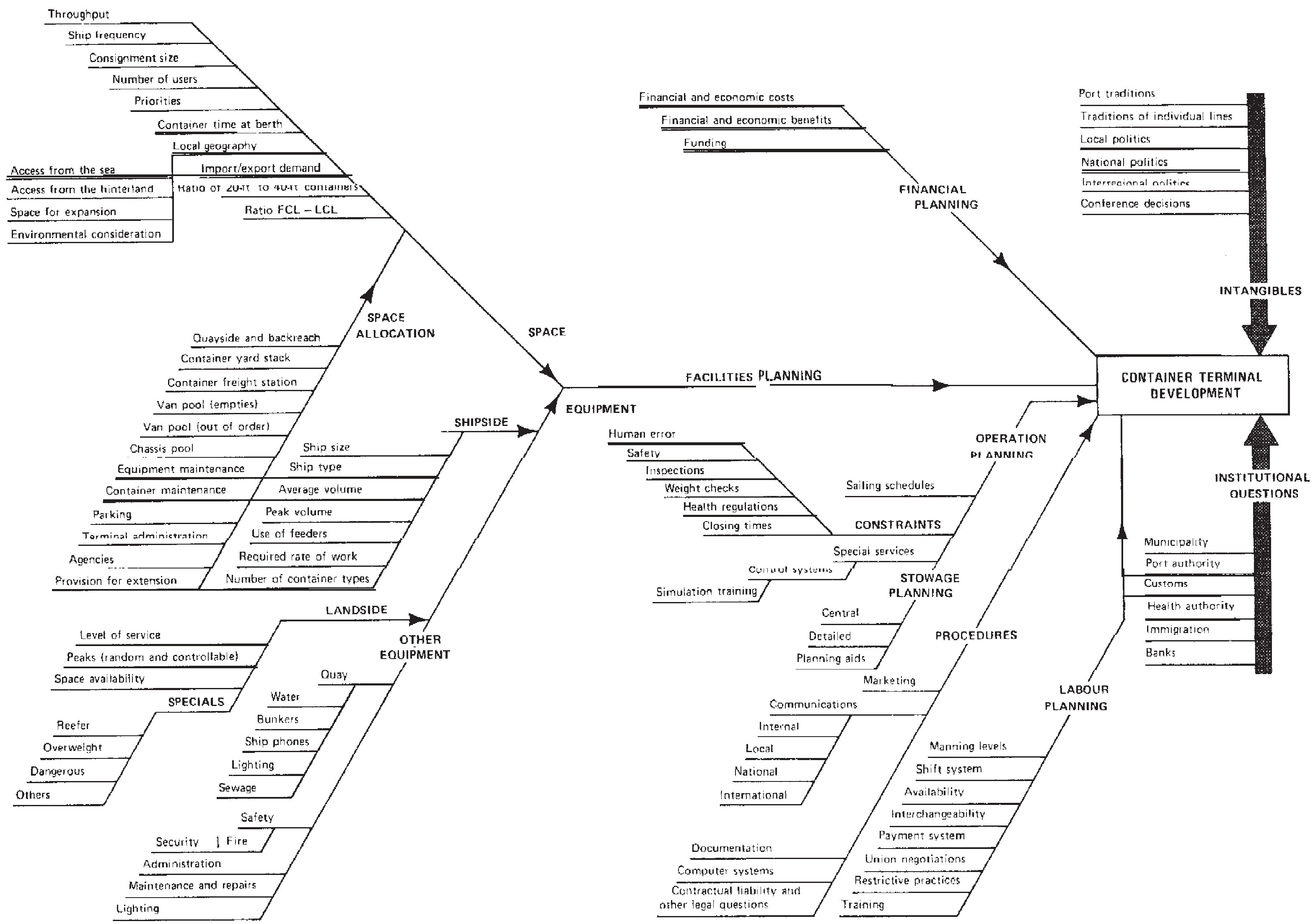
Average throughput per 24 hours = 24 (average output per crane) × (average number of cranes allocated) × (working time/berth time ratio)
= 24 (20 × 2) (0.80)
= about 770 containers.

117. The actual average throughput of the sample is slightly less than 60 per cent of this theoretical figure. Clearly the figures used in this procedure are too optimistic for planning purposes and more realistic figures should be used when calculating ship turn-round time for the economic analysis, especially when one considers that this sample is for major terminals handling second- and third-generation cellular vessels and working three shifts with two cranes on average.

[4] "Technological change in shipping and its effects on ports: the impact of unitization on port operations" (TD/B/C.4/129/Supp.1), para. 90.

FIGURE 16

Dependency tree for container terminal planning



118. There is little doubt among container terminal experts that the present performance of container facilities throughout the world is far from optimum. No doubt part of the difficulty stems from the fact that there is excess capacity at the present time of economic slump and that fewer goods are being moved by this form of transport. However, there are also operational inefficiencies which are due to inappropriate planning decisions, operating procedures, equipment or manpower policies. The main reasons lie in the imbalance between the capacities of the various system parts at a terminal, which results in low hourly productivity per crane, and inadequacies in the inland transport system, which often results in long non-operational periods.

119. In general, the capacity which has been provided for the loading and unloading of containers exceeds the terminal's transfer, stacking, storage and delivery capacity. This has been due primarily to an underestimation of the transfer distances that would have to be covered and of the proportion of time that equipment would be out of service for maintenance purposes. A survey carried out in four ports in the United Kingdom showed that the proportion of time during which straddle-carriers were out of service for maintenance averaged almost 30 per cent.[5] The figure was even higher than this in ports with a high workload. This fact supports the UNCTAD secretariat's view that, for developing countries, tractors and trailers are likely to be the most economic system for the transfer operation and that straddle-carriers should be considered as merely one possibility for the stacking operation.

D. Container handling systems

120. The four most commonly used container handling methods in operation today are the trailer storage system, the heavy-duty fork-lift truck system, the straddle-carrier system, and the gantry-crane system, the gantry-cranes being either rail mounted or rubber tyred. There can also be various combinations of these types of equipment at individual terminals. The essential features of each of the main systems are given in the following paragraphs.

1. Trailer storage system

121. The import containers discharged from a ship by crane are placed on a road trailer, which is towed to an assigned position in the storage area where it remains until collected by a road tractor. Trailers carrying containers for export are placed in the storage area by the road tractors and towed to the ship by port equipment. The containers are thus of necessity stored one high. requiring a large transit storage area (see figure 17). Limited soil improvement is required due to low loading. This is a very efficient system because every container is immediately available for removal by a tractor unit, but in addition to requiring a large area it also requires thousands of trailers, entailing considerable expense. This method is therefore normally used only when a shipping company provides the trailers and either operates at a leased or reserved berth or has access to a special trailer compound. This makes trailer storage generally unsuited for use by multi-user terminals. As a rough rule of thumb for 2,000 TEUs, a container storage area of 100,000 square metres is required.

2. Fork-lift truck system

122. A heavy-duty fork-lift truck with a capacity of 42 tons and a top-lift spreader is capable of stacking fully loaded 40-foot containers two or three high, with the most common stacking height of two high. A side spreader can be used for 20-foot containers, both full and empty, and for 40-foot empties. Empty containers can be stacked four high. This system places heavy loading on the surface of the terminal and adequate soil improvement and surfacing must therefore be provided. Most port authorities and cargo-handling companies have experience in both the operation and maintenance of fork-lift trucks. Such trucks can transfer containers from the ship's side to the stacking area, or tractor-trailer units can be used which will reduce the number of fork-lift trucks required. Typical aisle widths in the stacking area are 18 metres for 40-foot units and 12 metres for 20-foot units. As a rough rule of thumb for 2,000 TEUs, with an average stacking height of 1.5 boxes, a container storage area of 72,000 square metres would be required.

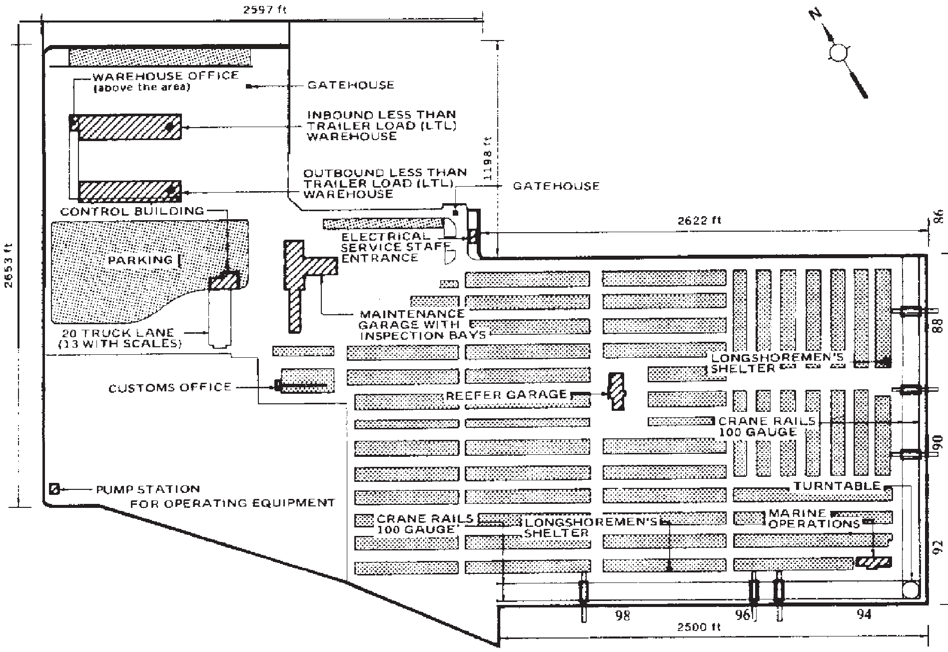
3. Straddle-carrier system

123. At the present time the straddle-carrier system is the predominant one. Straddle-carriers can stack containers two or three high, move them between quay crane and storage area, and load or unload them to or from road transport (see figure 18). In the past, however, these machines have had a poor reliability record. poor visibility, high maintenance costs and a short life. Leaks from joints in the hydraulic system and oil spillage from damaged pipework caused highly slippery surfaces, broke up asphalt paving and necessitated continual renewal of the white lines and numbers essential in stacking areas. Safe operation demanded that straddle-carriers should operate within a restricted area, and that workers on foot should be kept out of the working area. The fact that despite these drawbacks the straddle-carrier is so widely used is a testimony to its flexibility and its ability to meet peak requirements. Furthermore, major improvements have been made in the design of straddle-carriers, and most of their poor maintenance record resulted from a lack of preventive maintenance and the excessive use of the equipment for transfer operations. A variant of this system is the use of tractor-trailer units for the transfers between quayside and storage area, and the use of straddle-carriers only within the storage area for stacking and selecting containers. Approximately six straddle-carriers are required for each ship-to-shore gantry-

[5] H. K. Dally, "Straddle carrier and container crane evaluation", *National Ports Council Bulletin* (London), No. 3, 1972.

FIGURE 17

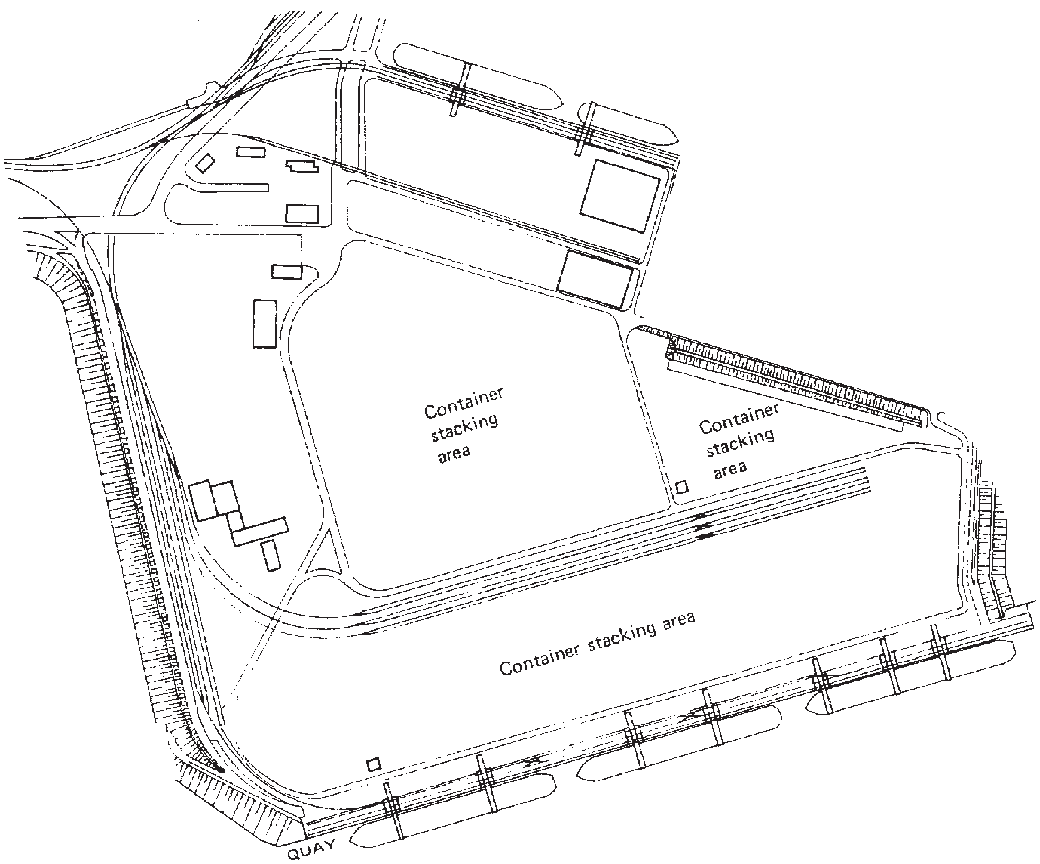
Example of trailer storage container terminal layout



General plan of new sea-land terminal at Elizabeth, New Jersey.
(Parking space 3,757 35-ft containers and 2,498 40-ft containers.)

FIGURE 18

Example of straddle-carrier container terminal layout



Container terminal, Bremerhaven (Federal Republic of Germany) crane. As a rough rule of thumb for 2,000 TEUs, a container storage area of 40,000 square metres for 1.5-high stacking, or 30,000 square metres for two-high stacking is required.

4. Gantry-crane system

124. In this system, containers in the storage area are stacked by rail-mounted or rubber-tyred gantry-cranes (see figure 19). Rail cranes can stack containers up to five high (although normally containers are stacked no more than four high). Rubber-tyred gantry-cranes can normally stack containers two to three high. Tractor-trailer units make the transfers between quayside and storage area. This system is economical in land because of the high stacking, and is suitable for varying degrees of automation. Gantry-cranes have a good safety record, are reliable and have low maintenance costs and a long life in comparison with straddle-carriers. They are far less flexible but to offset this, gantry-cranes (particularly the rail-mounted type) are better suited for automation. In the longer term, the need to economize in land is likely to be very important, and this favours the use of gantry-cranes. This system is especially useful where exports are a substantial proportion of the total traffic, but perhaps less than optimum where import cargoes constitute the major portion of the traffic. This is because import containers need to be retrieved in a random fashion and, with high-stacking freight, many units need to be shifted. As a rough rule of thumb for 2.000 TEUs, a container storage area of 16,000 square metres is required for 3.5-high stacking.

5. Mixed systems

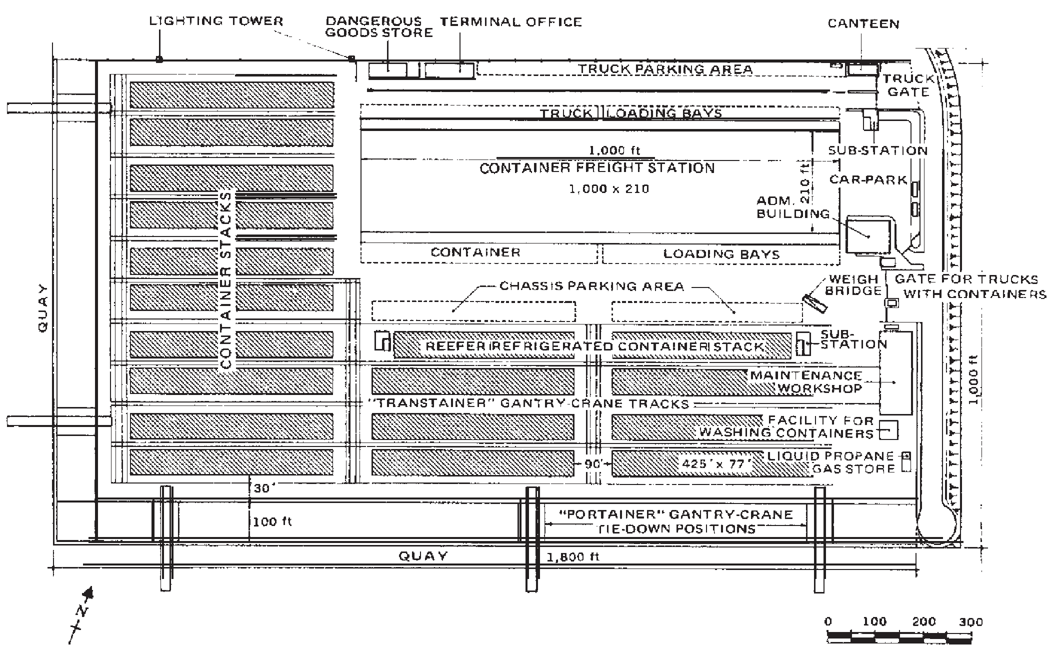
125. Mixed systems employ the best equipment for the particular operation. However, for such systems to be successful, a comprehensive information system and rigid operating policies are required, together with excellent management. For example, straddle-carriers are used for extracting individual import containers and delivering them to road vehicles, but gantry-cranes are used in the container park for feeding exports to the ship where it is possible to work straight off an export stack. Another mixed system is one using straddle-carriers for stacking full containers and fork-lift trucks for empty containers.

E. Area requirements

126. The choice of operating methods and equipment, and thus the area of land needed for a container terminal, depends to a high degree on the availability of local land and on soil conditions. If the terminal is located far from urban agglomerations and land is plentiful and inexpensive, a system of storing containers only one high may be the most economical. For this layout, no costly equipment is needed for stacking containers but transfer distances may become long, resulting in additional transfer equipment being needed. Also, on reclaimed land with relatively soft soil, this one-high method is particularly advantageous since the carrying capacity of the soil does not need to be reinforced as it would for heavy stacking equipment. On the other hand, if land is scarce and expensive, the stacking of containers as high as physical conditions and commercial requirements allow becomes a necessity

FIGURE 19

Example of gantry-crane container terminal layout



127. Lack of container storage space has been another serious constraint on operations. It is true that, since the introduction of containerization on the major trade routes, there is a trend towards larger storage areas for container terminals. but in many. planned developments the space requirements are still under-estimated. Sufficient operational area must be left for interchange areas for both ship-to-shore and stack-to-inland operations, as well as for vehicle parking, maintenance, workshops and administrative buildings.

128. The most frequent error has been to assume that the maximum stacking height can always be attained. In practice the average stacking height is much lower, depending on the amount of shifting of containers necessary in the storage area. and the need for containers to be segregated by destination, weight class. direction of travel (inward or outward). sometimes by type and often by shipping line or service. The need for storage of empty units and of unserviceable containers has also often been overlooked.

129. A further serious mistake is the belief that containers have a shorter terminal transit time than break-bulk cargo. In fact, the same constraints which cause break-bulk cargo to stay in the port will often have a similar effect on container cargo. In practice it is not unusual to find that the transit times for both are very similar. The following are typical delay times for containers at container terminals taken from a number of terminals:

	Days
Containers carrying import cargo	7
Containers carrying export cargo	5
Empty containers	20

130. Planning charts similar to those whose use is explained in section G of chapter II, "The break-bulk berth group", are also helpful in container terminal planning.

131. When sufficient space is set aside for the container park, container freight station (CFS), marshalling and other administrative areas for a terminal operating adjacent to the quay, then there are bound to be enough berths for the traffic. For this reason, the terminal area requirements are calculated first, and then the number of berths checked to see if there is enough berthing capacity.

132. Container terminal, planning chart I (see figure 20) is used to determine the most important dimension of a container terminal, the container park area. The figure for the number of TEUs to be handled across the quay per year is entered on the planning chart. The planner descends vertically to the turning-point where the vertical line meets the line representing the average time the container spends in transit at the terminal. He then moves horizontally to the left to the next turning-point defined by this horizontal and the appropriate line for the area requirement per TEU.

133. The area requirement per TEU depends on the type of container-handling equipment used and the consequent access requirements and maximum stacking height. Typical area requirements are as follows:

	Stacking height (number of containers)	*Square metres per TEU*	
		20-ft container	*40-ft container*
Trailer	1	60	45
Fork-lift truck	1	60	80
	2	30	40
	3	20	27
Straddle-carrier		30	
	2	15	
	3	10	
Gantry-crane	2	15	
	3	10	
	4	7.5	

134. The planner then descends again to the ratio of the average to the maximum stacking height of containers. The average height is the level at which operationally the container park area is considered full. For example. although a straddle-carrier can stack containers three high, it would not be practical for the operator to stack the entire park three high as it would then be impossible to remove individual containers. An adjustment factor must therefore be applied to allow for this fact. The planner now moves horizontally to the right to the reserve capacity safety factor-the factor which allows the park to handle peaks in demand.

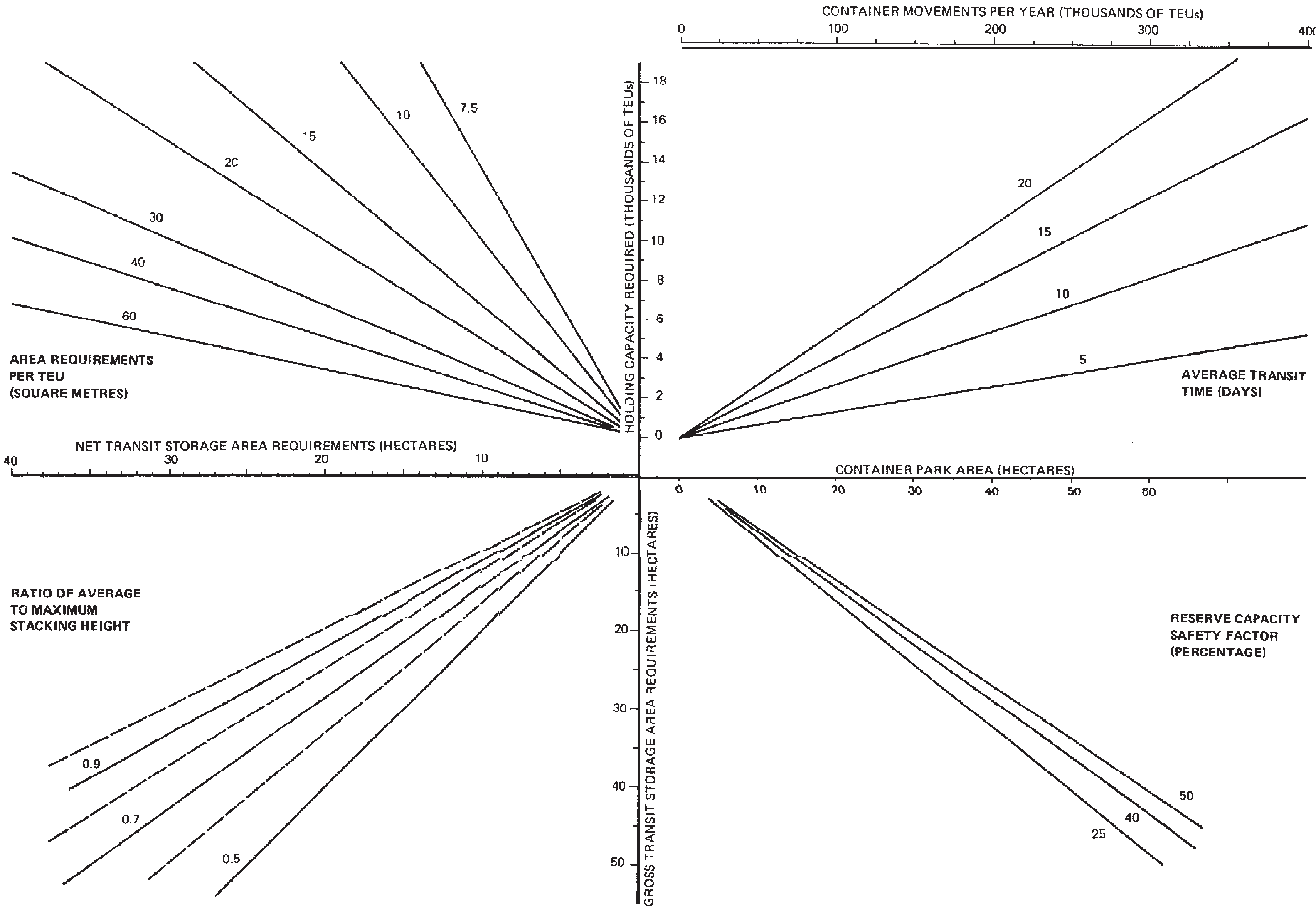
135. Finally he moves upwards to the container park area required. The intersections of the trajectory and the axes give the planner the following information: holding capacity required, in TEUs; net transit storage area requirements; gross transit storage area requirements; and container park area. The chart may be used repeatedly to determine the effect on area requirements of different handling equipment in order to find the most economical solution for local conditions.

136. The planner must now estimate the area requirements for the CFS, the structure used for "stuffing" and "stripping" containers and for consolidating and sorting consignments in the port area. Assuming that each TEU container handled via the CFS requires 29 cubic metres of space, the CFS storage area can be determined by using planning chart II (see figure 21). The following turning-points are used: average transit time of consignment; average stacking height in CFS; access factor to allow for circulation and operational areas in the CFS; and reserve capacity safety factor for periods of peak demand. For example, a terminal at which 20,000 TEUs per year pass through the port CFS, with a mean transit time of 10 days. a stacking height of 2 metres, an access factor of 0.4 and a safety factor of 25 per cent, would require a CFS storage area of 14,500 square metres[6]. The structure should also have a large roof overhang to allow protection of the container loading bays from the weather (see figure 22).

[6] This figure can be compared with other CFS areas at the following container terminals: Guam: 2 berths. CFS 3.066 m²; Keelung: 5 berths, CFS 2,700 m²; Port Kelang: 2 berths. CFS 6,771 m²; Singapore. East Lagoon, 3 berths. CFS 21.000 m²; Kwai Chung berth 4: 3 berths, CFS 23.241 m²

FIGURE 20

Container terminal, planning chart I: container park area



Note: 1 hectare = 10,000 m^2.

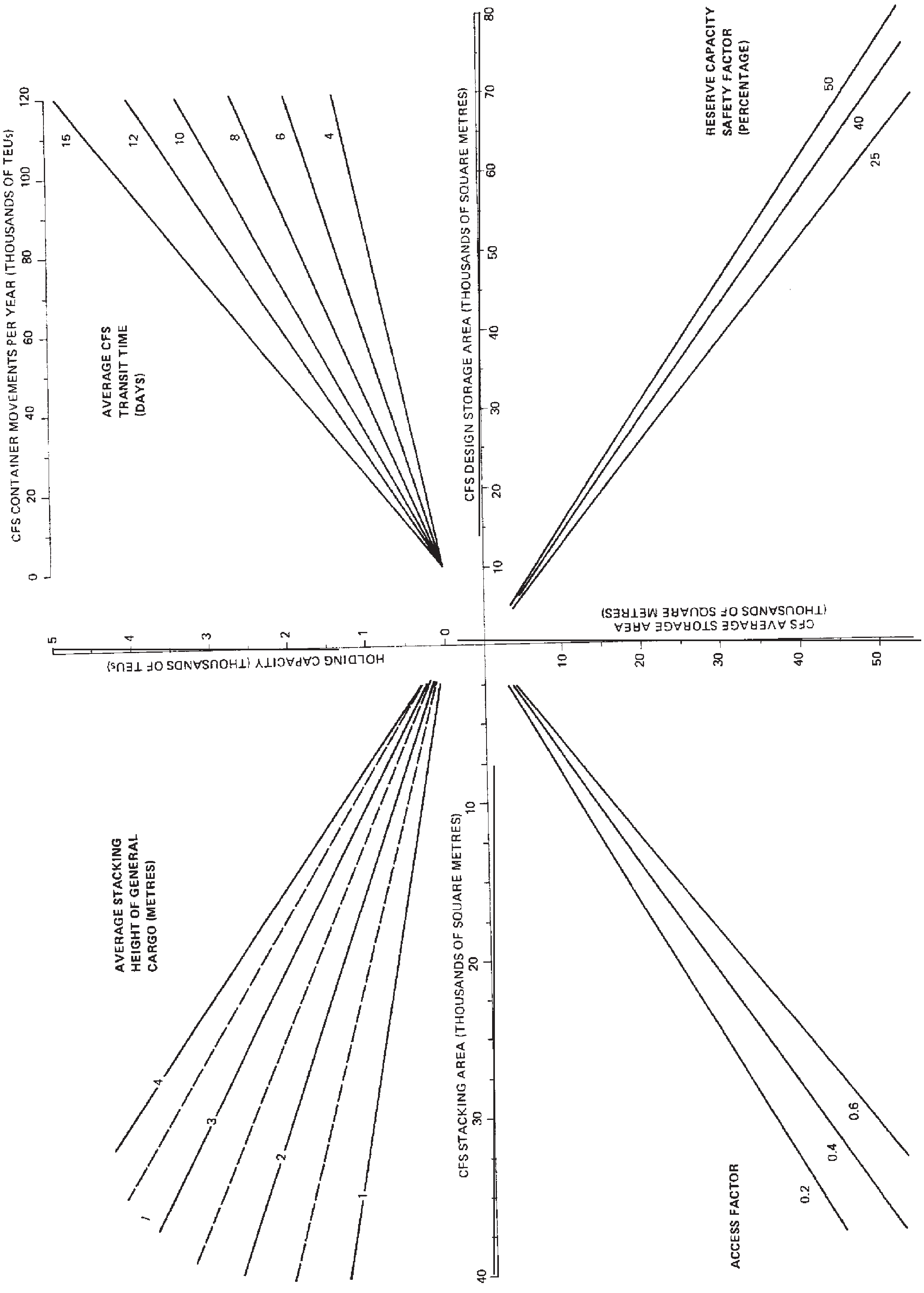
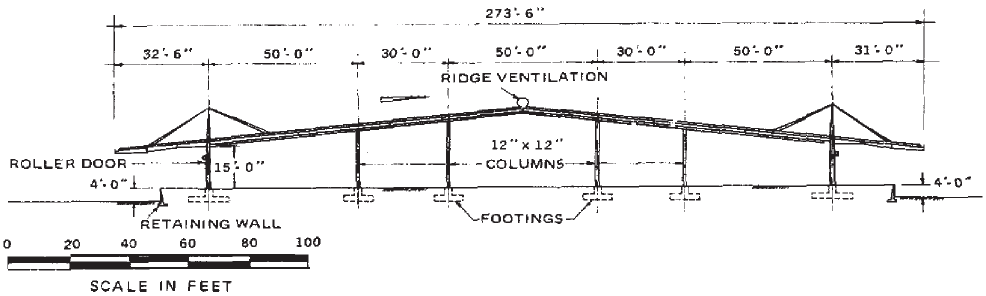

CFS CONTAINER MOVEMENTS PER YEAR (THOUSANDS OF TEUs)
0
20
40
60
80
100
120
AVERAGE CFS TRANSIT TIME (DAYS)
15
12
10
8
6
4
CFS DESIGN STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
60
70
80
RESERVE CAPACITY SAFETY FACTOR (PERCENTAGE)
50
40
25
HOLDING CAPACITY (THOUSANDS OF TEUs)
0
1
2
3
4
5
CFS AVERAGE STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
AVERAGE STACKING HEIGHT OF GENERAL CARGO (METRES)
4
3
2
1
CFS STACKING AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
ACCESS FACTOR
0.2
0.4
0.6

FIGURE 22

Cross-section of container freight station



137. As previously mentioned, in addition to the container park and CFS areas, the terminal requires space for marshalling areas, vehicle parking, rail and road access, customs, damaged containers, reefer cargoes, staff, administration, maintenance and dangerous goods storage facilities. Typical additional requirements per berth could be from 20,000 to 30,000 square metres.

F. Berth occupancy at specialized unit terminals

138. Specialized berths such as container terminals can achieve cargo-handling rates five or even ten times higher than conventional berths. In addition, unitization results in a considerable reduction in the number of calls through the pooling of services, with larger consignments per vessel, which further increases the productivity per call. Thus, in unitized form, a given quantity of cargo can be handled at fewer berths, and it will be rare that a container terminal investment decision will involve more than two berths in the initial phase. Therefore the berth occupancies which will be appropriate in order to keep waiting time to an acceptable level will be low. The fact that container ships are much more expensive than general cargo vessels reinforces this need to minimize waiting time. In the planning procedure given below, the basic economic effect of waiting time will be a main factor in the investment decision, but there will in addition be the need to consider other criteria.

139. In the case of any special-purpose or advanced type of installation, the following three criteria should normally be considered:

(a) Whether the resulting berth occupancy will give the right balance between ships waiting for a berth and berths waiting for a ship;

(6) Whether the average ship turn-round time will satisfy the normal user, irrespective of what this implies with regard to berth utilization;

(c) Whether there is sufficient peak capacity to give a satisfactory individual service to the exceptional, more demanding, user and to ensure generally against congestion during periods of exceptional traffic.

140. Performance calculations should be carried out to demonstrate that all three of these criteria are satisfied. There will often be a difference in the capacities which will satisfy the different criteria, and it will be necessary to reach a compromise. In reaching this compromise the port management will often need to take an entrepreneurial decision: there may be no clear cut single solution with an economic justification which at the same time gives a level of service that will satisfy customers. It will be for the decision authority to consider these investment risks, and in order that it may do this the planning team should present separate proposals, according to each of the three criteria, for purposes of comparison. These will be more useful to the decision authority than a single proposal that attempts to meet all three criteria.

141. The container terminal planning chart III (see figure 23) is utilized to determine the berth-day requirement. The method used is similar to that used for the previous charts, starting with the standard working hours per day that ships will be worked when at the terminal, and with the following turning-points: average number of units per hour per crane, which should include an allowance for equipment down-time; number of cranes used per ship (gantry-crane effectiveness factor per crane = 1 crane : 1; 2 cranes: 0.9; 3 cranes: 0.8); average number of moves per ship; and number of ships per year. This path gives the average number of units per day per berth, the average number of units per day per crane, the average berth time per ship (which includes a one-hour period for berthing and deberthing the ship) and the annual berth-day requirement.

142. As we are now considering the performance of the terminal, note that we are using units (i.e. number of containers) rather than TEUs (i.e. twenty-foot equivalent units). When the containers to be worked to and from a ship are estimated in TEUs, this figure must then be converted into units by estimating the proportion of 40-foot units among the total number of units. The number of moves for discharging and reloading hatch covers should also be included.

143. Starting with the berth-day requirement, the following turning-points should be used in planning chart IV (figure 24): number of berths; commission days per year; number of berths; and average daily ship cost. The path traced gives the total time at port and the annual ship cost. Operators of expensive container ships may wish to know, in addition to the average ship time in port, the probability of a ship having to wait before agreeing to use the terminal. For this reason, additional scales are given on the lower left of the chart which show, for one, two or three berths, the probab-

FIGURE 23

Container terminal, planning chart 111: berth-day requirement

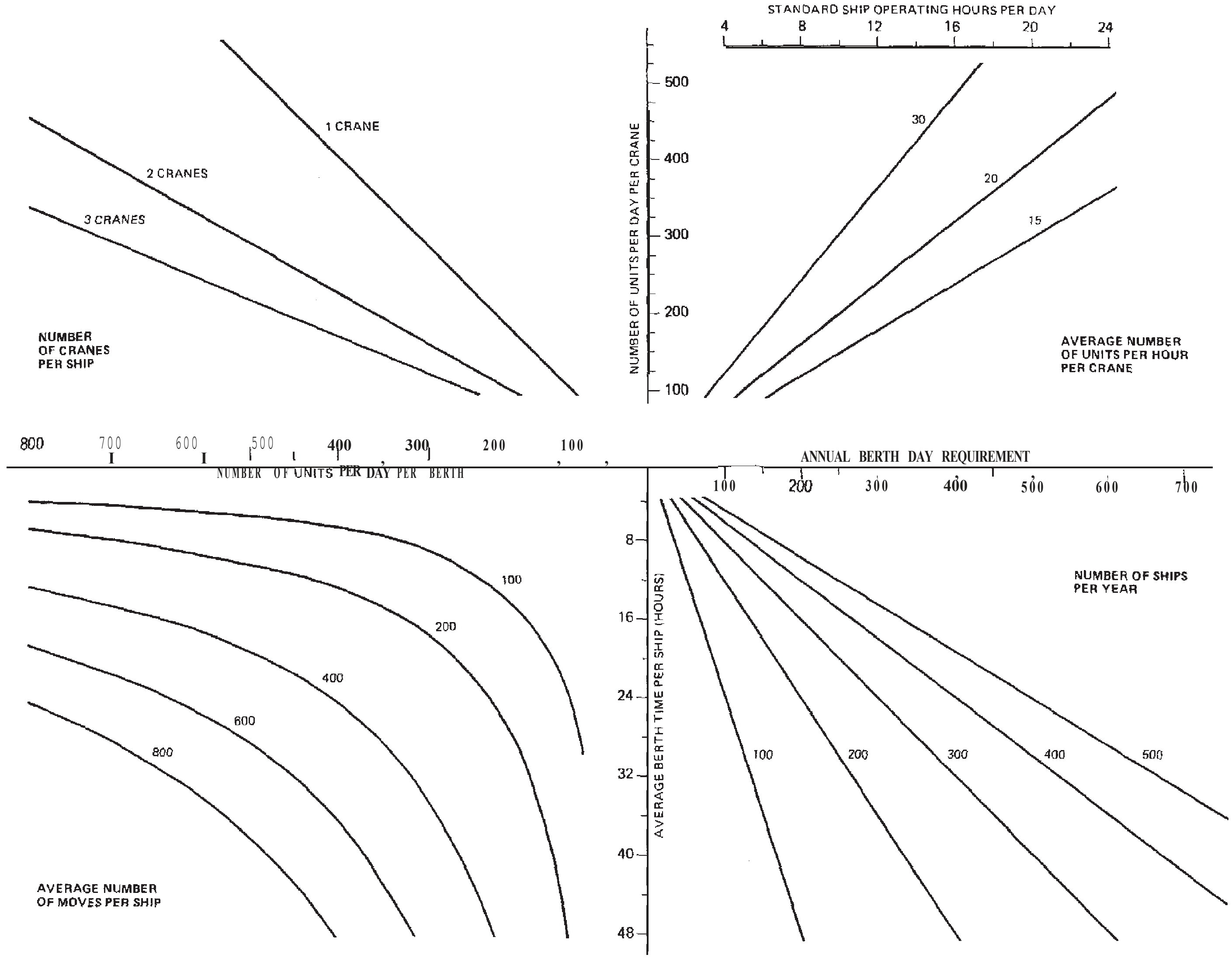
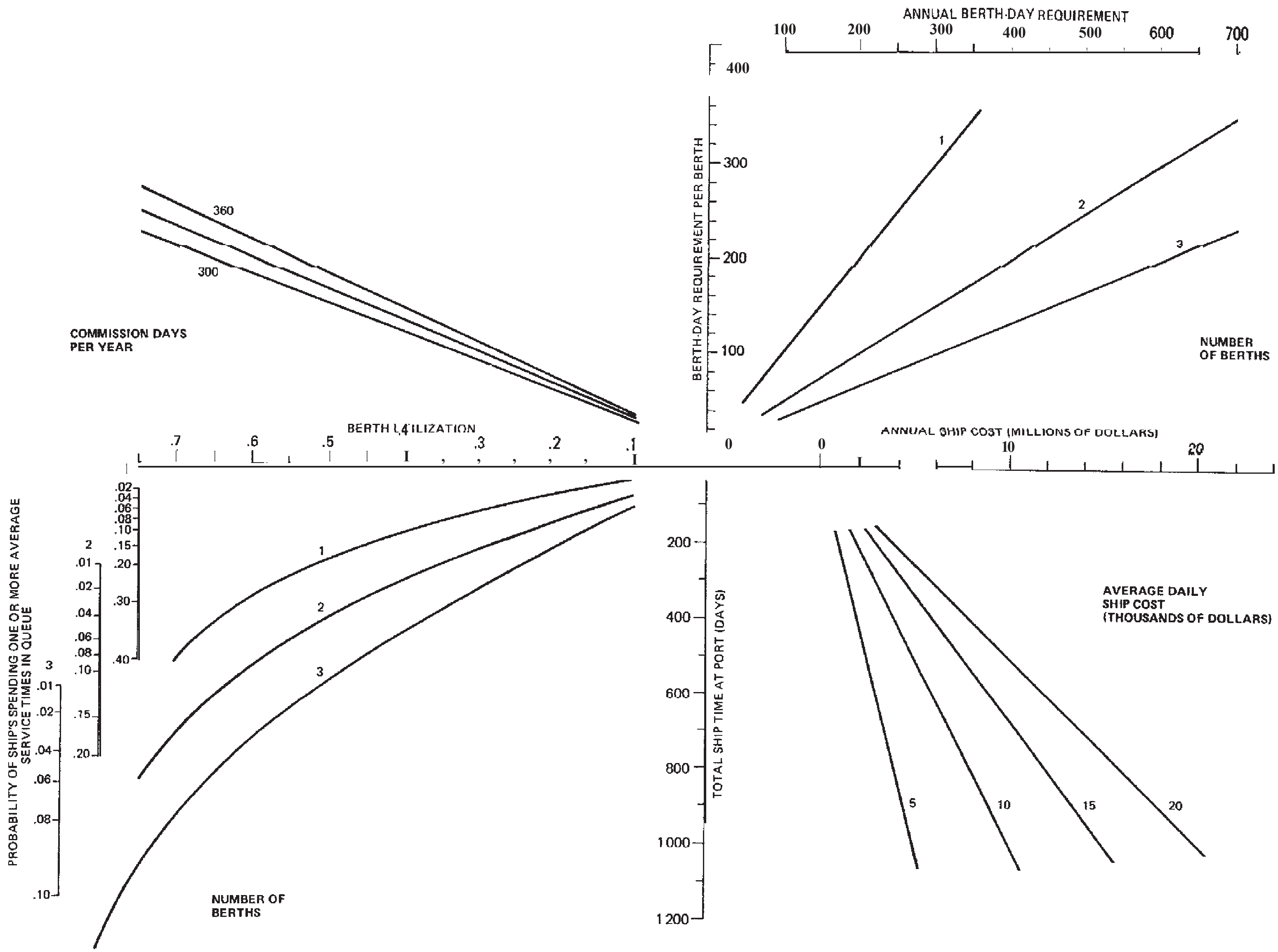


FIGURE 24

Container terminal, planning chart IV: ship cost



ility of a ship having to spend one or more average service times queueing for a berth. For example, if the average time at berth is 12 hours, then the probability shown is the chance of a ship having to wait 12 hours or more for a vacant berth. The probabilities are given as a fraction; thus 0.10 equals a 10 per cent chance. To use these probability scales, draw a line horizontally to the left from the "number of berths" turning-point.

144. The relationship between berth utilization and total time at port is based on queueing theory. The assumption has been used that the service time and the inter-arrival time follow an Erlang 2 distribution. A more detailed discussion is given in annex II, section D. For a terminal servicing a near-sea route for one or two operators, the arrivals would be more regular and the berth waiting time for a given berth utilization would be less. However, these curves can be used with a high degree of confidence for most container terminals.

G. Information systems

145. Many terminal operators have decided to utilize an electronic data processing system to assist in the collection and processing of the required information. It is generally accepted that for terminals handling 100,000 or more containers a year, a manual system, which may have proved very satisfactory up to that point, becomes far less practicable. A computer system can be introduced to handle the large quantity of information. There are, however, cases where efficient manual systems have been successfully used for much larger throughputs.

146. At present, many container terminals have both a manual and a computerized system, but each has a specific function. The manual system serves mainly to assist the terminal operator in the control of all terminal operations (including the location of the containers at the terminal). The computer-assisted system, on the other hand, is used to process invoices, gather statistical data and to present the container operators with detailed information, for example, on the type and number of units at the terminal, the availability of empty units and productivity rates on the ship. The project proposal for a container terminal should include any such data processing equipment as a terminal equipment cost item.

H. Schedule-day agreements

147. The need to achieve a reasonable level of berth occupancy without increasing the probability of ships having to wait has raised the question of the scheduling of arrivals. If vessel arrivals can be scheduled, a much higher berth utilization is possible without significant waiting. It may be possible for agreements to be concluded between container terminal operators and shipping lines for specified schedule-days, particularly with short-sea services. Ships that arrive in the scheduled slot are then guaranteed immediate berthing.

148. Unfortunately. the risk that vessels will be slowed down on deep-sea routes, for example by weather, means that large safety margins normally have to be provided. These destroy much of the advantage of the scheduling, and experience has shown that the ships from several lines arriving at a deep-sea container terminal are only slightly more systematic in their arrival patterns than the traditional liners they replace, The arrival pattern at a terminal is also affected by the hours of work at other ports. For example, if other terminals in the area do not work at the weekend, one that does is likely to find a group of vessels arriving at the end of the week.

149. Faced with this situation, the best that a large container terminal operator may be able to do is to give the fastest turn-round service possible on a first-come first-served basis. The use of a buffer stack of cargo to speed up service is a possibility. There could. for example, be a "post-stack" for import cargoes and a "pre-stack" for export cargoes, the stacks being placed directly on the quay near the vessel.

I. Container feeder services

150. The trend towards concentrating traffic at a small number of pivot or gateway ports is particularly pronounced on the long-distance container routes. The specialized container vessels have become larger and more sophisticated, while the cost of building a modern container terminal is very high. The economics are more and more in favour of unloading and loading all containers at one well-equipped port, and distributing them by coastal feeder vessels to other ports in the region.

151. It is difficult to forecast such developments, and close discussion is needed between the planner and the shipping lines concerned. The attitude of shipping lines is liable to change, and while they may initially wish the mother ships to call at every port, at a later date they may wish to introduce feeder services. Shippers prefer direct calls as this reduces both transport time and the chance of damage to goods.

152. Feeder ships are normally designed for a specific service, with the characteristics of the port in mind. They are relatively small (usually having between 10 and 20 per cent of the capacity of the trunk route vessel), and can be built without ship's gear in order to increase their carrying capacity, to improve their stability and to reduce costs. The majority are probably ro/ro ships, but there are also pure cellular feeder ships and combination ro/ro and lift-off vessels.

153. The load factor of feeder vessels is normally very high, approaching unity. At the ports serviced only by the feeder vessels. however, handling rates—although much higher than with the traditional break-bulk operation-will be lower than at the pivot or gateway specialized terminal because only one gantry-crane can work the feeder vessel. A typical figure of 15 units per hour may be achieved for a feeder ship with a capacity of 100 TEUs. Table 3 gives the principal characteristics of several ships in this class.

TABLE 3

Typical container **feeder ships**

Type	*Dwt*	*Container capacity (TEUs)*	*Overall length (metres)*	*Overall width (metres)*	*Draught (metres)*	*Special features*
Roll-oniroll-off	4 580	176	130	17	6.25	Catamaran design
Lift-on/lift-off	1 260	106	77	13	3.70	Gearless
Roll-on/roll-off Lift-on/lift-off	6 500	330	115	19	7.40	Equipped with angled stern ramp and one 38-ton gantry-crane
Roll-on/roll-off Lift-on/lift-off	2 080	111	87	14	4.70	Equipped with stern ramp and one 30-ton gantry-crane

J. Types of container handling equipment

154. The large size of IS0 containers necessitates large equipment for handling. The choice of a particular handling method is related to the type of traffic (for example, ship to shore, train to truck or truck to ground), the number of containers to be handled per hour and the distance of travel, which depends on the size and the shape of the site and the number of containers to be stored.

1.55. Ship-to-shore gantry-cranes are specially designed for container traffic. They are capable of substantial cantilever lifting, with spreaders mounted on rotating tables so that containers can be aligned straight into a stack, or on to a vehicle (figure 25). These are expensive pieces of plant, a 35-ton capacity crane for ship-to-shore operation costing approximately $4.5 million (mid-1981 values), including the rail track. The planner must design circulation routes so that any stoppage will not interfere with crane movement. For reliability, a terminal will normally require a minimum of two ship-to-shore gantry-cranes.

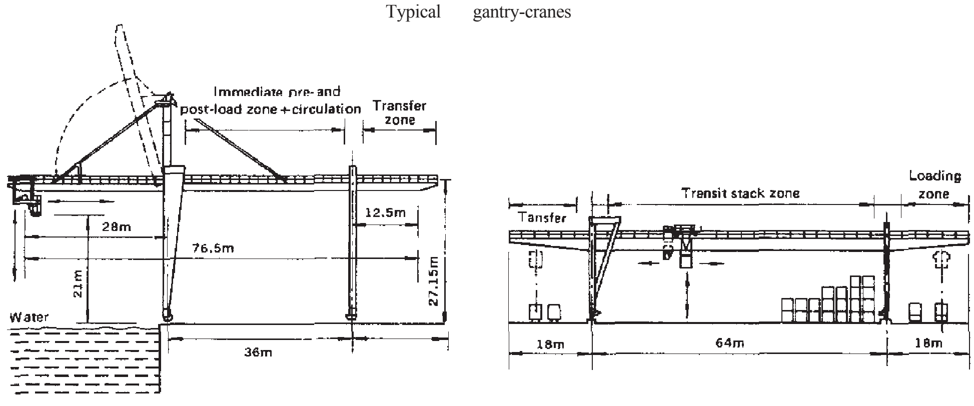
156. Gantry-cranes can also be used in the container yard, where they combine the mobility of straddle-carriers, although slower, with the wide span and height of the ship-to-shore gantry-crane. The yard gantry-cranes may be on rubber tyres, which allows them to move to another task at a different part of the site. The weight of the gantry requires special runways to avoid damage to the terminal surface. Rail-mounted gantries allow wider spans and higher stacking heights. A rubber-tyred gantry crane costs approximately $0.75 million and a rail mounted gantry, including rails, about $1.5 million (mid-1981 values).

157. Straddle-carriers are efficient for linear stacking operations up to a height of three containers. While these carriers are fast and manoeuvrable, they are expensive to buy and operate, with a typical purchase price of $0.5 million (mid-1981 values) for a carrier capable of stacking containers three high. Among the reasons for the high operating costs are maintenance costs and down-time. Modifications are improving the reliability of this type of equipment.

158. Fork-lift trucks can be used for container handling. Operators equip their fork-lift trucks with top-lift or side-lift spreader beams as well. The use of these attachments for container movements by fork-lift truck removes the risk of damage by forks. Normal fork-lift trucks can be used for the handling and stacking of empty containers with fork tunnels, while a special heavy-duty truck is required for full units. The investment for a 35-ton fork-lift truck, including the spreader, is around $300,000 (mid-1981 values). A 3-ton capacity fork-lift truck would cost approximately $30,000 and a 10-ton capacity truck $100,000.

FIGURE 25

Typical gantry-cranes



A. *Ship-loading gantry container crane*

B. Gantry-crane *for stacking and sorting containers and feeding ship-loading crane*