Chapter 1

Introduction

By nature port planning is a multidisciplinary activity. It involves expertise in the field of transport economics, shipping, nautical matters, safety and logistics. But also knowledge of waves and currents, sediment transport and coastal morphology, dredging and land reclamation, and design of breakwaters and quays. Hence port planning is teamwork. But within this team the port planner plays a central role in developing the concepts and obtaining the required expertise at the right time. Most port planners are civil engineers with hydraulic engineering training and experience. But they need to have two important qualities in addition to that:

(i) a basic understanding of the other disciplines involved
(ii) creativity

The first quality is needed to direct the work done by these experts and to integrate the results into a balanced design of the port lay-out. The integration process itself is the creative part of the work: after having determined the basic dimensions of approach channel and turning basins, of quays and terminals and of the corridors for hinterland connections, there are often many ways to physically arrange them into a port lay-out. Here the second quality mentioned above plays a crucial role in developing the right one.

The first part of this book (Chapter 1 through 6) is aimed at providing the basic elements to perform this planning process. In Chapter 7 the detailed planning of container terminals is treated, including the logistic process. Further attention is paid to design aspects, typical for such terminals. The objective is to provide the basis for an all-round port engineer, somebody who can participate in the design of any given type of port or terminal.

Chapters 8-14 present the planning aspects of other types of terminals.

Chapter 2

Maritime Transport

2.1 Introduction

Maritime transport is (in terms of tonne kilometres) the most important of the 6 transport modes, the other five being inland water transport, road, rail and air transport and transport by pipeline. It is relevant to make the distinction between intercontinental maritime transport and that within a continent, because of the different competitive position. For the intercontinental shipping air transport is the only alternative, but not really a competitor because of the great difference in freight rates (see Table 2.1). Broadly speaking only passengers and high-value goods are carried by plane and this share of the market for transportation is well defined.
Maritime transport within a continent has many competitors, road transport being the most important one. Again the air transport mode is quite distinct from the others in terms of freight rate. But maritime transport, road, rail and inland water transport are in the same cost range and therefore in fierce competition. Maritime transport used to be at a disadvantage compared with roads for two reasons:

(i) it often needs additional transport between seaport and final destination. This creates two extra links in the chain, which increases costs, time and unreliability (see Figure 2.1)
(ii) ports presented an uncertain element, due to the conventional custom procedures and the frequent labour strikes, which could cripple transport for weeks.

Both the intercontinental and the continental maritime transport volumes are increasing. The former due to the steady growth of world trade, the latter also because sea transport is becoming more attractive. Customs procedures become shorter by modern technology such

Table 2.1 Freight rates across the Atlantic Ocean

Transport mode	Door-to-door time (days)	Freight rate (US$/kg)
Priority air	2-3	3.30
Standard air	4-7	1.00-1.90
Direct ocean	14-28	0.13-0.26

as *Electronic Data Interchange (EDI)* and *Smart Card*. The reliability of the connections between sea and land transport become better by fixed routes and schedules and in many parts of the world the ports become more 'business oriented' and provide faster and more reliable services.
And last but not least there is an added environmental advantage as the CO_2 emissions are relatively small as compared to other transport modes. Approximate values for CO_2 emission per tonne.km are:

Air transport	550 g
Road transport	50 g
Rail transport	20 g
Maritime transport	3 g

Containerisation in particular represents a major factor in the growth of cargo volume and therefore in the increase of port capacity required. The average growth rate of container terminal throughput between 2000 and 2010 was around 10% per year. This figure comprises the absolute growth of (general) cargo volume, but also the shift of conventional general cargo to containerised cargo. It means new terminal capacity, cranes and other equipment. This is illustrative for the present trend in port development world-wide: quite a number of ports are reaching saturation and are being expanded. Examples nearby are Rotterdam (Maasvlakte 2), Antwerp and Le Havre. The upturn is caused by the impressive economic growth in Asia, in particular in China, where the port of Shanghai at the end of 2004 took over the position of largest port in the world from Rotterdam. The most recent economic crisis has caused a temporary reduction of throughput, but this is being recovered and expectations are that the above mentioned growth will be resumed.
Port development depends on the development of maritime transport, both in terms of volumes per commodity and in relation to types and sizes of vessels. For port planning a good understanding of these developments is mandatory. The following sections present data on ship design and cargo handling (as far as relevant for port planning) and some trends.

2.2 Specific Data of Merchant Ships

2.2.1 Transport Capacity

The tonnage of a ship is an indication of the carrying capacity in terms of the amount of cargo she can transport. Unfortunately, depending on the type of vessel, the country of origin, or the purpose for which the tonnage is used (for instance for harbour dues), there exist several ways to express tonnages. The most important ones are:

GRT	Gross Register Tonnage
NRT	Net Register Tonnage
DWT	Deadweight Tonnage

The relations between these three parameters are not fixed unconditionally: they depend mainly on the type of vessel concerned. However, within certain limits, the following rela-

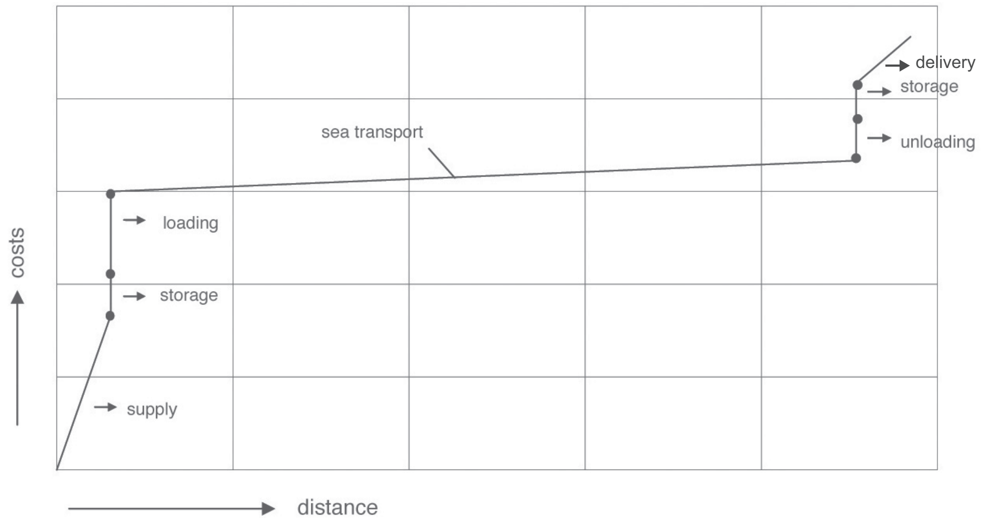


Figure 2.1 Cost elements in a transport chain

tions can serve as a first approximation:

General cargo ships:	DWT $\approx$ 1.5 · GRT $\approx$ 2.5 · NRT,
Very large crude oil carriers:	DWT · 2.0 · GRT $\approx$ 2.6· NRT

The definitions of the tonnages are as follows:

GRT is the total volume of all permanently enclosed space above and below decks, with certain exceptions, such as the wheelhouse, chart room, radio room and other specific space above deck, expressed in tons, in which one ton is equal to 100 ft^3 = 2.83 m^3. GRT is normally used as the basis for calculating port dues.

NRT is the total of all space destined for cargo, expressed in units of 2.83 m^3. The NRT is equal to the GRT minus the crew's accommodation, workshops, engine room etc.

DWT is the difference between loaded and light displacement, in which:

- *Loaded displacement* is the ship's mass when fully loaded, so including hull, engines, cargo, crew etc. Fully loaded means that the ship sinks into the water down to her summer draught line (see Plimsoll Mark).
- *Light displacement* is the mass of the ship's hull, engines, spares, and all other items necessary for normal working performance.

In other words, the DWT gives the mass of the cargo, fuel, crew, passengers, fresh water, victuals, etc. expressed in metric tonnes.
The following units are used:

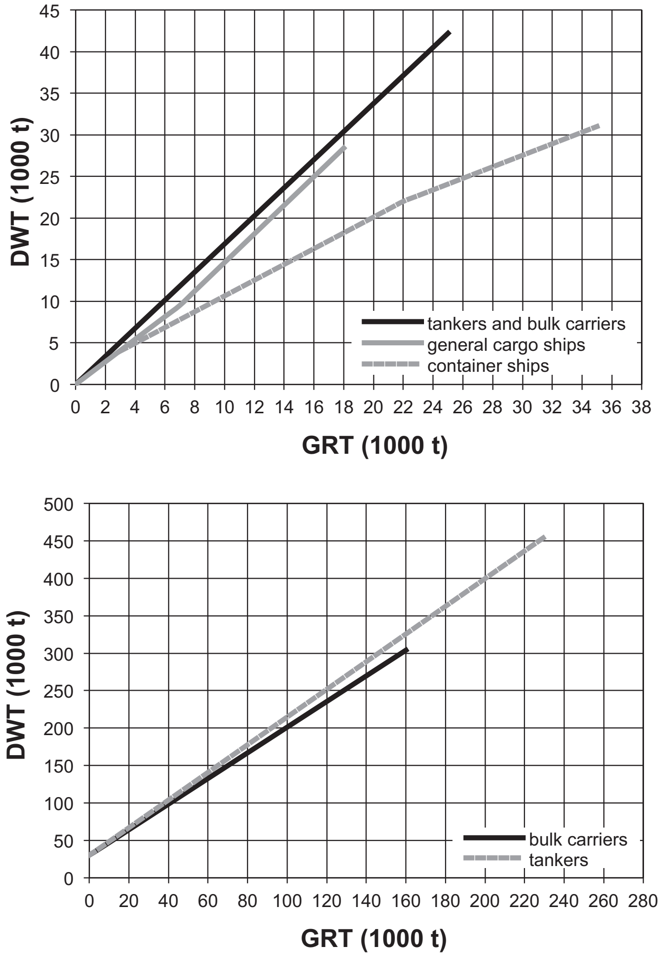


Figure 2.2 GRT versus DWT

- Tonne or metric ton (t = 1000 kg)
- English or long ton (1016 kg)
- Short ton (907 kg)
- Port- or shipping tons are used to determine sea transport charges. A port or shipping ton is equal to 1 m^3 and equal to 1 t when the specific weight of cargo is bigger than 1 t/m^3.

For some specialised ships the carrying capacity is not only expressed in GRT, NRT or DWT, but also in other units, typical for the type of vessel concerned. Examples of this are:

TEU This unit is normally used to express the capacity for container storage on board of a ship. TEU stands for Twenty Foot Equivalent Unit, which is the space taken by a standard container of the following dimensions:

Length	=	20 feet	=	6.03 m,
Height	=	8 feet	=	2.44 m, and
Width	=	8 feet	=	2.44 m, thus
Volume	=	$6.03 \cdot 2.44 \cdot 2.44$	=	35.9 m^3.

2.2.2 Vertical Dimensions

Draught

The *draught D* of a vessel is the maximum distance in meters between the waterline and the keel of the ship (Figure 2.3). Displacement tonnages are calculated in respect of the *draught D* and the *stationary freeboard* h_f, which is indicated on the ship's side.
The maximum draught line is indicated by the so-called *Plimsoll Mark*. This mark is composed of a circle and a horizontal bar with two letters on either side of the circle. The letters stand for the classification society of the Plimsoll Mark, that issues binding conditions for sizes and quality of materials to be used, tests to be carried out, etc. Without "classification" a ship is virtually non-insurable.

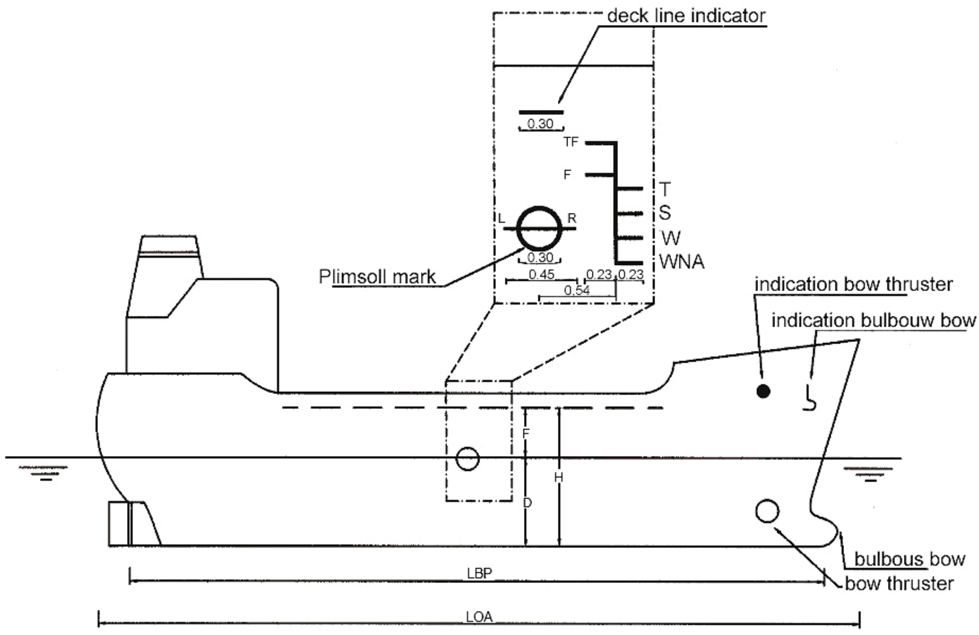


Figure 2.3 Ships dimensions

Most common letters are:

LR: Lloyds Register (England)
BV: Bureau Veritas (France), and
AB: American Bureau of Shipping (USA).

The draught of a vessel is related to the density of the water in which she is sailing (uplifting force). Since the density does not have a constant value over the year, and also differs with *longitude* and *latitude* (a ship sinks deeper into the water in summer around the equator than in winter on the North Atlantic), another indicator is to be found at the right side of the Plimsoll Mark. This indicates the maximum permissible draught under various conditions, such as:

TF	=	Tropical Fresh Water
F	=	Fresh Water
T	=	Tropical Salt Water
S	=	Summer Salt Water
W	=	Winter Salt Water, and
WNA	=	Winter Salt Water on the North Atlantic

A certain safety margin is also incorporated in the markings of maximum permissible draught. The draught of a vessel is indicated by numbers that are painted on both sides of the ships hull, usually at the bow, amidships, and at the stern. Often, these figures indicate the draught in feet (1 foot = 0.308 meter).

2.2.3 Horizontal Dimensions

Length

The length of a vessel can be expressed in two different ways:

L_{BP}: Length Between Perpendiculars, and
L_{OA}: Length Over All

Both lengths are indicated in Figure 2.3.
The definitions are as follows:

L_{BP}: is the horizontal distance in meters between the points of intersection of the ship's bow and the summer salt water line when fully loaded and the vertical line through the axis of the rudder of the ship.
L_{OA}: is the horizontal distance between two vertical lines; one tangent to the ship's bow and one to the ship's stern.

For dimensioning harbour basins and berths normally L_{OA} is normative. Unless specifically mentioned L_{OA} is used in this book.

Beam

The *beam* or *breadth* B_s, is the maximum distance in meters between the two sides of the ship.

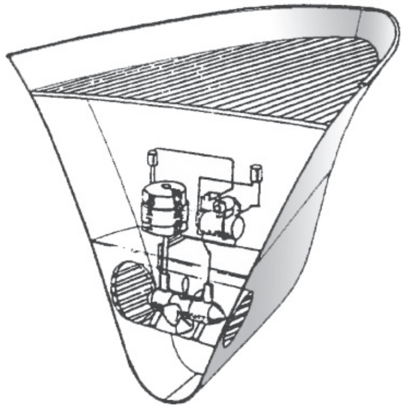


Figure 2.4 Kamewa bow thruster

2.2.4 Other Relevant Data

Without going into the details of ship design some information is relevant for the manoeuvrability and hence for the design of approach channels and water areas inside a port.
Engine power and number/type of thrusters are decisive in this respect. Extremes are on one hand large bulk carriers and (high speed) ferries on the other. Notwithstanding their size some of the large ore carriers and crude oil tankers are equipped with only one screw or propeller and have a relatively low engine power. They are designed for long distance, low speed transportation and will require assistance by 3 or 4 tugs during arrival and departure in the ports.
Ferries are generally overpowered and are provided with 2 or more propellers and often 1 bow thruster (Figure 2.4). High-speed ferries have water jets instead of propellers.
Many ships built today are equipped with one or more thrusters, either at the bow or at the stern or both. For safety reasons the presence of a bow thruster is indicated on the bow above the waterline.
Vessel speed is expressed in *knots*. One knot is equal to one nautical mile (or 1852 meter) per hour, equivalent to 0.514 m/s. The maximum speed of bulk carriers and VLCC's amounts to 18 knots. Ferries are designed for maximum speeds of about 24 knots and empty high-speed ferries have maximum speeds of about 40 knots, while the service speed (full load) amounts to 35 knots.

2.3 Commodities and types of vessels

2.3.1 Introduction

Cargo flows can be classified according to type of cargo and according to the form in which it is transported (dry bulk, containers, etc.).
The first classification follows the internationally agreed division into 10 main groups of cargo referred to as *NSTR* (*Nomenclature uniforme des marchandises pour les Statistiques*

de Transport, Reviseé).
These main groups are:

0. Agricultural products and livestock
1. Other food products and fodder
2. Solid mineral fuels (e.g. coals, cokes etc)
3. Oil and oil products, incl. fuel gas
4. Iron ore and metal scrap
5. Iron, steel and non-ferro metals
6. Raw minerals; construction materials
7. Fertilisers
8. Chemical products
9. Vehicles, machinery and other goods

Standardisation of these categories allows to use the statistics of different countries and individual ports to quantify international flows of cargo and to forecast future developments. As explained in Chapter 4 any port planning study starts with such forecasts dealing with above main groups of cargo, but often going into subcategories (e.g. fruits as a subcategory of Agricultural products).
For the subsequent physical planning of terminals within a port master plan, the cargo characteristics are important in so far as they affect the location and possible combination of different cargo flows within the port area. These considerations will be treated in the chapters on terminal design, but a simple example may illustrate such effects: Categories 3 and 8 include hazardous goods and are therefore subject to safety requirements regarding the location of such terminals with respect to other terminals and surrounding areas.
The second classification of cargo is important for the actual design of terminals. With respect to the form in which cargo is transported the following division is made:

A. Dry bulk
B. Liquid bulk
C. Containers
D. Roll-on/Roll-off
E. Other

The last category ”Other” is almost identical to conventional general cargo, which includes the *break-bulk cargo* (many pieces of various dimensions and weights), *mass-break-bulk* or *neo-bulk* (many pieces of mostly uniform size and sometimes uniform weight) and *bagged goods*.
In the next section these categories of cargo types will be discussed as well as the different types of vessels in which they are carried. Furthermore, special types of vessels will be treated, such as ferries and cruise vessels for passenger transport. For further reading on shipping business reference is made to the Unesco-IHE lecture notes on Merchant Shipping (Kruk and De Heer, 2005). Many of the examples of different types of ships shown in the subsequent pages have been taken from ’Shipping’ (Wijnolst e.a. 1996). And the graphs

(in Figures 2.32 - 2.26) with typical dimensions of General Cargo-, container-, dry bulk- and oil tankers respectively have been updated on the basis of the study ’Ship dimensions in 2020’ (Lloyd’s Register M.S., 1998).

2.3.2 Break-bulk or Conventional General Cargo

Break-bulk is defined as all kinds of boxes, crates, bags, sacks, drums, machine parts, refrigerated cargo as fruit, meat etc. Generally the break-bulk cargo will be transported by one of the three types of break-bulk ships, i.e. conventional general cargo ships, multipurpose ships and refrigerated ships.

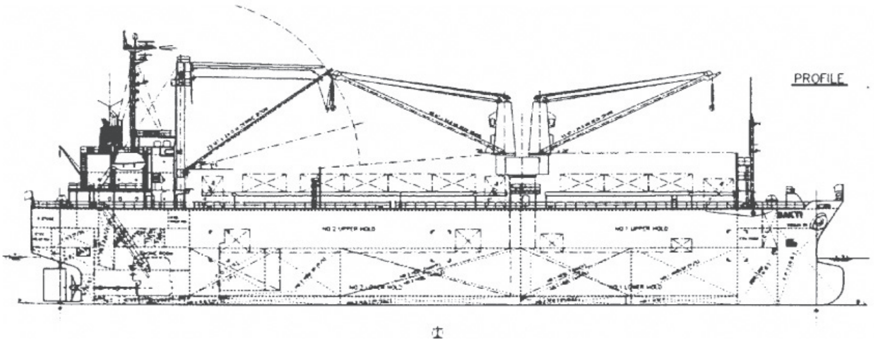
General cargo ship

A general cargo ship may carry all kinds of break-bulk cargo. The weight of each piece of cargo (a *lift*) is limited by the maximum lifting capacity of the shore based crane or the ship’s derrick. Each piece of cargo is handled separately or sometimes as an assembly of some smaller items. The *cassette system* is relatively new, and designed for efficient handling of rolls of paper.

Table 2.2 Freight rates across the Atlantic Ocean

Categories of break-bulk	Shape or packing	Cargo handling method
1. Bagged goods	Undefined shape	Ropes, on pallets
2. Normal break-bulk	Crates, boxes, drums	Ropes, hooks, pallets
3. Neo-bulk	Steel plates, bars and wire, lumber and timber, paper	Ropes and hooks, cassettes

The general cargo ship is the archetype of cargo ship. All new, specialised vessels originate from the general cargo ship.



Length Over All:	113.22 m
Length Between Perpendiculars:	105.40 m
Breadth:	19.60 m
Draught:	7.29 m
Deadweight:	8,739 t
Maximum speed:	13.30 knots

Figure 2.5 General cargo ship 'Sakti'

The capacity of the conventional general cargo ship ranges from 5000 to 25000 t. It has four to five holds (space for cargo storage below deck) and usually one or two tween decks, which run all along the ship. This makes it possible to stow cargo in such a way, that it can be distributed evenly over the ship's length and/or to unload a certain quantity of cargo in a certain port without moving other cargo as well.
The older general cargo ships can easily be identified by the many derricks (ship's cranes) placed on deck. These are arranged in such a way, that each hold can be served by at least

two derricks. The older designs of general cargo ships show the wheelhouse amidships, but more recent designs show a tendency to place it three-quarters aft or aft.
The draught of the vessel is usually small, ranging from 7.5 to approximately 10 meters, which enables the ship to call at most ports of the world, even the smaller ones. An example of a general cargo ship is shown in Figure 2.5.
Over the recent years, when more and more emphasis was put on the reduction of the ship's turnaround time, some new developments took place in design, as well as in cargo handling methods, of the general cargo ship:

a. The openings of the holds (hatches) became wider and were placed in one vertical line to ease the vertical movement of cargo. It even became possible to lower small equipment for cargo handling, such as forklift trucks, into the holds. The aim to achieve unobstructed movements of cargo was also one of the reasons why nowadays most wheelhouses of general cargo ships are placed aft instead of amidships.
b. Horizontal cargo handling through side loading ports (see Figure 2.6)
c. The development of the *Unit Load Concept (ULC)*, from pallets to other forms of unitization such as cassettes for paper.

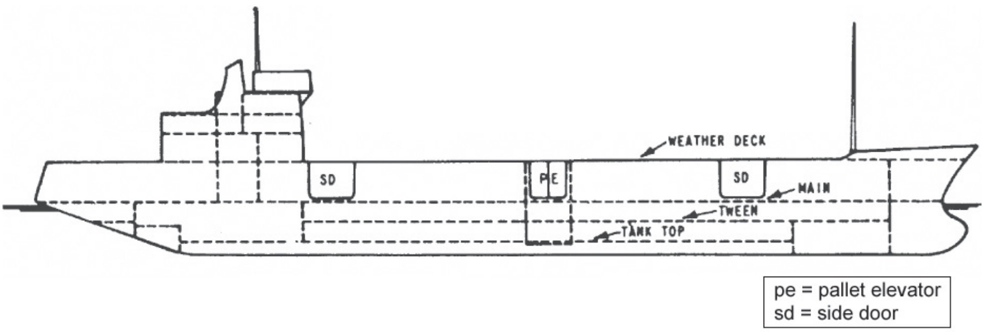


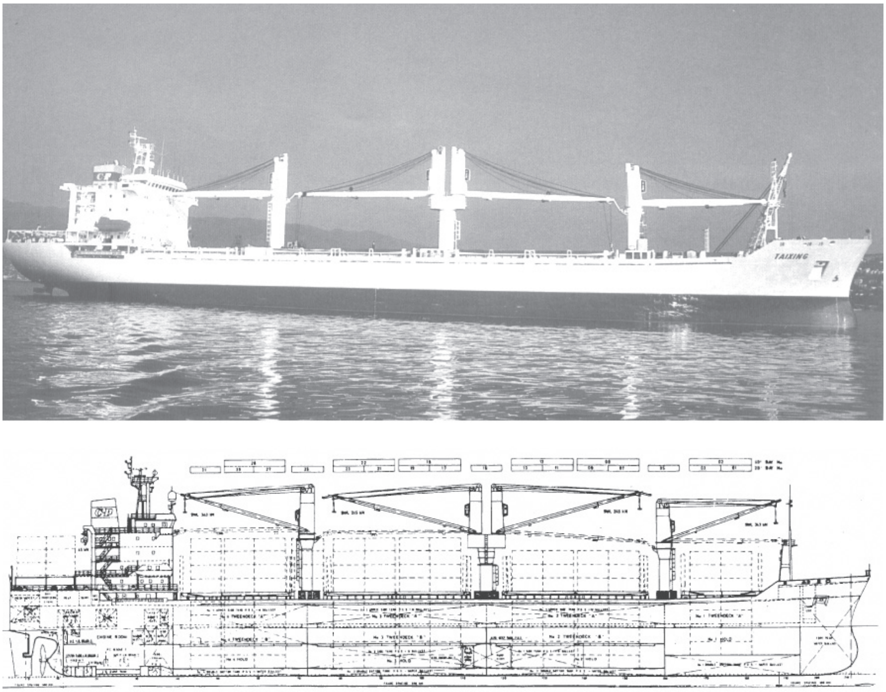
Figure 2.6 Horizontal cargo handling through side loading doors

Multipurpose ship

The multipurpose ship, in fact a general cargo ship, capable of transporting almost any piece of cargo, ranging from a small box to a container or even a truck. The designs made in recent years also show a limited capacity to carry bulk cargo, either liquid (oil, chemical products), or dry bulk (grain, ore, etc.) and refrigerated cargo. Especially directed toward less developed ports, the ship has heavy lifting equipment on deck. The ship can easily be defined by:

a. The robust shape and heavy lift deck equipment.
b. The hatch covers that have been constructed in such a way that they can withstand the load of heavy pieces of cargo or containers placed on it.
c. Bow thrusters and bulbous bow.
d. Side loading doors for horizontal cargo handling.

An example of a multipurpose ship is shown in Figure 2.7.



Length Over All:	169.69 m
Length Between Perpendiculars:	162.50 m
Breadth:	27.50 m
Draught:	9.32 m
Deadweight:	22,271 t
Maximum speed:	16.20 knots

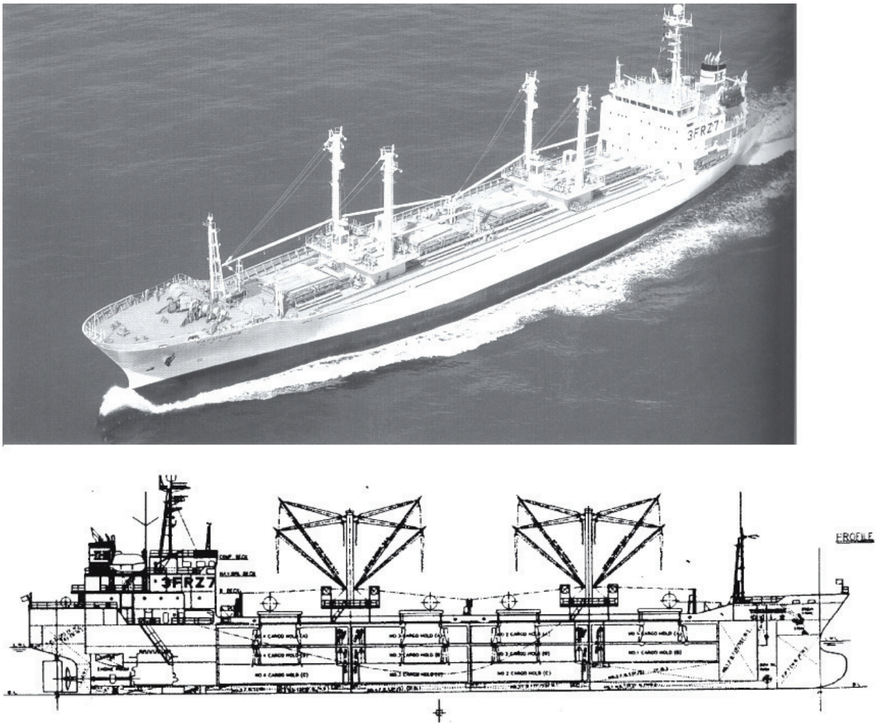
Figure 2.7 Multipurpose ship 'Taixing'

Refrigerated general cargo ship (reefer)

This general cargo ship is solely used for the transportation of fruit, meat, or other perishable commodities, which are kept on board at temperatures between 30°C and 12°C.
The *reefer* distinguishes herself from the conventional general cargo ship by the following features:

- the ship is usually painted white
- her speed is higher; usually from 18-25 knots
- she looks quite elegant and fast; the appearance is streamlined

In recent years, container ships are provided with slots for *refrigerated containers*. These do not supplant the specialised ships such as a *reefer*, of which an example is given in Figure 2.8.



Length Over All:	120.12 m
Length Between Perpendiculars:	111.60 m
Breadth:	16.80 m
Draught:	7.00 m
Deadweight:	5,563 t
Maximum speed:	18.87 knots

Figure 2.8 Refrigerated cargo ship 'Yakushima'

2.3.3 Container Vessels

Notwithstanding the introduction of ULC in the handling of break-bulk cargo the turnaround times of general cargo vessels remained high. After World War II world trade increased rapidly and with it the sea transportation, leading to serious congestion in the ports and long waiting times.

The container had been introduced in the fifties as standard size box for the transport of cargo by truck and rail across the USA. Its use in sea transport seemed a logic step in view of the abovementioned problems, but received initially severe resistance, in particular by the powerful unions of dockworkers. It did reduce the turnaround times and waiting times in ports substantially. Initially limited to coastal shipping along the US West and East Coast, the first *SeaLand containers* arrived in Rotterdam in 1966. Over the past 45 years container shipping has spread across the globe, taking over a major share of the general cargo trade.

The first containers had dimensions of 8 ft.×8 ft.× 20 ft. (2.44×2.44×6.10 m). Because of this dimension the capacity of a ship or a container storage yard is still expressed in *Twenty Feet Equivalent Units (TEU)*. Nowadays forty feet long containers are used besides the twenty feet, and other sizes have been introduced for length, width and height.

The increased productivity is partly due to the fact that many pieces of cargo are packed into one container, that can be handled in one lift, and partly due to the use of the twist lock during handling and transportation (Figure 2.9). The *twist locks*, that are mounted on the spreader, are inserted into the four upper corner castings of the container and fastened automatically in a matter of seconds. On a truck or rail wagon the lower four corner castings are also fastened by twist locks.

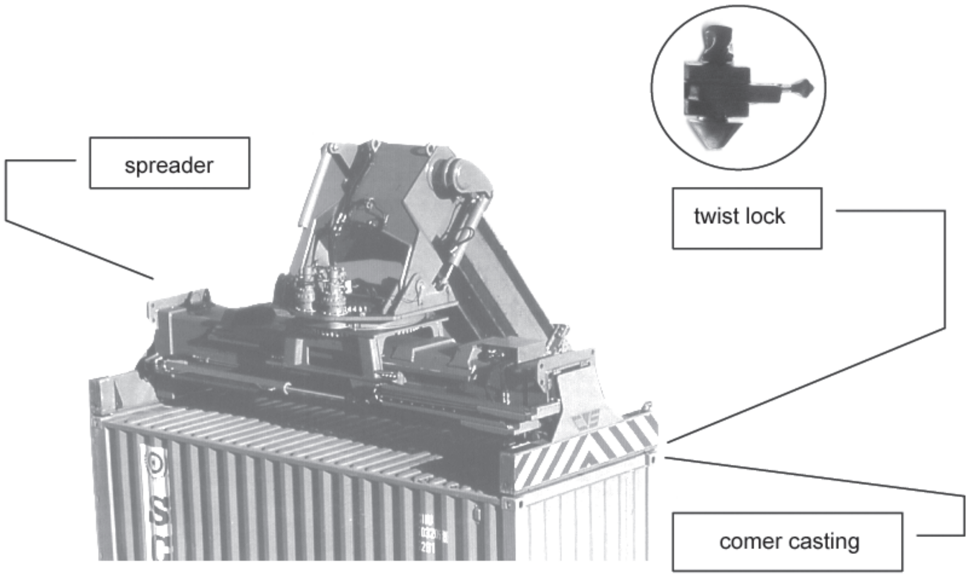


Figure 2.9 Twist lock and corner casting

The ”first generation” container ships were general cargo vessels, converted to carry containers. Since then several classes of container ships have been built with increasing dimensions and capacities (see Table 2.3).

Table 2.3 Container vessel characteristics

Class	TEU capacity	DWT (average)	L (m)	D (m)	B (m)
1st generation	750-1100	14,000	180-200	9	27
2nd generation	1500-1800	30,000	225-240	11.5	30
3rd generation	2400-3000	45,000	275-300	12.5	32
4th generation	4000-4500	57,000	290-310	12.5	32.3
Post Panamax	4300-5000	54,000	270-300	12	38-40
Super Post Panamax or Jumbo	6000-9000	90,000	310-350	14	43
Ultra Large Container Ship (ULCS)	14,000	157,000	400	15.5	56.

The following points should be noted:

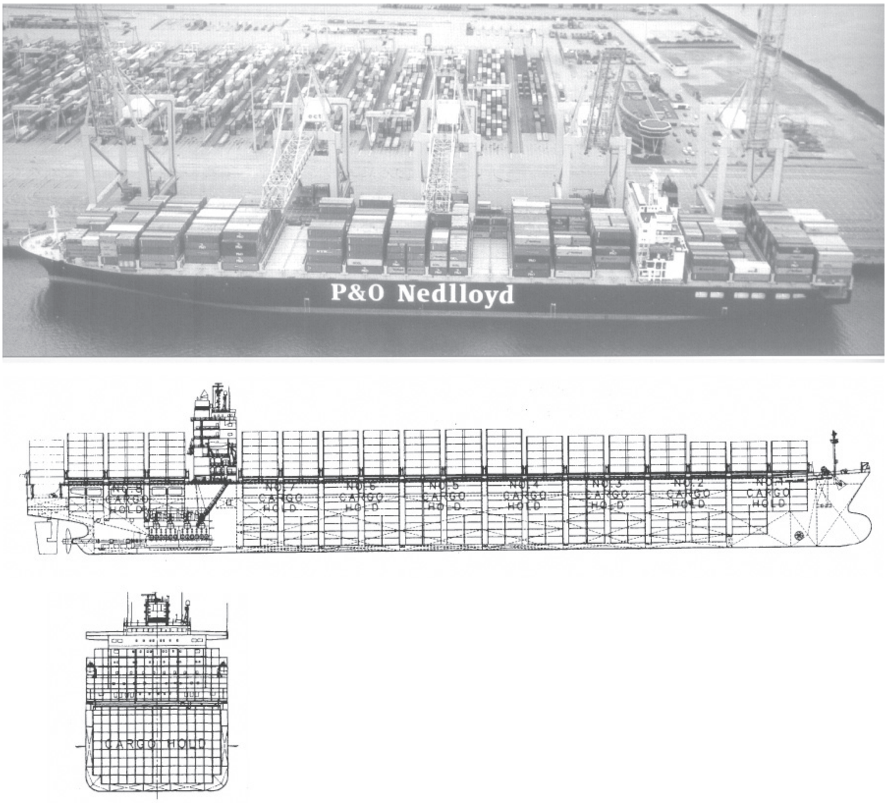
(i) the 2nd and subsequent generation ships were designed to carry only containers, the so-called full or cellular container ships. The boxes were placed below deck in the bays, divided into cells with vertical guiding rails along which the containers are lowered into and hoisted out of the bay. On deck the containers are arranged in rows parallel to the ship's axis and secured by lashing systems.

(ii) up to the 4th generation the vessels have a beam limited to 32.3 m, allowing them to pass the locks in the Panama Canal. Traffic between the East- and West coast of the USA was still of high economic (and military strategic) importance. In the eighties the Asia-Westbound and Pacific Trades became more dominant, and shipping lines made the step to Post Panamax, accepting that these vessels could not pass the Panama Canal.

(iii) in 1996 the vessel size made a considerable jump to Super Post Panamax or Jumbo (see Figure 2.9). It is pointed out that this growth does not only require greater depth, but also leads to higher cranes, with longer booms.

(iv) In 2006 another jump was made by the addition of the Emma Maersk to the fleet of this shipping company. This ship was officially listed having a capacity of 12,500 TEU, but from its dimensions (of which the draught is estimated) it can be deduced to be at or above 14,000 TEU.

(v) Early 2011 Maersk Lines has ordered 50 new ships with a capacity of 18,000 TEU, L_s = 400 m, B_s = 58 m and D = 15.0 m.



Length Over All:	299.00 m
Length Between Perpendiculars:	283.80 m
Breadth:	42.80 m
Draught:	13.50 m
Deadweight:	83,826 t
Maximum speed:	24.50 knots

Figure 2.10 Jumbo container ship 'P&O Nedlloyd Southampton'

Another trend in container ship design was the introduction, by former Nedlloyd (now Maersk), of hatch coverless vessels with full height cell guides (including 4 tiers high above the board of the ship).

The time involved in lifting off the hatch covers, removing the lashings and placing both back (roughly two hours for the larger ships) would be eliminated. A number of ships of this design has been built (Figure 2.11), but in practice the reduction of service time in port appears to be less than anticipated. Some negative effects of the design, e.g. overcoming seawater in the holds, made that the concept did not get follow-up.

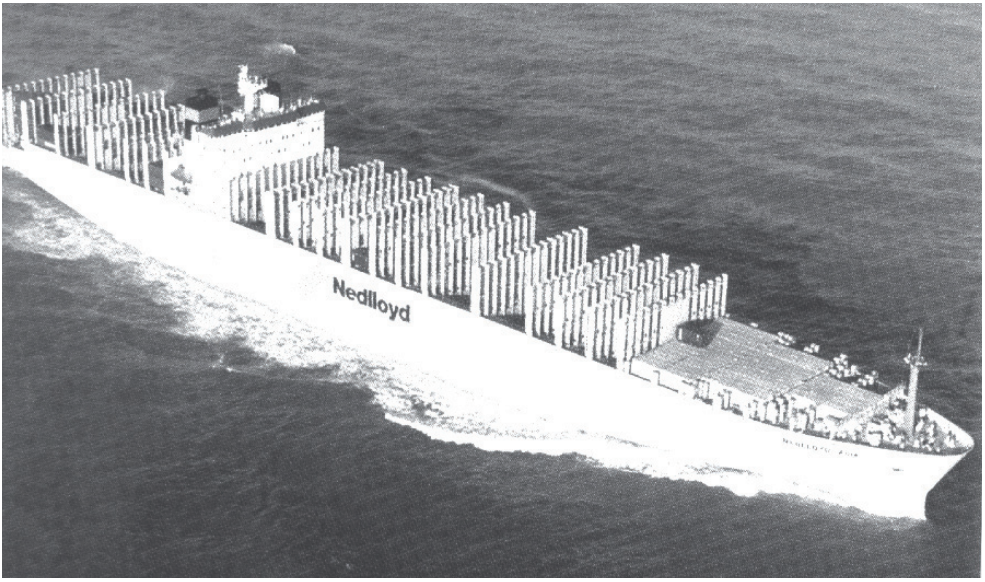


Figure 2.11 Container ship without hatch covers

In the early period of containerization some ships carried their own equipment to handle the boxes. This is the *shiptainer*, a gantry crane on board of the vessel, able to run from forward to aft on rails on the deck. In ship new-building this is no longer practice, mainly because most ports have shore based cranes (portainers, see Figure 2.12).

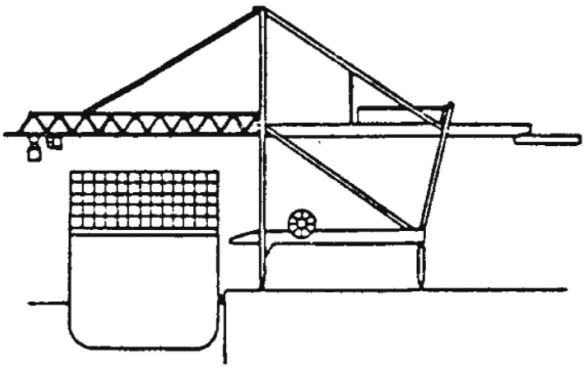


Figure 2.12 A portainer

2.3.4 Ro/Ro Vessels

Another type of unitised cargo, which was developed in road transport, is the *trailer*. They are also known as *continental containers*, but have two important differences with the sea containers: they are not fit to carry the weight of other containers and they can not be lifted (no corner castings). While *sea containers* are sometimes referred to as *Lo/Lo* cargo (lift on / lift off), the transport of trailers and trucks is known as *Ro/Ro* (roll on / roll off). In most cases the chassis are carried overseas without the trucks. Movement onto and from the ship is done by special yard equipment. At some terminals the entire truck-trailer combination is taken aboard.

The Ro/Ro ships are therefore comparable with ferries, they must have a facility to drive the cargo on and off the ship. Contrary to the ferry, which normally sails on short routes only, this type of ship serves on the longer routes.

The first types of Ro/Ro ships usually had the ramp at the stern of the ship. When at sea it was pulled up into a vertical position and in port it was lowered onto the quay. The disadvantage of this type of ramp is, that a special place in the port or even a special berth construction is necessary (see Figure 2.13). The manoeuvring with long trailers may be difficult, since much space is required which is not always available. The problems with high tide differences were solved by use of a pontoon between ship and quay.

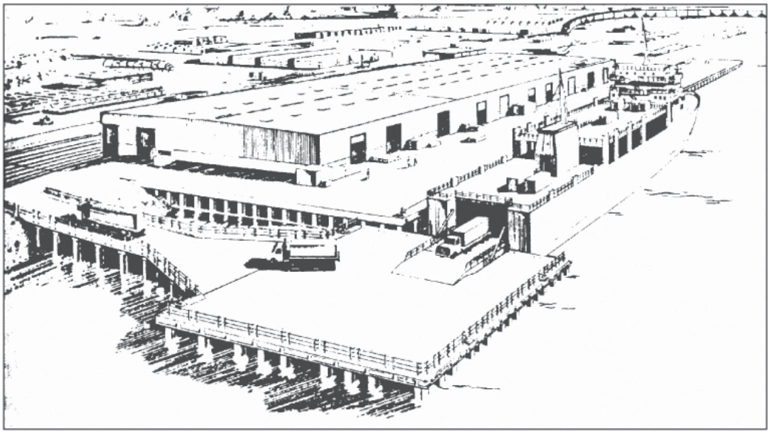


Figure 2.13 Special berth structure

To attain more flexibility in the allocation of a berth in a port, Ro/Ro ships were later on provided with a quarter ramp, which makes an angle with the axis of the ship and enables the ship to berth at any part of a straight quay (see Figure 2.14).

The carrying capacity of Ro/Ro ships is usually expressed in lane length, being the total length of the lanes in which the Ro/Ro cargo is placed on the different decks of the ship (standard width of 2.50 m). The latest types of Ro/Ro ships have a total lane length of about 6000 m. An example of a Ro/Ro ship will both quarter and stern ramp is given in Figure 2.15.

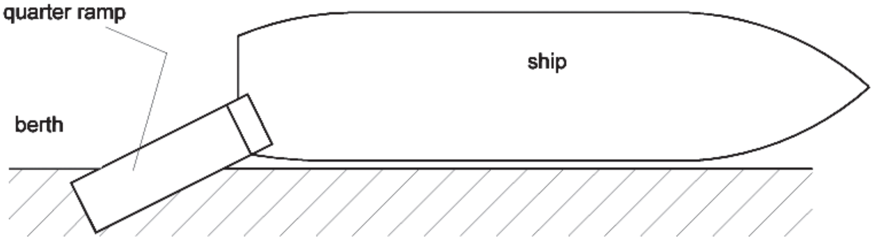
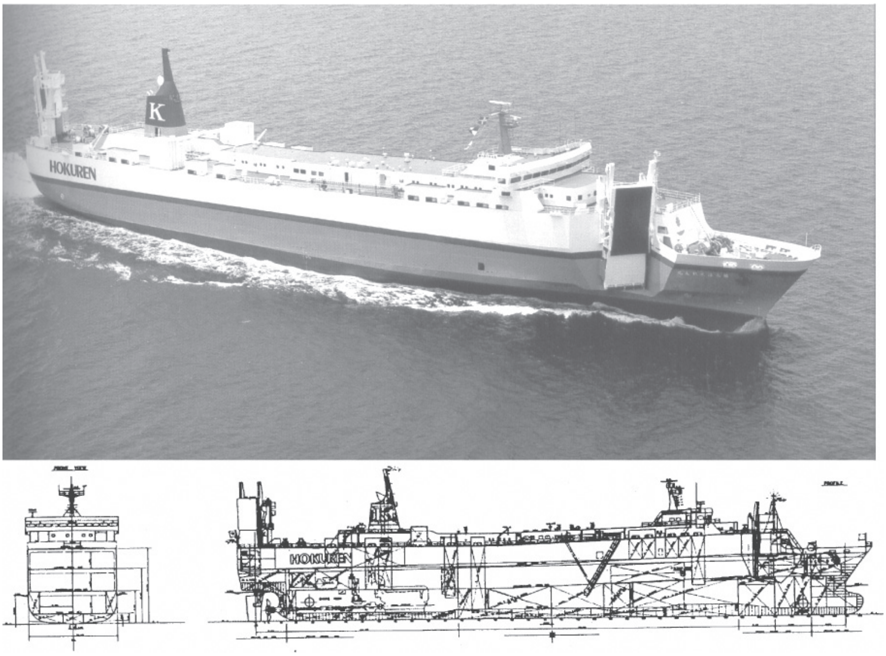


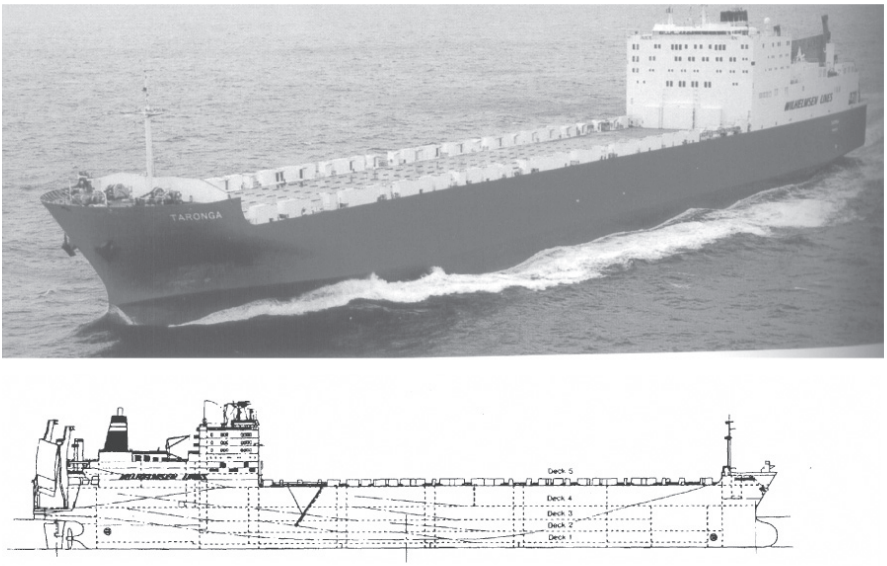
Figure 2.14 Quarter ramp

Various ship designs exist, combining Ro/Ro facilities with place for sea containers, the latter usually on the deck. An example of such a Ro/Ro-container ship is given in Figure 2.16.



Length Over All:	153.62 m
Length Between Perpendiculars:	142.80 m
Breadth:	21.40 m
Draught:	6.975 m
Deadweight:	5,445 t
Maximum speed:	24.971 knots

Figure 2.15 Ro/Ro ship 'No. 2 Hokuren Maru'



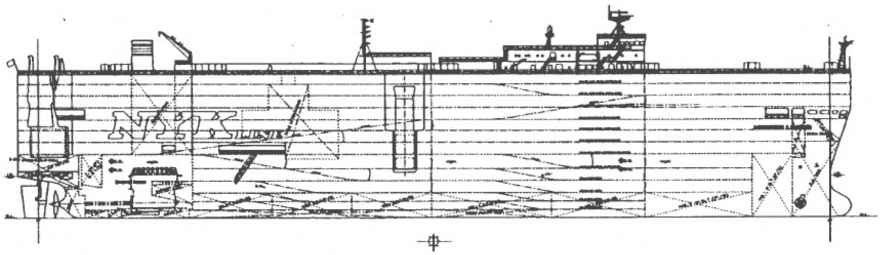
Length Over All:	264.60 m
Length Between Perpendiculars:	249.00 m
Breadth:	32.26 m
Draught:	11.75 m
Deadweight:	47,144 t
Maximum speed:	22.16 knots

Figure 2.16 Ro/Ro container ship 'Taronga'

2.3.5 Car Carriers and Other Special Vessels

Car carrier

These ships have been designed for the transportation of newly built motorcars from the producer to the consumer markets. Like Ro/Ro vessels they have ramps to the shore. In addition to the quarter ramp, these vessels often have one or more side ramps to speed up the loading and unloading process. Because the net load of motorcars is relatively low, these vessels have a small draught and a large freeboard, as shown in Figure 2.17. This implies that they are sensitive to wind and require substantial tug assistance while in port.



Length Over All:	199.93 m
Length Between Perpendiculars:	190.00 m
Breadth:	32.26 m
Draught:	10.00 m
Deadweight:	22,815 t
Maximum speed:	20.61 knots

Figure 2.17 Car carrier 'Aquarius Leader'

Lash ship

The *lash* (Lighter Aboard Ship) is an example of integration of sea and barge transport. The principle of the system is as follows:

1. The cargo is stowed into a floatable barge at the producer's premises.
2. The barges are pushed or towed to the place where the Lash ship is to arrive, where they are put in a barge parking area.
3. After the Lash ship has arrived, the barges for the port concerned are unloaded and the already parked barges are put on board of the Lash ship.

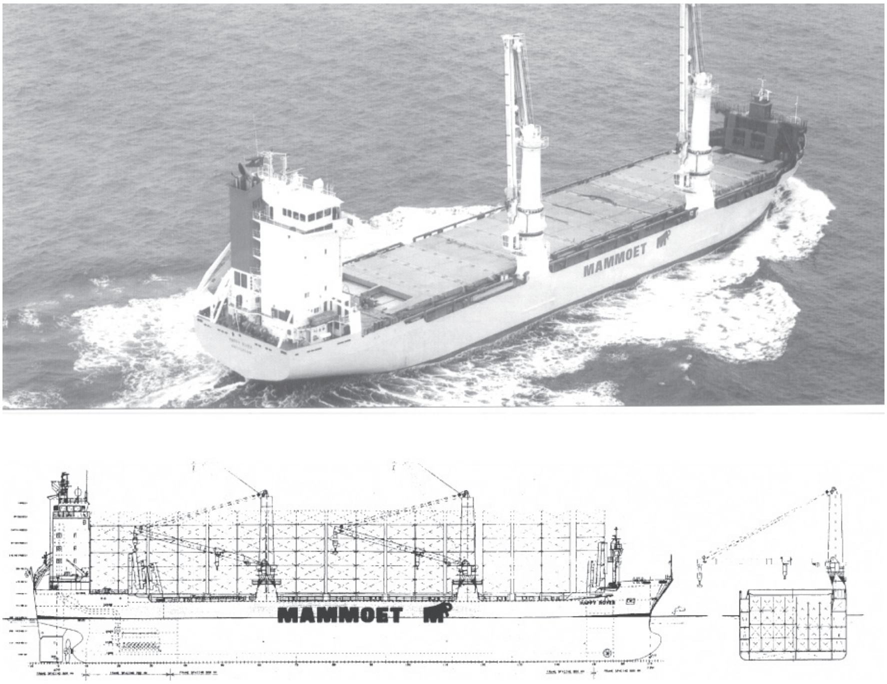
Figure 2.18 Lash ship 'Arcadia Forest'

4. The unloaded barges are put together in a formation and pushed or towed to the customer.

This set-up is the application of an advanced door-to-door transport system, provided consumer and producer can both be reached by water. Within the system the barges become the means of transportation itself.
The *Lash ship* was still in use till recently, for instance in the Waalhaven, Port of Rotterdam, an area was reserved for the mooring of these vessels and the parking of barges. Yet there is no new building of Lash ships reported in recent years and the service to Rotterdam has been abandoned.

Heavy lift carrier

The *Heavy Lift Carrier (HLC)* is another specialised ship, designed to transport huge, heavy units of cargo, that cannot, or can hardly be transported by any other type of vessel. Cargo, carried by HLC's, may for instance be dredgers, assembly parts of factories or refineries, drilling platforms, container cranes, etc. The ship is characterised by the vast deck-space, on which the superstructure with the wheelhouse has been placed at one of the extremes (either at the bow or at the stern), to create as much deck place as possible. Another characteristic is the presence of the one or more heavy-duty cranes or derricks with capacities of up to 500 t or more. The cargo can be placed on deck either by the ship's own gear or by auxiliary equipment, such as a floating or shore based crane or can be put on board in the roll-on/roll-off fashion, provided the HLC is equipped with a ramp. The method of operation of some HLC's is such, that the cargo can also be put on board by floatation, because the ship is submersible (in the same manner as a *floating dry-dock*). See Figure 2.19 for an example of a heavy lift carrier.

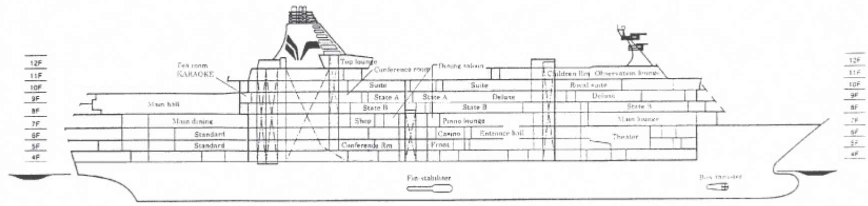


Length Over All:	138.00 m
Length Between Perpendiculars:	127.94 m
Breadth:	22.80 m
Draught:	9.50 m
Deadweight:	15,634 t
Maximum speed:	16.0 knots

Figure 2.19 Heavy lift carrier 'Happy river'

Cruise ships

Modern cruise ships are getting bigger, to such extent that existing terminals become inadequate, in terms of water depth or passenger facilities or both. Hence a lot of new cruise terminals are built, especially in the popular regions such as the Caribbean, the Mediterranean, etc. See Figure 2.20. The largest cruise ships under construction or in operation are of the Genesis class, measuring $L = 362$ m, $B = 47$ m and $D = 9$-10 m have a length overall of 330 m.

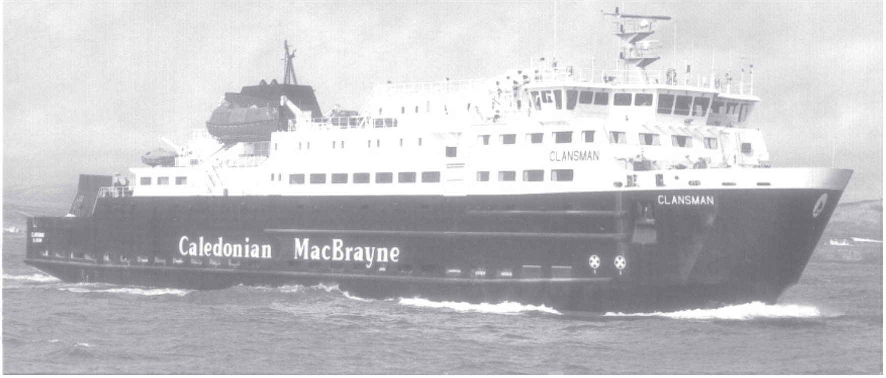


Length Over All:	183.40 m
Length Between Perpendiculars:	160.00 m
Breadth:	25.00 m
Draught:	6.50 m
Deadweight:	4,202 t
Maximum speed:	21.97 knots

Figure 2.20 Cruise ship 'Pacific Venus'

Ferry

The ferry vessel is also showing much development, both in terms of size and speed. As mentioned before, the ferry is employed on fixed routes over limited distances. They carry passengers, motor cars and trucks in different percentages, depending on the demands for each. In the past ferries used to transport entire train lengths, e.g. in connecting the rail lines on the Danish islands with the German and Swedish systems. Although these rail ferries still exist, they are not common in other parts of the world. The development of size is shown in Figure 2.21 showing one of the most recent designs.



Length Over All:	99.00 m
Length Between Perpendiculars:	91.20 m
Breadth:	15.8 m
Draught:	3.22 m
Deadweight:	600 t
Maximum speed:	16.50 knots

Figure 2.21 Ferry 'Clansman'

Figure 2.22 HSS 1500

The need to reduce transit time (in order to remain competitive with other modes of transport) led to the development of high speed ferries. Although smaller types have been in use for decades, several very large ships came into service, such as the HSS1500 by Stena Line, in the Baltic and Irish Sea. With its cruising speed of 40 knots, it reduces the total transit time by 50% (see Figure 2.22). Negative aspects of these vessels are the high fuel consumption (and large emissions) and the large wash waves generated, which forces them to reduce speed when approaching the coast.

Fast Ship

In Section 2.1 it was mentioned that there is little competition between international shipping and air transport because of the clear market and freight rate differentiation. In recent years one exception has developed, i.e. the fast ocean going vessels, which are designed to transport certain high-value cargo which used to be carried by plane. In Japan the so-called *Techno Super Liner* is actually built and in operation, having a capacity of 150 TEU, and a maximum speed of 54 knots (see Figure 2.23).
For service between the US-East coast and Europe the Fast Ship concept has been developed in conjunction with a very special type of terminal, the *Alicon system*. This ship is designed to carry 1450 TEU at a cruising speed of about 40 knots, thus reducing the sailing time across the Atlantic Ocean from 8 to 3.5 days. The concept is not yet realised, but plans were well advanced to start a regular service between Philadelphia and Cherbourg. Here also the high fuel consumption and negative environmental impact may play a role.
In terms of freight rate this type of vessel fits in between air transport and conventional shipping. Regarding environmental impact it also falls in between these two modes.

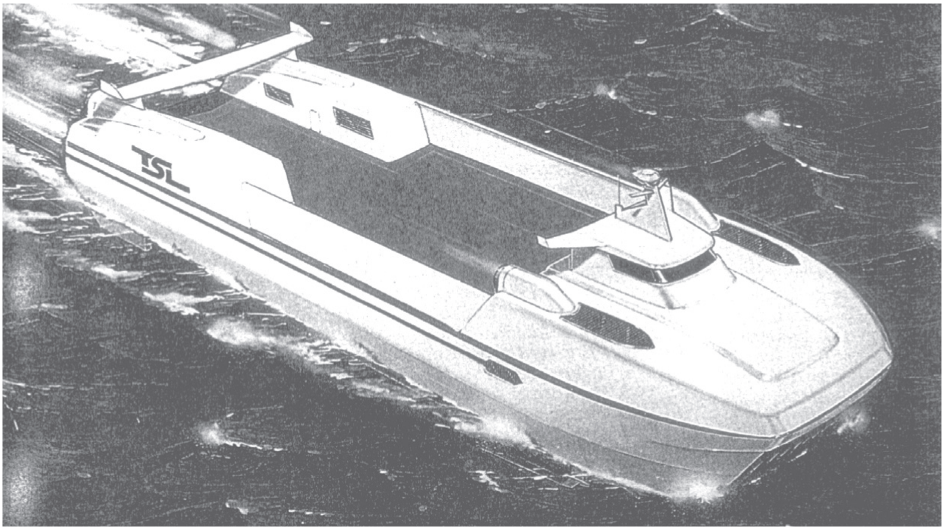


Figure 2.23 Artist impression Techno-Super liner (1993)

2.3.6 Bulk Cargo

Introduction

Bulk carriers usually carry large quantities of homogeneous, unpacked cargo, for instance liquids (oil, liquefied gas), chemical products (phosphate, fertilizer), cement, iron ore, coal, agro products (grain, rice etc.). Because of the homogeneous nature, this cargo can be handled in a more or less continuous way. The handling of bulk cargoes can be executed in various ways, such as pumping (liquids), sucking (cereals), slurrying (mixture of dry bulk cargo and liquid, which can be transported by pipeline), or by a combination of grabs and a conveyor belt system (coal and ores).
Bulk carriers can also be subdivided in several types, which will be treated in the following sections. In principle two types exist, viz.

1. Liquid bulk carriers
2. Dry bulk carriers

Table 2.4 gives an overview of the different bulk carrier types:

Table 2.4 Bulk carrier types

Type	Cargo	DWT (1000 t)
1. Liquid bulk		
– Crude carrier	Crude oil	20-40
– Product tanker	Refined products	0.5-100
– Parcel tanker	Refined products, chemicals	0.5-40
– LNG tanker	Liquefied natural gas	60-90
– LPG tanker	Liquefied pressurized gas	0.5-70
2. Dry bulk	Ore, coal	100-365
	Chemical	5-70
	Agro products	0.5-10

In addition, bulk carriers are classified according to size as shown in Table 2.5.

Table 2.5 Size classes of bulk carriers

Class	DWT (1000 t)
Handysize	20-30
Handymax	45
Panamax	79
Aframax	79-120
Suezmax	120-180
VLCC	200-300
ULCC	> 300

Liquid bulk carriers

Crude oil tanker (See Figure 2.24) Before the World War II, the consumption of oil was limited, because coal was the major source of energy in those days, and crude oil was therefore transported by small tankers. When after World War II the consumption started to rise (and soon to boom), the modern crude oil tankers appeared and soon grew larger and larger in size, trying to keep pace with the demands and trying also to reduce the transportation costs as much as possible (cost per tonne cargo diminishes with increasing vessel size).

Length Over All:	332.94 m
Length Between Perpendiculars:	320.00 m
Breadth:	60.00 m
Draught:	21.10 m
Deadweight:	300,058 t
Maximum speed:	16.80 knots

Figure 2.24 Ultra Large Crude Carrier 'New Vanguard'

The most important producers (and exporters) of crude oil are the Middle East countries around the Arabian Gulf, such as Saudi-Arabia, Kuwait, the United Arab Emirates, Iraq and Iran, and countries as Nigeria, Venezuela and Indonesia. The most important consumers (and importers) of oil are the countries in Western Europe, Japan and the United States of America. These countries largely depend on the oil from oil-producing countries, especially those of the Middle East. Figure 2.25 illustrates the development of the size of tankers:

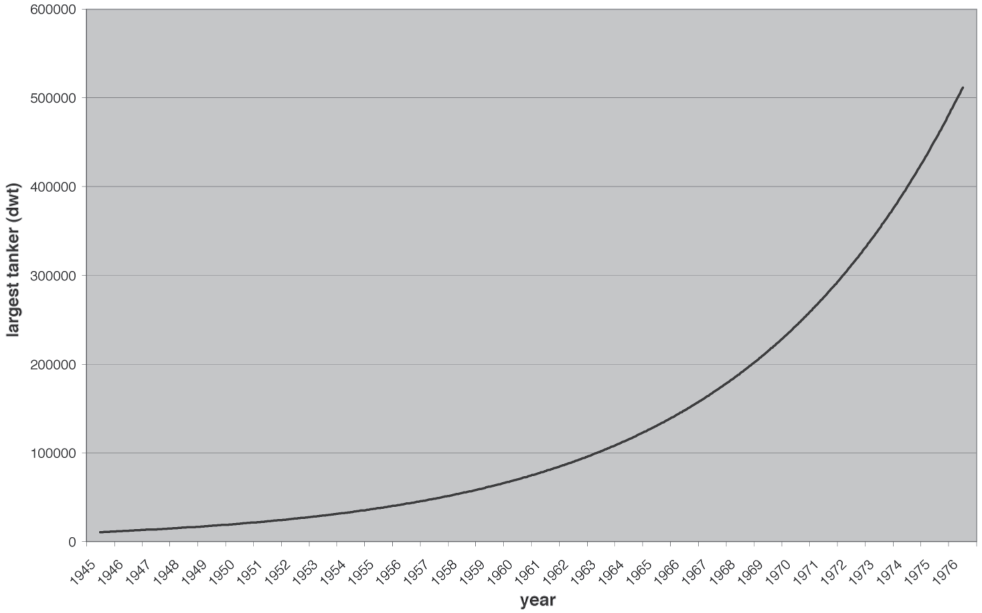


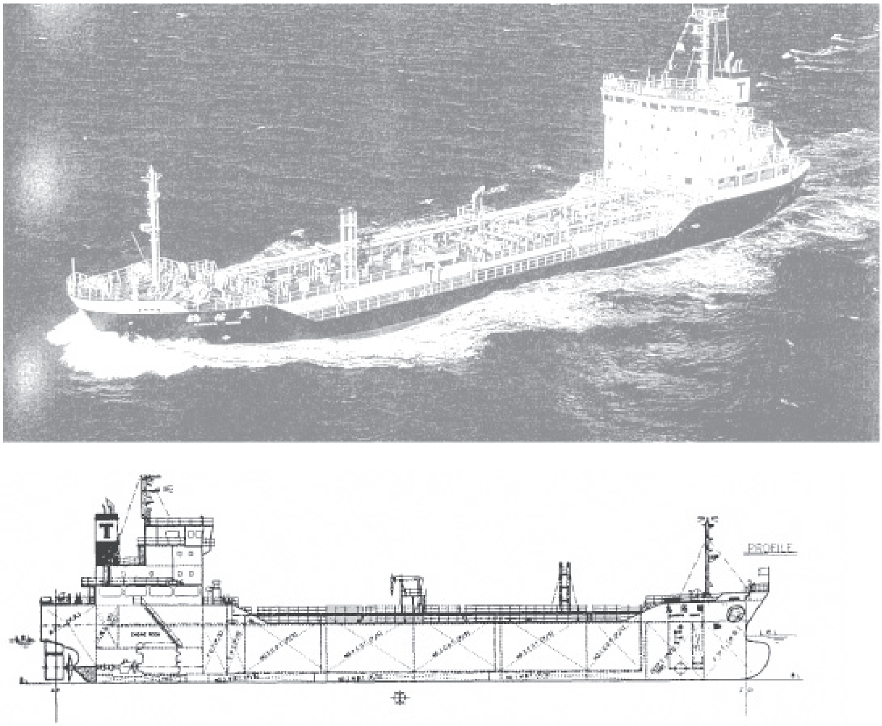
Figure 2.25 Growth of tanker size

Nowadays the intermediate size tanker (50,000-200,000 dwt) is becoming more important again due to:

1. Levelling off or even some reduction in the world crude oil trade.
2. Increased use of the (improved) Suez Canal instead of around the Cape services.
3. The fact that, although *VLCC's* (Very Large Crude Carriers) and *ULCC's* (Ultra Large Crude Carriers) can transport very large quantities of crude oil on one voyage, they can only call at few ports in the world, because of their large draught. In 1992 less than 10 ULCC's were still in operation world wide.

The crude oil tanker can easily be identified by her flat deck without derricks and hatch covers. Only some deck arrangements like stop locks, pumps, pipelines and small hose derricks with the manifold amidships can be observed. A remarkable feature is the catwalk, a horizontal gangway, that runs along the deck from bow to stern, to enable the crew to move along the ship. Older types of tankers have, like the older general cargo vessels, the main superstructure amidships, but with the newer and bigger types all is aft; superstructure, wheelhouse, engine room, etc.
A remarkable feature of the very large types is the return of the crow's nest at the bow, that is necessary because of the limited view from the wheelhouse aft.

Product tanker (see Figure 2.26) The definition of product tankers given by Lloyd's Register (Ref. Lloyd's Register Management Services, Ship Dimensions in 2020, Rotterdam, May 1998) is: a vessel with independent tanks for the transportation of petroleum products in bulk. Many tankers have a dead-weight capacity smaller than 7500 t, but there is a large class of vessels with a capacity between 30,000 and 40,000 t. The largest product tankers are about 110,000 t.



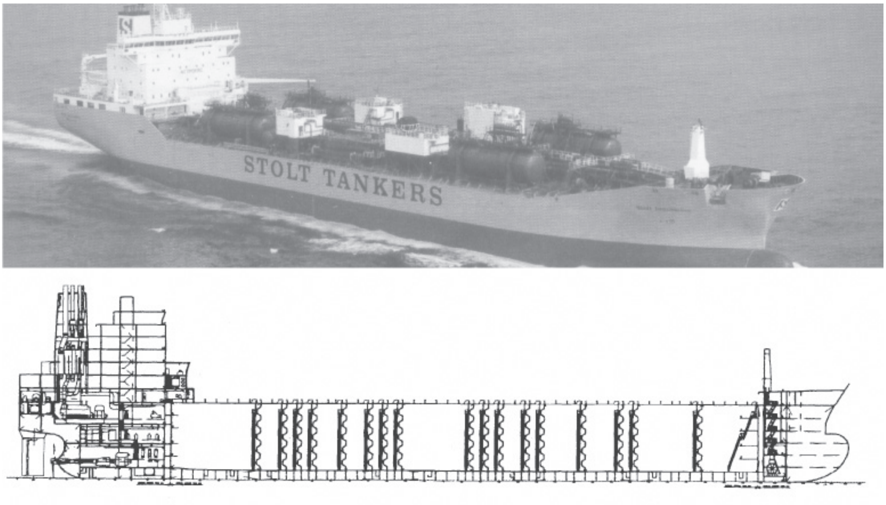
Length Over All:	91.00 m
Length Between Perpendiculars:	86.00 m
Breadth:	15.80 m
Draught:	5.455 m
Deadweight:	3,898 t
Maximum speed:	13.13 knots

Figure 2.26 Petroleum product tanker 'Kakuyu Maru'

Parcel tanker (see Figure 2.27) The parcel tanker is a specialised tanker for transportation of refined oil products, such as paraffin, diesel oil and/or chemical liquids. The parcel tanker has received her name from the fact that the many relatively small compartments in the hold can be used separately, by which various products can be transported at the same time.

The parcel tanker can be distinguished from the crude oil tanker by various additional characteristics, such as numerous small tank hatches, many fore-and-aft running pipes and, amidships, the manifold with its complex arrangements of pipes and valves, connected to the ship's tanks system. The manifold is the focal point of the loading and discharging

operations by means of the ship's own pumps. Close to the manifold are two light hose-derricks.
To reduce the hazards of fire, the holds fore and aft are equipped with double watertight bulkheads (*cofferdams*). One of the great problems of parcel tankers is the cleaning of tanks. When a certain type of cargo has been brought to her destination, and another type of cargo is to be loaded, the tanks have first to be cleaned. In well equipped ports facilities are available to execute this in a professional way. If this is not the case, illegal dumpings at sea may occur, which may seriously harm the marine environment. A general lay-out of a parcel tanker is given in Figure 2.27.



Length Over All:	176.75 m
Length Between Perpendiculars:	168.50 m
Breadth:	31.00 m
Draught:	10.80 m
Deadweight:	37,015 t
Maximum speed:	16.50 knots

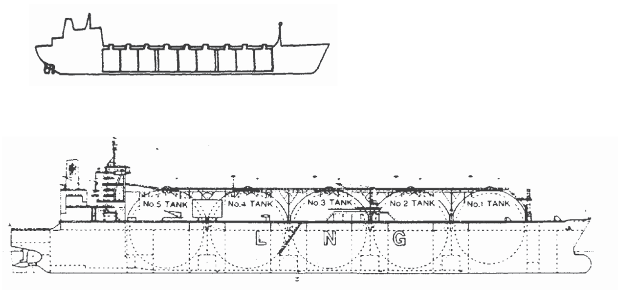
Figure 2.27 Parcel tanker 'Stolt innovation'

Liquid gas tanker (see Figure 2.28) The gas is transported at a high pressure or at a low temperature or a combination of both.
The products involved are:

- *LPG (Liquefied Petroleum Gas)*, a mixture of propane and butane,
- *LNG (Liquefied Natural Gas)*, which consists mainly of methane, and
- Other types of chemical gas, like ammonia, ethylene, etc.

The gas is mostly transported at atmospheric pressure and low temperature (LPG: −46°C and LNG: −162°C) in liquid form in separate tanks in the hold of the ship, i.e. the so-called *cryogenic transport*. In liquid form natural gas retains only 1/634th of its original volume. Figure 2.29 gives the development of the liquefied gas carriers. *LNG carriers* have grown recently to a capacity of 262,000 m^3 with a length of 345 m. For smaller quantities e.g. coaster type and size ships LPG is also transported in pressurised form at normal temperatures. LNG cannot be liquefied by pressurisation at temperatures above $-80°C$. The capacity of gas tankers is normally expressed in m^3. In principle LNG-carriers are capable to transport LPG as well; but LPG tankers cannot carry LNG.

Figure 2.28 Examples of LNG-tankers (left) and LPG-tankers



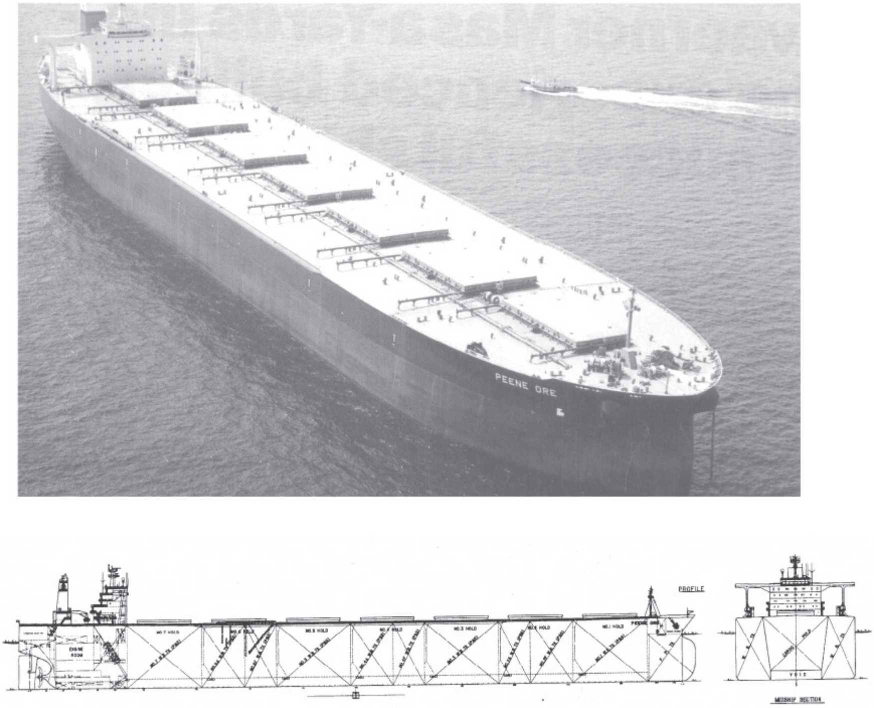
Methane princess, 1964
Capacity: 27,400 m^3
LOA: 175.00 m
Breadth: 24.80 m
Draught: 7.90 m

Al Khor, 1997
Capacity: 137,550 m^3
LOA: 297.50 m
Breadth: 45.75 m
Draught: 11.215 m

Figure 2.29 Development of liquid gas carriers

Dry bulk carriers

Dry bulk ships are designed to carry big quantities of uniform, unpacked commodities such as grain, coal, ore etc. Loading is always carried out by shore equipment, unloading sometimes by shore equipment, sometimes by ship-based equipment. A large number of dry bulk vessels are 'ungeared bulk carriers' that have no self-loading capability. *Geared bulk carriers* are equipped with derricks at all holds or with gantry cranes and do not require shore cranes. In contrast to the tanker, the dry bulk carrier has hatches. The hatches are usually very wide, in order to give access to the handling equipment in every place in the holds. Until recently the largest bulk carriers in use (*VLOC's = Very Large Ore Carrier*) measured about 350,000 t, see Figure 2.3.6. But in 2011 the first 6 out of 19 ULOC's (Ultra Large Ore Carrier) ordered by the Brazilian mining company Vale have come into operation. They are also referred to as Valemax or Chinamax carriers - as they are intended for the export of iron ore from Brazil to China - and have the following characteristics: 400,000 dwt, $L_{OA} = 362$ m, $D = 23$ m.



Length Over All:	332.00 m
Length Between Perpendiculars:	320.00 m
Breadth:	58.00 m
Draught:	23.00 m
Deadweight:	322,398 t
Maximum speed:	14.70 knots

Figure 2.30 Very Large Ore Carrier 'Peene ore'

Some types of dry bulk ships, the *CSU's (Continuous Self Unloader)*, are self-discharging via an ingenious conveyor system. Capacities up to 6,000 t/hour can be reached (see also Figure 2.31). The advantage of these self unloaders is that only some dolphins are necessary for a berth.

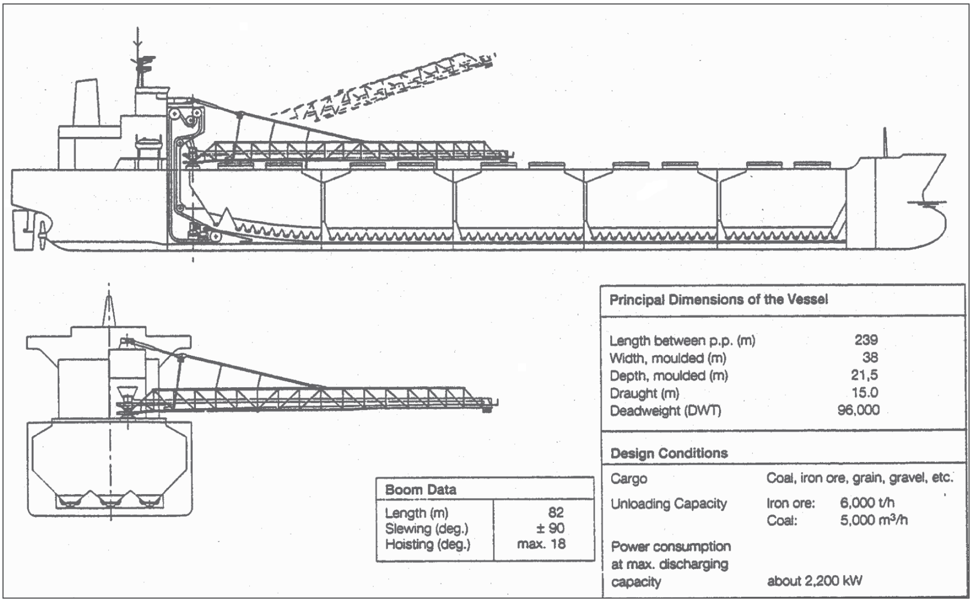


Figure 2.31 Self-unloading gear of the M/V Western / Eastern Bridge

2.3.7 Short Sea Trader

The short sea trader is a sea going ship with a capacity of between 300 and 3000 dwt. In several countries short sea traders with capacities ranging from 300 to 1500 GRT are referred to as *coasters*. Usually, the short sea trader runs the shorter routes, connecting the ports around the North Sea, the Baltic Sea, the Mediterranean Sea and similar areas in the world. As discussed in the previous chapters, the size and therefore also the draught of ocean going vessels have increased sharply over the past decade. This has increased the importance of *short sea traders*, mainly due to the following two reasons:

- Large vessels tend to call at as few ports as possible, in order to reduce costs, and
- Large vessels are no longer able to call at every port due to restrictions caused by the dimensions of the ships

To maintain the connection between the ports of call of the large vessels and the other ports the short sea trader is a most useful tool. If a short sea trader is employed in this way, she is also referred to as *feeder*. Due to her limited dimensions the ship can call at most ports. Furthermore it can be observed, that she is economic in use, because of the simplicity of the ship and the small crew, economic in use. The short sea trader can transport any kind of cargo, such as general, palletised, containerised or bulk cargo.
Depending on the type, the short sea trader is often fully equipped with cargo handling gear, which also enables her to load or unload cargo at small ports with limited facilities.

2.4 Tramp and Liner Trade

International shipping can be subdivided into two major categories:

- liner trade
- tramp trade

2.4.1 Liner Trade

Liner trade is a seaborne trade of one company (or a consortium of companies), which maintains regular services between a certain number of ports. Within this trade one can further distinguish main routes: east-west and vice versa, north-south and vice versa and short-sea lines. The latter provide a regular service between a number of ports at the same continent, e.g. Rotterdam-Bilbao-Southampton-Rotterdam. The essence of all these lines is:

- Times of arrival and departure in any port of the route are scheduled (and published) over a certain period in advance; high reliability
- Tariffs are fixed over a certain period
- Berth location in most ports is fixed

In container shipping a peculiar phenomenon developed, i.e. main lines, which call on only few ports in their route, with *feeder ships* collecting and distributing the containers within a region around such a *main port*. Another name for this system is *hub-and-spoke*. The reasons for this development are clear: the main line vessels were becoming too large and too expensive to call on smaller ports. The transfer from main line vessel to feeder and vice-versa is called *transshipment*. The total container throughput of the main ports comprises hinterland cargo and transshipment cargo, the latter being counted double (on entering and on leaving the port). Singapore port has mainly transshipment cargo, whereas in Rotterdam the container throughput is about 15 % transshipment.
Over the past few years competition between the main line shipping companies, the *mega carriers*, has led to concentration and rationalization. Concentration implies merges and takeovers, leaving only about 20 companies to provide the intercontinental services. An example is Maersk that consolidated its no. 1 position by taking over P&O Nedlloyd, leading to a total number of 500 container vessels with a total capacity of 15 million TEU. Rationalization has also been applied to maximize slot usage, in other words, to make sure that the vessels are loaded up to TEU capacity. This is achieved by forming consortia or alliances (see Table 2.6).
Another way to achieve optimum usage of the capacity of scheduled ships is slot sharing. This implies the chartering of container space (slots) on a competitors vessel on an as-need basis. Notwithstanding all these measures to improve shipping economy, presently the relative overcapacity leads to low tariffs and poor performance of most shipping companies.

Table 2.6 Alliances bulk carrier types

Name	Members	number of ships	Fleet capacity (TEU)
Grand Alliance	Hapag-Lloyd OOCL NYK	250	740,000
The New World Alliance	APL Hyundai MOL	220	670,000
CYKHS	Cosco K Line Yangming Hanjin Senator	330	993,000

2.4.2 Tramp Trade

Tramp trade is the opposite form of seaborne line trade. It is being applied whenever or wherever needed. Tramp trade is mostly found in the bulk shipping trade, where the markets are more volatile than in merchant shipping. Sometimes tramp ships are contracted by liner companies on short or long term contracts, in case their own fleet is not adequate or available to provide the services required. Chartering occurs through open markets mainly in London and New York. The chartering through open markets is reason for strong varying tramp tariffs because of the limited flexibility of the transport capacity. Therefore raw materials processing industries are concluding long term contracts. This security of long term contracts offers the possibility to use larger and more specialised bulk carriers.
To illustrate the importance of tramp shipping, the distribution of the world crude oil transport in 1992 as follows:

Approx. 15%	was transported by vessels owned by the major oil companies
Approx. 84%	by independent tramp companies, which have leased their ship on short and long term contracts to oil companies and oil traders
Approx. 1%	was carried out by ships owned by governments

2.5 Graphs and Observations

Some graphs with respect to the main dimensions of ships are presented in the following Figures (based upon data from Lloyds Register of Ships and other sources).
With reference to Section 2.3.6 large ships are often referred to as being ''Panamax size", ''Suezmax size", etc., reflecting the fact that they have dimensions just allowing them to pass the Panama Canal locks, the Suez Canal or similar important natural of man-made barriers for navigation. Ships can be adapted to the restrictions imposed by these obstacles but, sometimes and within limits, the obstacles can also be adapted to the demand for the

passage of bigger ships. It is a complex balancing act controlled by economic and strategic considerations. If transport chains and the appurtenant infrastructure were managed by one and the same party, this balancing act would be relatively simple, but in practice there are a number of stake-holders and non-rational aspects that come into play.
Canals and natural channels can in principle be deepened and widened and ship-locks can be replaced by bigger ones, but usually all at considerable cost. Ship-locks constitute a limiting factor for the reception or passage of big ships at quite a number of locations, not only in Europe.
Important ship-locks and their lock chamber dimensions ($L \times B \times D$) are:

- Panama Canal, new locks under construction, $427 \times 55 \times 18.3$ m.
- Antwerp, Berendrechtsluis, $500 \times 68 \times 13.6$ m, and under construction: Deurganckdoksluis $500 \times 68 \times 17.8$ m, the world biggest for the time being.
- Bremerhafen, Kaiserschleuse, $505 \times 55 \times 13$ m, particularly for the passage of car carriers.
- IJmuiden, Noordersluis, $400 \times 50 \times 15$ m, new lock in planning stage: $500 \times 60 to 70 \times 15$ m.
- Terneuzen, access to the port of Gent, construction of new lock about to be started $427 \times 55 \times 16$ m.
- Le Havre, cluse François I, $400 \times 67 \times 24$ m.

The limitations imposed by ship locks on shipping is not only matter of sheer sizes of the locks but also of delays caused in transiting the locks and the fear by shipping lines that operate on a strict time schedule, e.g. main container lines, to have their ships ”imprisoned” in port for an indefinite period of time in case of damage to the vulnerable lock doors. For that reason and for quite some time already ports like Antwerp and Le Havre have been shifting part of their container operations to the tidal waters outside the locks notwithstanding the fact that quay wall construction is far more expensive there and that STS crane productivity is lower. For example at tidal births in Le Havre quay walls and cranes have to cope with a tidal range of some 8 m.

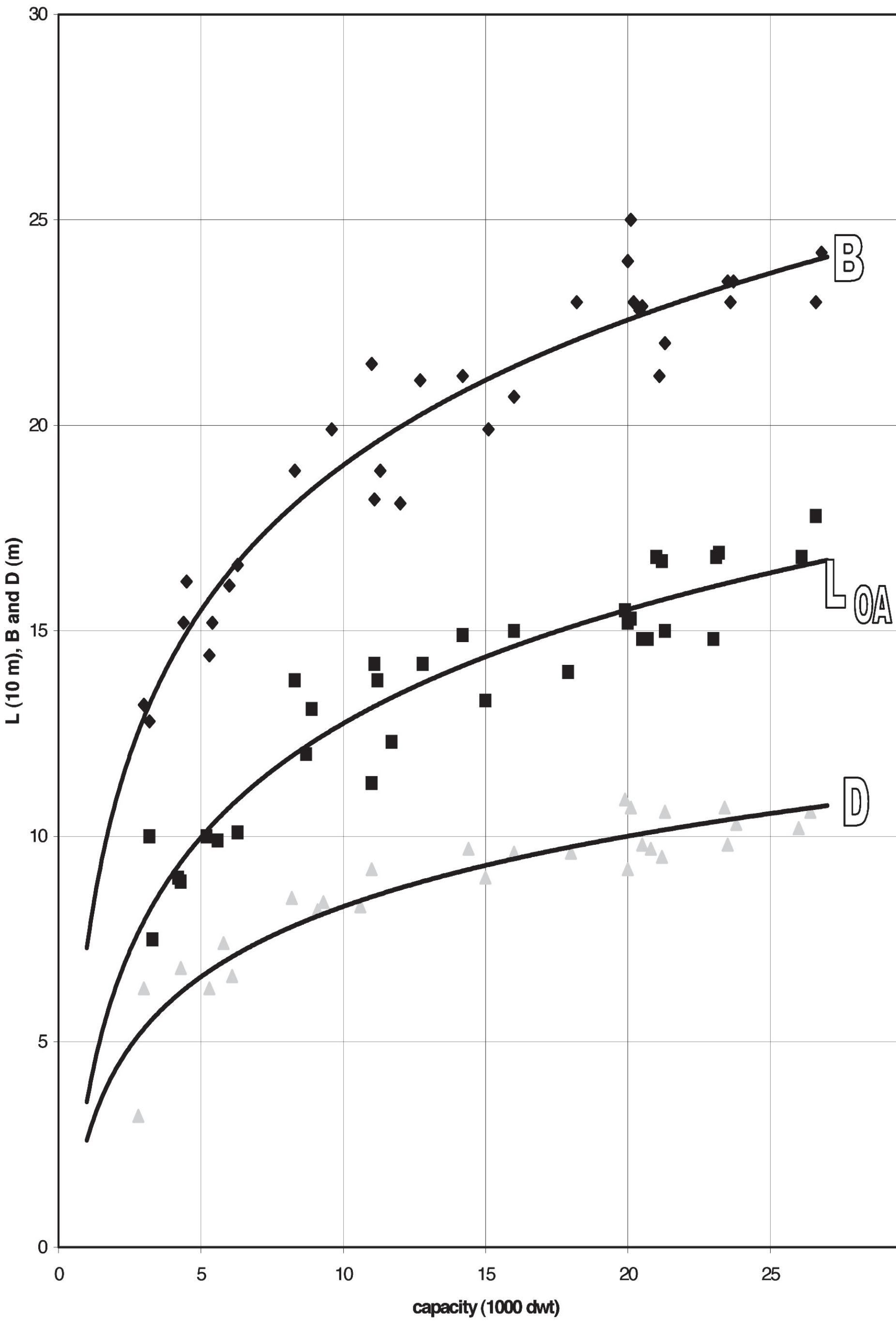


Figure 2.32 Principal dimensions of general cargo ships

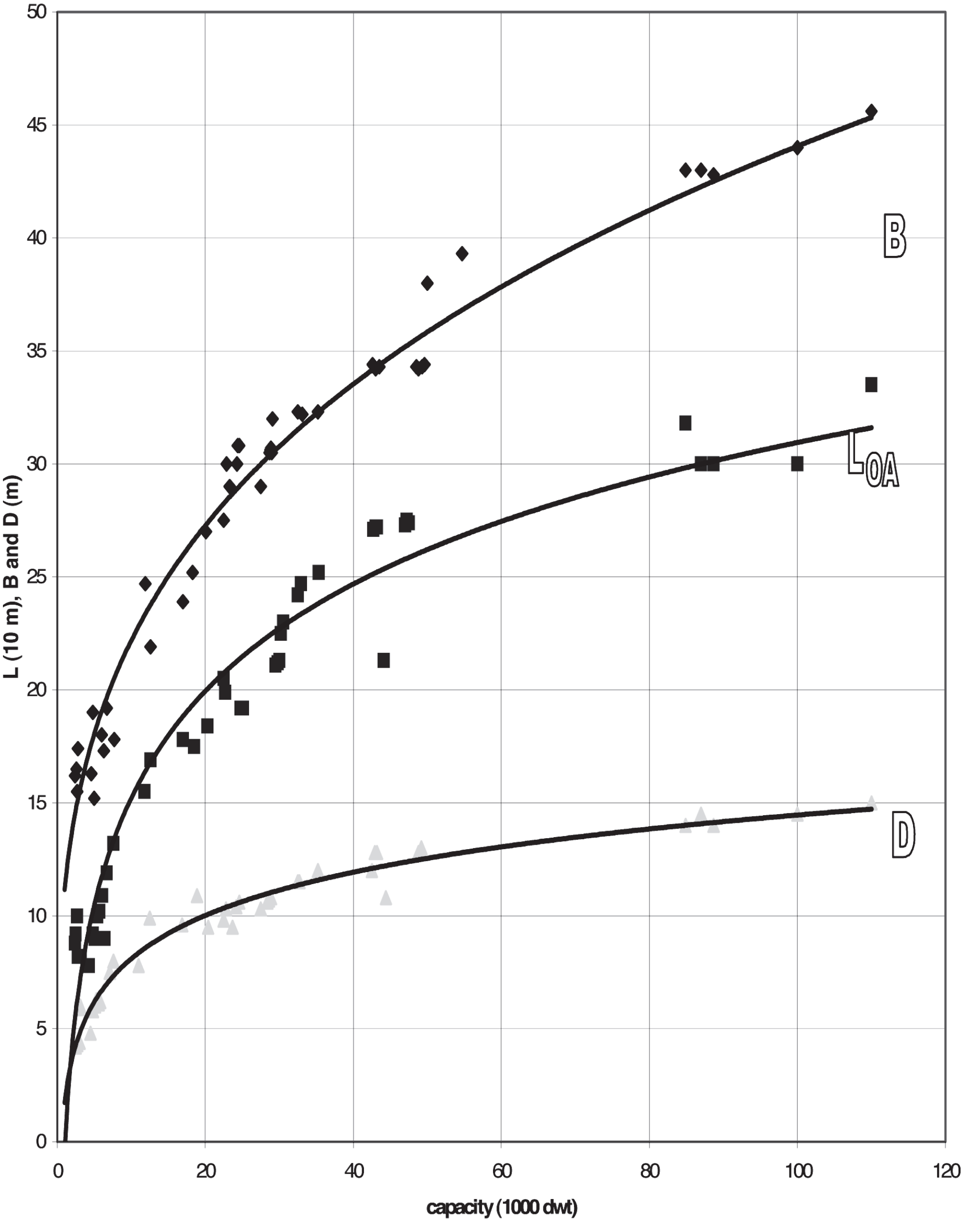


Figure 2.33 Principal dimensions of container vessels

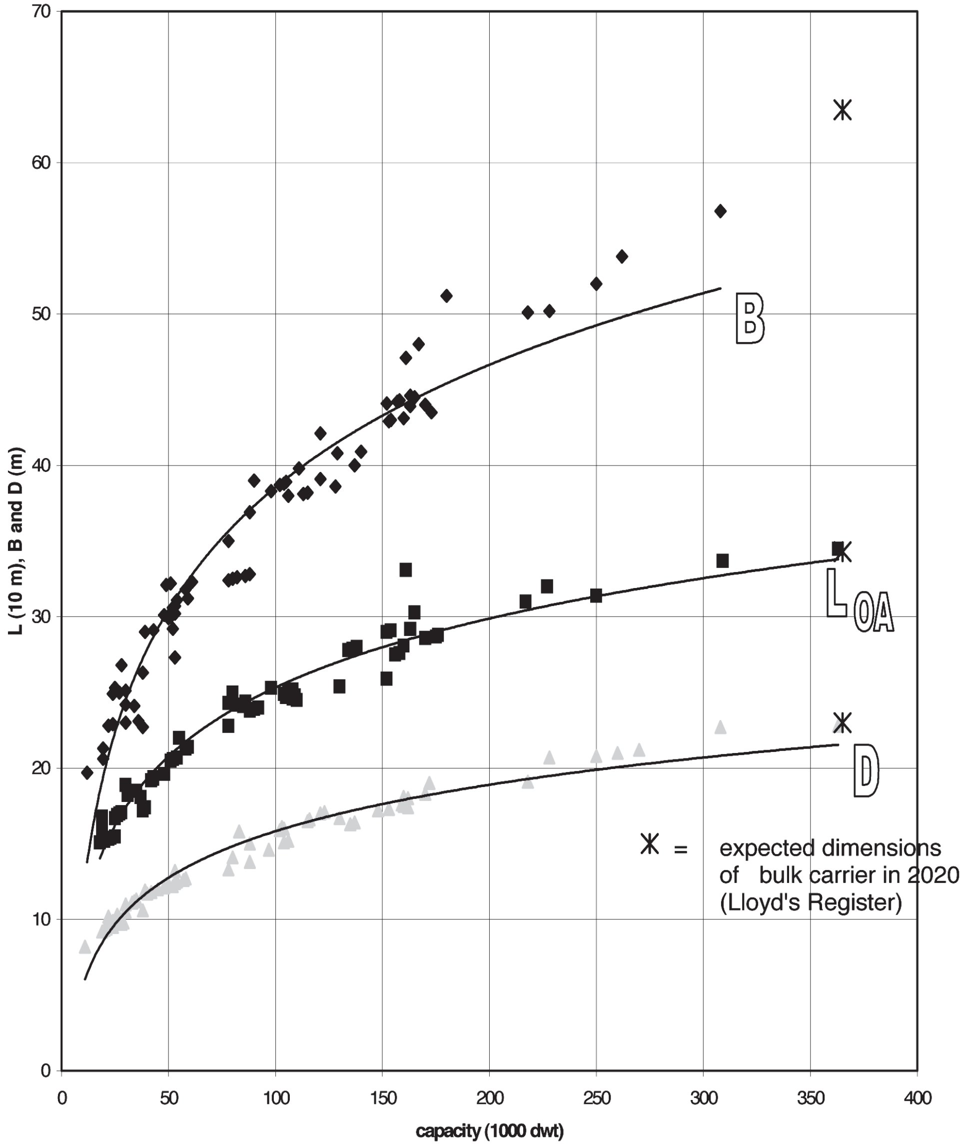


Figure 2.34 Principal dimensions of bulk carriers. The squares (□) denote the expected dimensions of bulk carriers in 2020 (Lloyd's Register)

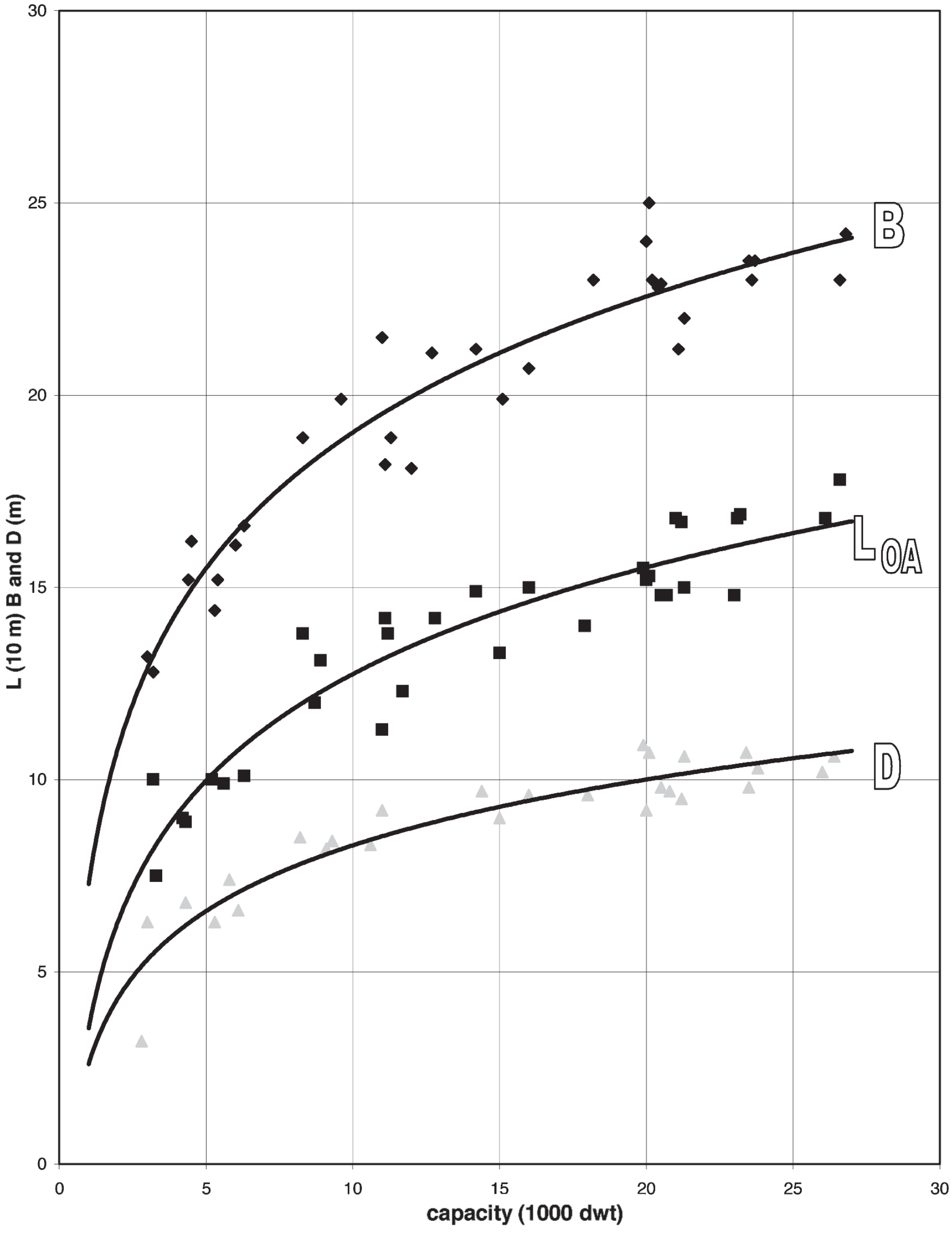


Figure 2.35 Principal dimensions of tankers

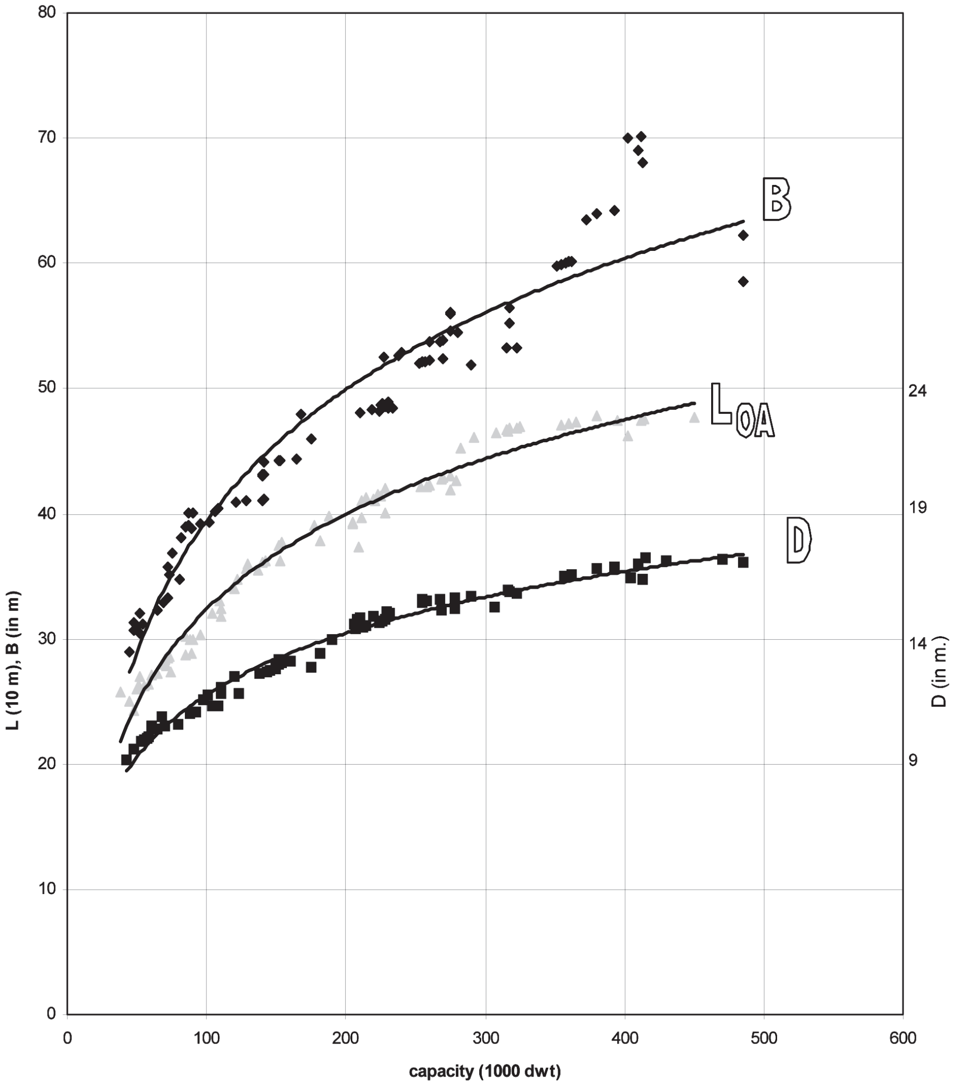


Figure 2.36 Principal dimensions of tankers > 40,000 t

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Chapter 3

Port Functions and Organisation

3.1 Introduction

Before entering into planning and design of ports it is necessary to determine the functions of a port and to understand its organisation. Both factors are relevant for the economic and financial decisions to be taken as part of the planning process. Recently privatisation of (public) ports and private development of entirely new ports have become a trend, but the success of these policies depends very much on the function and the legal and institutional conditions of the port concerned.

3.2 Functions

The primary functions of a port are:

- Traffic function: the port is a nodal point in the traffic, connecting water and various land modes.
- Transport function: ports are turntables for various cargo flows.

Besides these, ports can have several other functions, such as:

- Industrial activities, often in relation to the cargo flows, to shiprepair and shipbuilding, or offshore-supply. But the vicinity of sea transport may in itself be the reason to locate an industry.
- Commercial and financial services, including banks.

The traffic function requires three conditions to be fulfilled, i.e. a good ”front door”, a good ”backdoor” and sufficient capacity and services in the port itself:

- Entrance from sea, needs to be accessible and safe;
- Port basins and quays, adequate space for manoeuvring and berthing of the ships, capacity for handling and storage;
- Hinterland connections, road, rail, inland waterways, pipeline, depending on the transport function.

The safety of ships and crew is most important and receives much attention. This is understandable, when recognising that ships are designed for manoeuvring in open water and at cruising speed. Entering a port means speed reduction, entailing poor manoeuvrability, stopping in limited waters and often having other ships around. For this reason the nautical services are essential: starting with nautical aids (buoyage, lights), getting pilot assistance and tugs, and moving to high-tech aids to navigation: the *Vessel Traffic Service (VTS)*, which implies monitoring of all vessel movements in a port by central radar.
However, a port with very good nautical entrance, but insufficient space and/or bad hinterland connections becomes quickly clogged and does not function. Hence the above three conditions must be in balance.
Regarding the transport functions the conditions are depending on the particular situation of the port:

(i) If a port has its 'natural' hinterland, which it serves for import and export without much competition, it is in the interest of society that this service is provided efficiently, uninterrupted and at minimum costs. The absence of competition led in the past to the 'public ports', which often failed to achieve these goals. They became either 'money earners', or had more ships at anchorage outside than berthed inside the port, or both.
(ii) Where several ports are competing for cargo from and to the same hinterland, or for the transshipment trade, the efficiency of cargo handling and costs for pilotage, harbour dues, etc. becomes important. Ports become business in itself and privatisation of port functions is a logical step to achieve the necessary efficiency.

In Section 3.4 this issue of public versus private will be further elaborated. Here the question is posed whether the transport function deserves to be expanded in a competitive situation. The investment costs are high, which benefits justify them? This question has become more relevant, since the direct employment in the port has reduced drastically over the past decades as a result of improved handling methods and automation. There is no simple answer to the question, but some considerations are applicable:

- Competition between ports is good to stimulate efficiency, and to keep the costs down. Too much competition leads to overcapacity and losses, which in most cases is paid for by the public.
- Unfair competition (e.g. by subsidies) should be avoided, because it leads to price distortion (European Commission, 1995) and overcapacity.
- In the cost/benefit analysis of port development projects, the long term, indirect, social benefits have to be included (de Brucker, 1998).
- Ports should strive to include employment generating activities in their development strategies, in order to maintain the positive profile and public support in the local community.
- Environmental effects have to be taken into account on a rational basis, e.g. by quantitative evaluation methods and against a uniform and transparent set of regulations.

The above aspects are all related to the investment decision in the planning stage of port expansion. In the direct competition between ports to attract certain trades and cargo volumes the following competitive factors are all important:

- Availability of land for terminals and the related cost per m^2.
- Port tariffs and dues.
- Quality of the port and/or existing stevedores (efficiency, reliability, flexibility, handling costs).
- Quality of the hinterland connections.
- Environmental requirements.
- Customs regime.
- Nautical safety.

In order to be able to attract new business, the port must have some excess space. It is important to realise that this may also be found inside the existing port boundaries, for instance where old and declined areas have become obsolete and can be converted to suit the requirements of new trades.
This process has been observed in many existing ports and is described in the so-called *Port Life Cycle theory* (Charlier, 1992). The cycle, shown in Figure 3.1, implies that a port area develops with the growth of cargo throughput, reaches maturity (or saturation), starts to age (due to changes in cargo pattern or in ship design) and then reaches a state of obsolescence, which will continue, unless a revitalisation process is initiated.

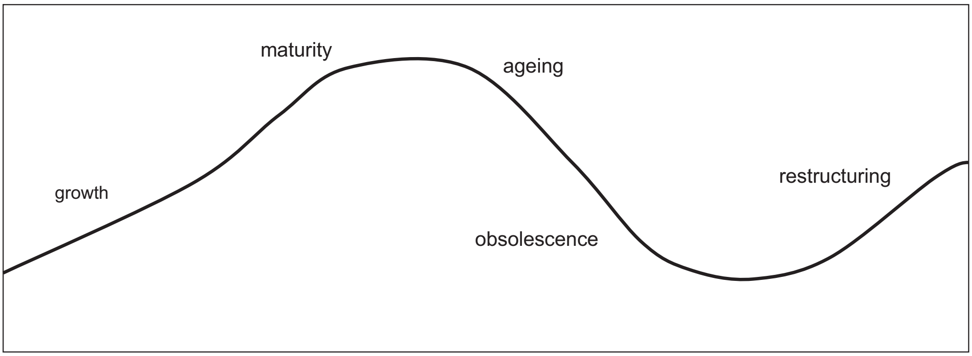

Figure 3.1 The Port Life Cycle (Charlier, 1992)

The change-over from conventional general cargo to containerised cargo is a good example. In many ports this has made existing terminals obsolete, leaving deserted areas with empty warehouses.
The message is to start the revitalisation process before this happens, as soon as the signs of ageing become clear. This is a task for the port authority, but involves port planning in the same way as expansion outside the existing port boundaries.

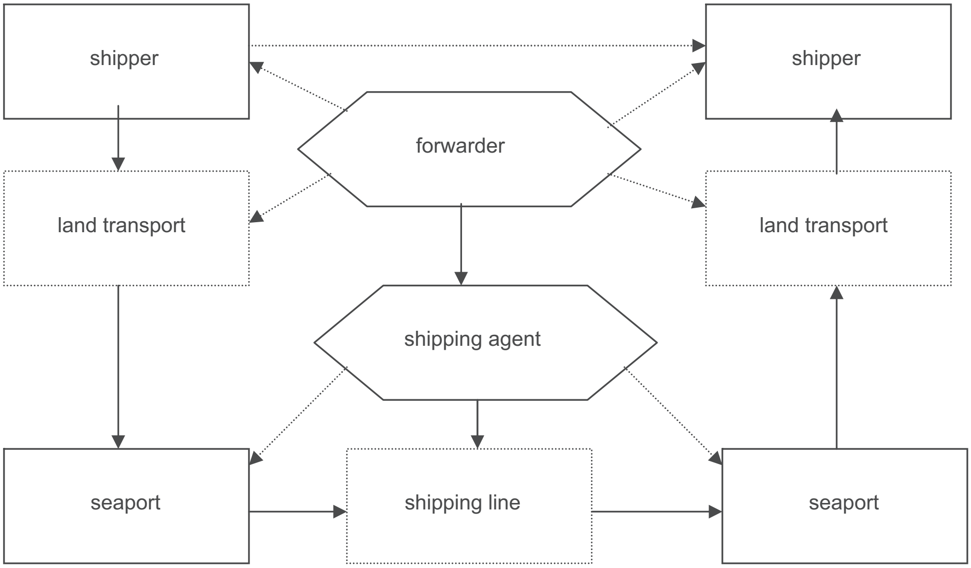

Figure 3.2 Elements in the transport chain

3.3 Transport Chain

In the previous section the transport function is stated to be carried out by the 'port'. Nowadays there are only few ports in the world where the port authority is also responsible for the ship unloading/loading and the storage of the goods. Often these activities are supplied by a stevedoring firm, that is specialised and therefore can provide better services at a competitive price. The place of the stevedore in the overall transport chain is shown in Figure 3.2. This scheme also explains the role of two other agencies: the forwarder, who is hired by the shipper of the cargo (not to be confused with the shipping company) to arrange the land transport, and a shipping agent, who in turn arranges the shipping line and the stevedoring in the seaports on both ends. This process is identified by the term 'merchant haulage'.

For large cargo volumes at regular intervals over a period of several years, forwarders tend to prefer one contract for the entire transport chain. In response to this, shipping companies have started to offer 'door-to-door' services, in particular for containerised cargo, so-called *carrier haulage*. And as a logical step shipping lines diversified their business to include land transportation and stevedoring. An example is APM Terminals as a subsidiary of the shipping line Maersk.

At this point it is relevant to mention the growing market for intermodal transport. In Chapter 2 the competition between road, rail and IWT for the hinterland transport was sketched. Intermodal transport concerns the combination of rail with road and IWT with road. The present policy in Europe is to stimulate this intermodal transport in order to reduce the congestion of the road network and for environmental reasons. To illustrate the latter point Figure 3.3 gives the number and the total length of all units placed one behind the other for of units of the different transport modes needed to carry 1200 tonne cargo. This is an indication of the corresponding energy consumption and air pollution.

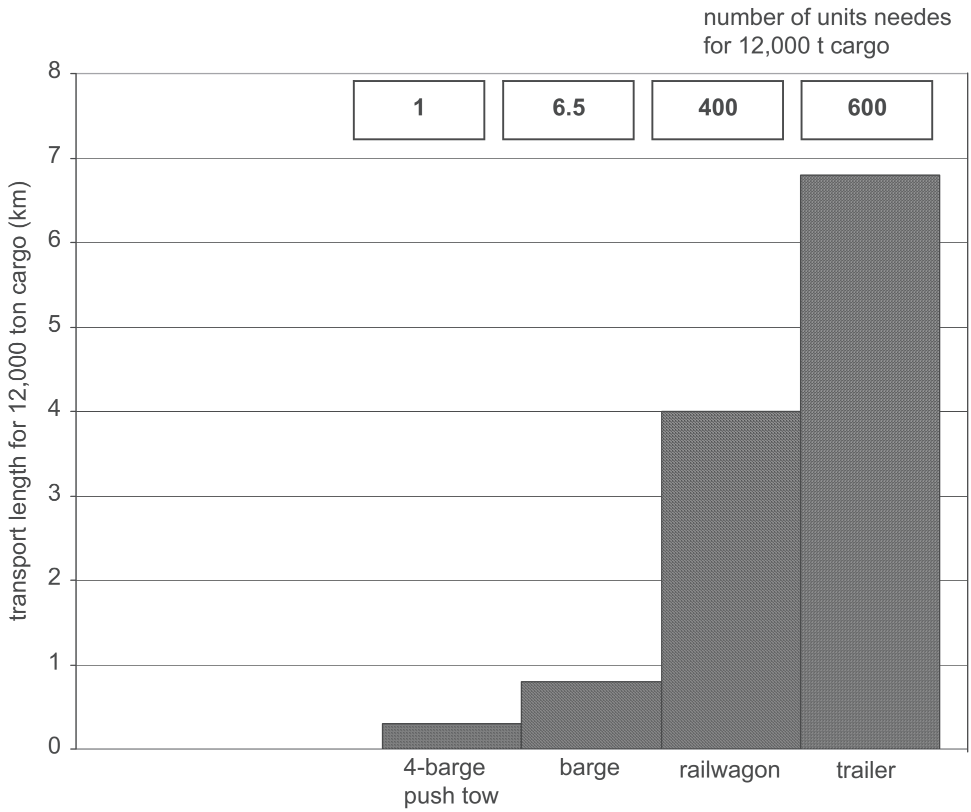

Figure 3.3 Length of all transport units in a row for different modes

Promotion of intermodal transport can be achieved by improvement of rail infrastructure for cargo (e.g. the Betuwe Line in the Netherlands) and the infrastructures for IWT (widening of the Meuse and of various canals). Additionally there exists a subsidy for the private development of terminals along rivers and canals.

3.4 Organisation of Seaports

It has been mentioned that many ports started as a public organisation. Consequently they were government-owned, be it the National Government, a municipality, or a separate status of Port Trust or Port Authority. Exceptions were so-called *captive ports*, built and operated by an industry for its own use, such as the tanker berths for a refinery or the bulk export terminal for a mining company.
World-wide one can distinguish three different forms of organisation of the public ports:

- The *Service Port*: all services including cargo handling and storage are provided by the port authority. This form was common in the old times and can still be found in some developing countries. It was often characterised by bureaucracy and red tape and can only survive in case there is a natural hinterland without competition of other ports.

- The *Landlord Port*: the port authority owns the land and gives concessions to private sector companies for provision of cargo handling and storage services. The port authority is responsible for the infrastructure, the nautical safety and access, including maintenance of approach channel and basins.
- The *Tool Port*: the port authority remains responsible for providing the main ship-to-shore handling equipment (usually light to medium multipurpose cranes), while cargo handling is carried out by private companies under licences given by the port authority.

A 1997 world review of the top 100 container ports shows that 88 out of 100 ports conform to the Landlord Port model. This is therefore becoming the standard, but for small ports, assuming 250,000-300,000 t of general cargo per annum to be minimum for an independent cargo handling company to be financially viable. Below this level the Tool Port model appears to be appropriate.

Besides these public ports fully private ports are becoming more common. These are ports built and operated by private companies, including the responsibility for maintenance. Statutory functions like navigation safety, environmental protection and customs remain government responsibility (Juhel, 1999)

The latter so-called *Built-Operate-Transfer (BOT)* projects are seen by many politicians all around the world as an attractive way to create infrastructure and thus overcome congestion in the existing ports without public finance. The reality is that the return on investment of most projects is insufficient (based on a 30 year pay-back period). Consequently the only way to realise them is by a combined approach, i.e. public finance of certain basic infrastructures and private financing of the rest. This is either achieved by following the "Landlord" approach, or in a commercial investment by public and private partners jointly, the *Public Private Partnership (PPP)*. This approach has been followed by Amsterdam Port Authorities in the realisation of several new terminals.

The advantages of various degrees of private sector investment and participation are clear:

(i.) It offers a good test on the financial feasibility of the port project (private sector is not interested in 'white elephants')

(ii.) Once in operation the efficiency and profitability of the port is driven by the commercial interests of the private partner, and less by social and political considerations. A good example of this is the privatisation in 1989 of quite a number of ports in the United Kingdom, under the name Associated British Ports. In six years time ABP had turned them around and made profit. This was achieved by labour reductions of 85% of the original workforce. And notwithstanding this reduction the total throughput showed a 13% increase.

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