UNIT 3

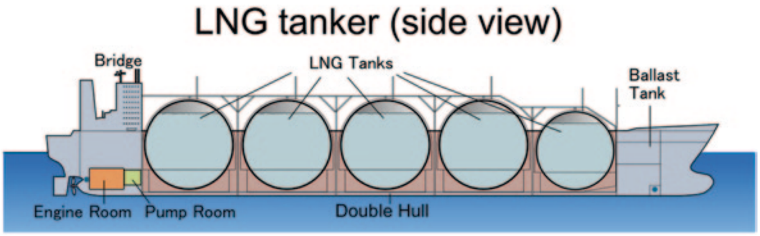


Fig. 2.22 LNG tanker (side view)

2.3.6 *Other Factors Affecting the Selection of Length*

1. Behavior in waves To avoid intense motions/accelerations in waves, which, beyond unfavorable structural loadings, lead to added resistance and additional powering in waves, thus also to *voluntary or involuntary* speed loss, regions of resonance of ship motions (of heave, pitch, and roll, which are characteristic by their natural periods/frequencies) should be avoided. In determining the ship's length, we are mainly interested in possible resonance in head seas, which primarily induce pitch and heave motions. Figure 2.23 (Lewis 1988) shows that, for a wavelength to ship length ratio $L_W/L = 1.0$ to 1.3 a resonance takes place and excessive values for both heave and pitch motions, which are mathematically coupled.

Of course, in practice it is difficult to avoid the resonance at certain wavelength, due to the existence of many wavelengths in the spectra of natural seas on earth, where seagoing merchant ships may operate. However, one may try to avoid resonance with the waves of higher energy density (at the *significant* wave period/length of known routes). These considerations are valuable for navigational areas for which sufficient statistical data of local wave spectra are available (especially for coastal ships) and they are anyway taken into account in naval ship design.

2. Freeboard The length significantly affects the freeboard of a ship, as it is the basis for calculating the *basic freeboard* in accordance with the Load Line Regulations (ICLL), see Sect. 2.19.

3. Passing limits of routes See dimensions of known canals/narrow straits, etc. (see Sect. 2.2).

2.3.7 *Ship Length Estimation Using Empirical Formulas*

Common empirical methods for estimating the length L are as follows:

a. Using coefficients ($L/\nabla^{1/3}$) for various ship types
b. Using semi-empirical mathematical formulas from statistical analyses that are based on purely economic criteria
c. Using semiempirical mathematical formulas derived from statistics of existing ships (based on hydrodynamic and economic criteria)
d. Using empirical diagrams for different types of ships

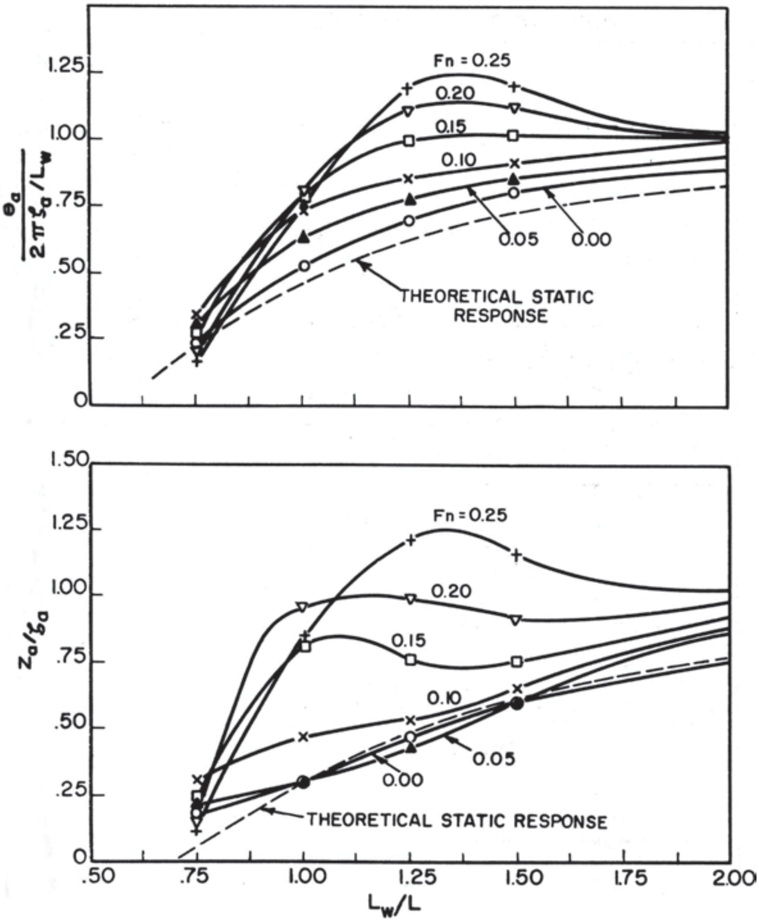


Fig. 2.23 Amplitude of pitch motion θ_α and heave motion z_α of a Series 60 ($C_B = 0.60$) model in head waves with amplitude ζ_α and length L_W, at different Froude numbers. (Lewis 1988)

Applications

a. After the prediction of the displacement and displaced volume ∇, it is possible to estimate the length by using the slenderness coefficients $L/\nabla^{1/3}$ from Tables 2.4 and 2.5 or from similar ships (see values in Appendix A).
b. Formula of "length of minimum building cost" according to Schneekluth (1985)

$$L = \Delta^{0.3} \cdot V^{0.3} \cdot C \tag{2.45a}$$

where

L: length between perpendiculars (m),
Δ: displacement (t),
V: service speed (kn) or

$$L = 1.22 \cdot \Delta^{0.3} \cdot V^{0.3} \cdot C \tag{2.45b}$$

for speed V in m/s

Table 2.4 Hull form coefficients and ratios of main dimensions for merchant ships (synthesis of original data by Strohbusch 1971, updated by Papanikolaou by use of IHS Fairplay World Shipping Encyclopedia, v. 12.01, 2011). Given upper and lower boundaries correspond to the standard deviation from the regression line of sample ships, as shown in Appendix A

Ship type	Hull form coefficients				Ratios of main dimensions		
	C_P	C_M	C_B	C_{WP}	L_{PP}/B	B/T	$L_{PP}/\nabla^{1/3}$
Fast seagoing cargo ships	0.57–0.65	0.97–0.98	0.56–0.64	0.68–0.74	5.7–7.8	2.2–2.6	5.6–5.9
Slow seagoing cargo ships	0.66–0.74	0.97–0.995	0.65–0.73	0.80–0.86	4.8–8.5	2.1–2.3	5.2–5.4
Coastal cargo ships	0.69–0.73	−0.985	0.58–0.72	0.78–0.83	4.5-5.5	2.5–2.7	4.2–4.8
Small short sea passenger ships	0.61–0.63	0.82–0.85	0.51–0.53	0.65–0.70	5.8-6.5	3.3–3.9	6.3–6.6
Ferries	0.53–0.62	0.91–0.98	0.50–0.60	0.69–0.81	5.9–6.2[a] 5.2–5.4[b]	3.7–4.0	6.2–6.9[a] 5.7–5.9[b]
Fishing vessels	0.61–0.63	0.87–0.90	0.53–0.56	0.76–0.79	5.1–6.1	2.3–2.6	5.0–5.4
Tugboats	0.61–0.68	0.75–0.85	0.50–0.58	0.79–0.84	3.8–4.5	2.4–2.6	4.0–4.6
Bulk carriers	0.79–0.84	0.990–0.997	0.72–0.86	0.88–0.92	5.0–7.1[a]	2.1–3.2	4.7–5.6
Tanker $F_n = 0.15$	0.835–0.855	0.992–0.996	0.82–0.88	0.88–0.94	5.1–6.8	2.4–3.2	4.5–5.6
Tankers $F_n = 0.16-0.18$	0.79–0.83	0.992–0.996	0.78–0.86	0.88–0.92	5.0–6.5	2.2–2.9	4.5–5.2
Fast seagoing reefers	(0.55)[c] 0.59–0.62	0.96–0.985	(0.53)[c] 0.57–0.59	0.68–0.72	6.7–7.2	2.8–3.0	6.1–6.5

[a] For $L > 100$ m
[b] For $L = 80-95$ m
[c] C_P, $C_B < 0.57$

Table 2.5 Hull form coefficients and ratios of main dimensions for merchant ships (synthesis of original data by Strohbusch, 1971, updated by use of IHS Fairplay World Shipping Encyclopedia, v. 12.01, 2011). Given upper and lower boundaries correspond to the standard deviation from the regression line of sample ships, as shown in Appendix A

Ship type	Ratio of main dimensions		
	L_{PP}/D	F_{FP}-%L_{PP}	L_P-%L_{PP}
Fast seagoing cargo ships	9.9–13.5	5.1–6.3	20–25
Slow seagoing cargo ships		5.8–7.0	30–35
Coastal cargo ships	10.0–12.0	up to 7.0	40–50
Small short sea passenger ships	10.4–11.6	6.6–7.9	20–25
Ferries	8.6–10.3	7.0–10.0	25–35
Fishing vessels	8.2–9.0	8.0–8.5	15–25
Tugboats	7.7–10.0	8.2–10.2	20–30
Bulk carriers	10.5–12.8	4.4–4.9	50–60
Tankers $F_n = 0.15$	12.0–14.0	3.6–4.5	50–60
Tankers $F_n = 0.16-0.18$	10.5–12.8	4.4–4.9	50–60
Fast seagoing reefers	−11.0	5.6–6.6	10–15

For both cases C takes the following value:

$$C = 3.2 \qquad\qquad \text{for } C_B = 0.145/F_n$$
$$= 3.2\frac{C_B + 0.5}{(0.145/F_n) + 0.5} \qquad \text{for } C_B \neq 0.145/F_n$$

The above constraints in the formula for the C_B are understood approximately.

The basic limitations for applying the above empirical formula are as following:

1. $\Delta \geq 1{,}000$ t.
2. V corresponding to $0.16 \leq F_n \leq 0.32$.
3. C_B within the boundaries $0.48 \leq C_B \leq 0.85$.
4. Proportional correction of the constant C (increase) for restrictions on B and T and high ratio of volume below D to displaced volume (∇_D/∇).
5. Correction of constant C (decrease) for the existence of optimized bulbous bow.

The constant C can be alternatively calculated by using the following formula (Friis et al. 2002):

$$C = 3.4 - (\Delta - 10^3)/10^6 \qquad \text{for} \quad 1{,}000\text{ t} \leq \Delta \leq 201{,}000\text{ t}$$
$$= 3.2 \qquad \text{for} \quad \Delta > 201{,}000\text{ t}$$

The above formula by Schneekluth (1985) is the result of statistical analysis of data of optimized ships with respect to only construction cost. However, taking into account as well the operating cost, which is equally important for the owner's interests, an increase of about 10% of the length resulting from the above formula is recommended (which leads to lower resistance, reduced propulsive power and fuel cost).

c. Formulas from statistical analyses of data of existing ships[8]

1. Ayre's formula for length estimation:

$$L_{PP}/\nabla^{1/3} = 3.33 + 1.67\, V/\sqrt{L_{PP}} \tag{2.46}$$

2. Posdunine/V. Lammeren's formula for length estimation

$$L_{WL}/\nabla^{1/3} = CV/(V+2)^2 \tag{2.47}$$

where

C = 7.62 (all types, Posdunine)
= 7.16 (cargo ships, V. Lammeren)
= 7.32 (fast twin-screw ships, V. Lammeren)
= 7.92 (fast passenger ships, V. Lammeren)

3. Völker's formula for length estimation

$$L_{PP}/\nabla^{1/3} = C_1 + 4.5V/\sqrt{g \cdot \nabla^{1/3}} \tag{2.48}$$

[8] All below formulas refer to the data of old ships; they deliver in general larger lengths than used today in practice; they are, however, a good yardstick for evaluating possible ship lengths at the conceptual design stage.

where

C_1 = 3.5 for dry bulk cargo ships/containerships
= 3.0 for reefer ships
= 2.0 for fishing/short sea cargo ships.

Notes on units in formulas 1 to 3 (Eqs. 2.46, 2.47, 2.48):

1. L (m); V (kn)
2. ∇: displaced volume (m^3); V (kn)
3. g (m/s^2): gravitational acceleration; V (m/s): design speed (service)

d. Use of diagrams for various types of ships

1. Figure 2.24: Relation of L_{PP} and of $L \cdot B \cdot D$ to the required hold capacity for tankers (Lamb 2003).
2. Figure 2.25: Relation of the ratios L_{PP}/B and L_{PP}/D to the required hold capacity for tankers (Lamb 2003).
3. Figure 2.26: Relation of the L_{PP} (B and D) to the required hold capacity ∇_{REQ} for cargo ships according to Watson and Gilfillan (1976).

~~*Instructions for use graph 2.26*~~

3.1. Estimation of ∇_{REQ} based on the required capacity GRAIN (+1 to + 2%) or BALE (+11 to +12%), for example 20,000 m^3.
3.2. Assumption of L/B and B/D based on similar ships, for example $L/B = 6.5$ and $B/D = 1.8$.
3.3. Assume the engine room position to be abaft or 3/4 of length abaft; here, for example, 3/4 L abaft amidships.
3.4. Find hull's total volume below the main deck (abscissa) ∇_H, for example 27,560 m^3, and the corresponding engine room volume, $\nabla_M = \nabla_H - \nabla_R$, for example, 7,560 m^3.
3.5. Find the product of $(L \times B \times D)$ (ordinate), for example 38,760 m^3, based on the approximation of the block coefficient C_{BD} at the height of D, for example 0.70. The latter may be estimated based on C_B, for the draft T, see 2.9, and use of the side graph of Fig. 2.26 (bottom left of Fig. 2.26).
3.6. Find the main dimensions of L_{PP}, B, and D from the side graph of Fig. 2.26 (top left), for example $L_{PP} = 139.8$ m, $B = 21.5$ m, $D = 12$ m, where the straight lines $L/B = 6.5$ and $B/D = 1.8$ can be replaced with other values, which correspond to respective similar ships.

4. Figure 2.27: Approximations of L_{PP}, coefficient $L \cdot B \cdot D$ and the ratio L_{PP}/B for ships carrying standardized containers as a function of the total number of transported TEU containers (Twenty Feet Equivalent Unit ISO standardized boxes of 20 ft length, 8 ft breadth and 8 (8.5) ft height).

5. Figure 2.28: Relation of the displacement Δ to the length L_{PP} (a), the coefficient $L \cdot B \cdot D$ to the installed power (b), and the ratio L/D to the waterline length L_{WL} (c) for *tugboats* (Lamb 2003).
6. Figure 2.29: Relation of the main dimensions and other characteristics for North Sea *fishing vessels* to the volume of fish hold (refrigerated hold) (Henschke 1964).

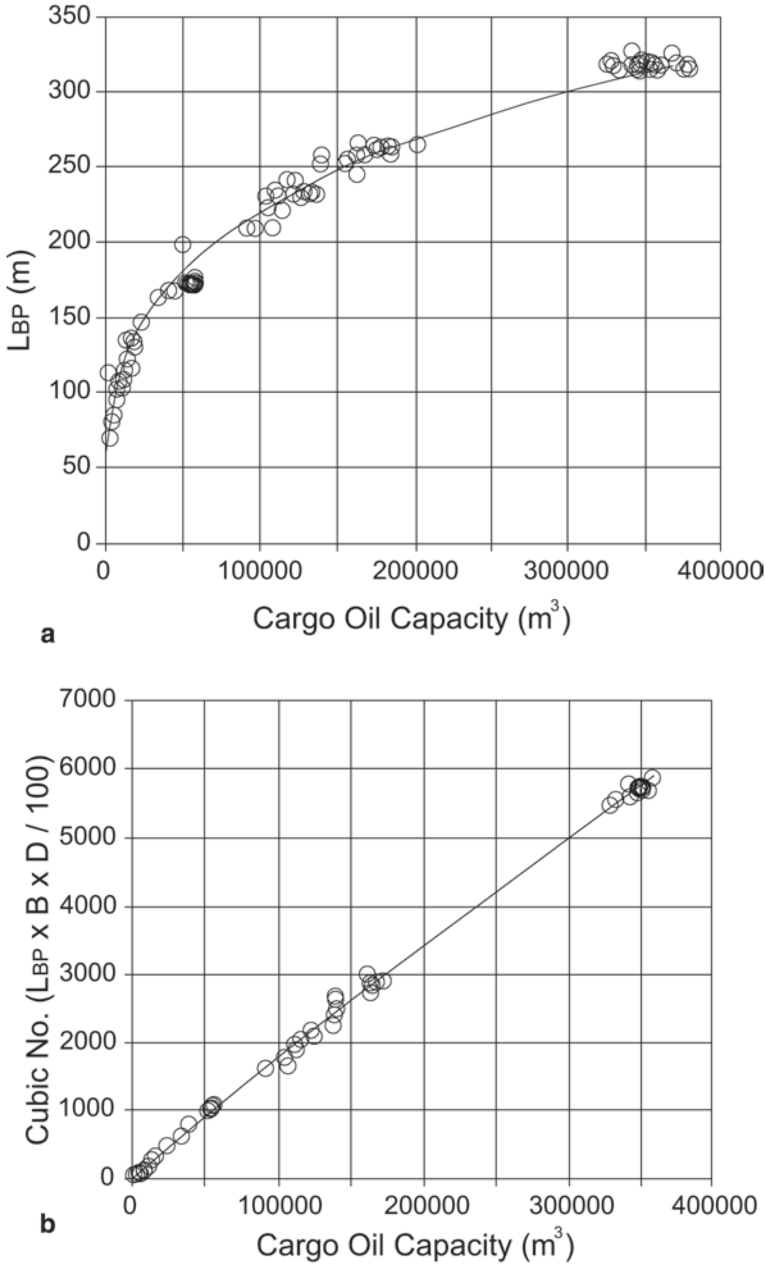


Fig. 2.24 Relations of L_{PP} and volumetric numeral $L \times B \times D$ to the hold capacity for tankers. (Lamb 2003)

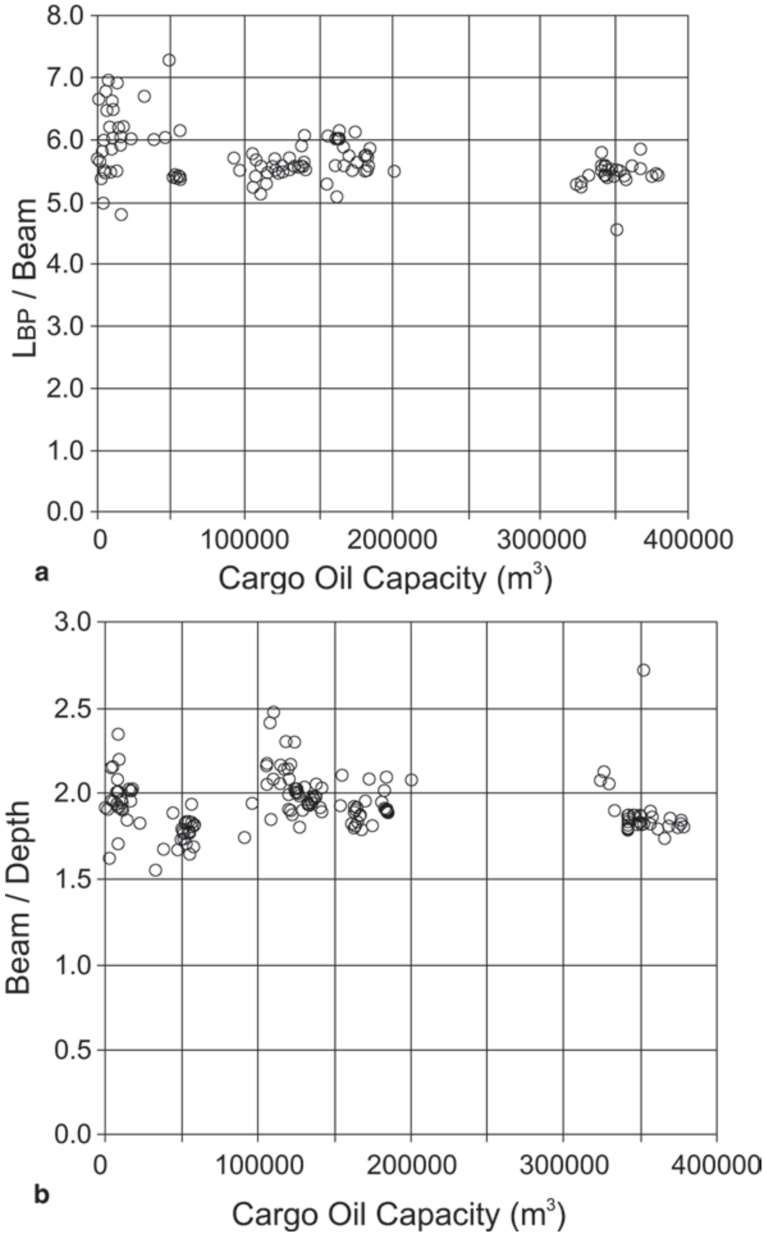


Fig. 2.25 Relation of the ratios L_{pp}/B. **a** and L_{pp}/D. **b** to the hold capacity for tankers. (Lamb 2003)

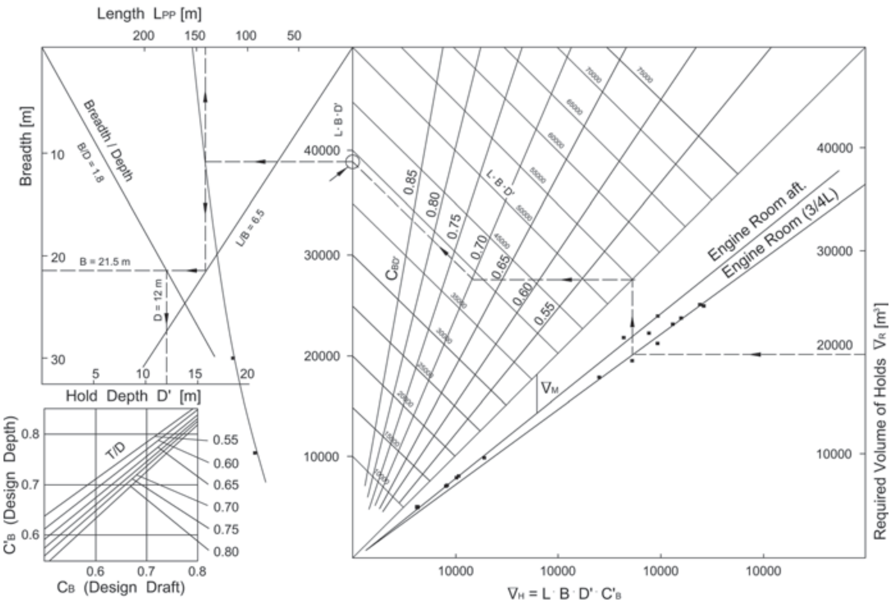


Fig. 2.26 Determination of main dimensions based on the required hold capacity under main deck ∇_R according to Watson and Gilfillan (1976), for $L/B = 6.5$ and $B/D = 1.8$

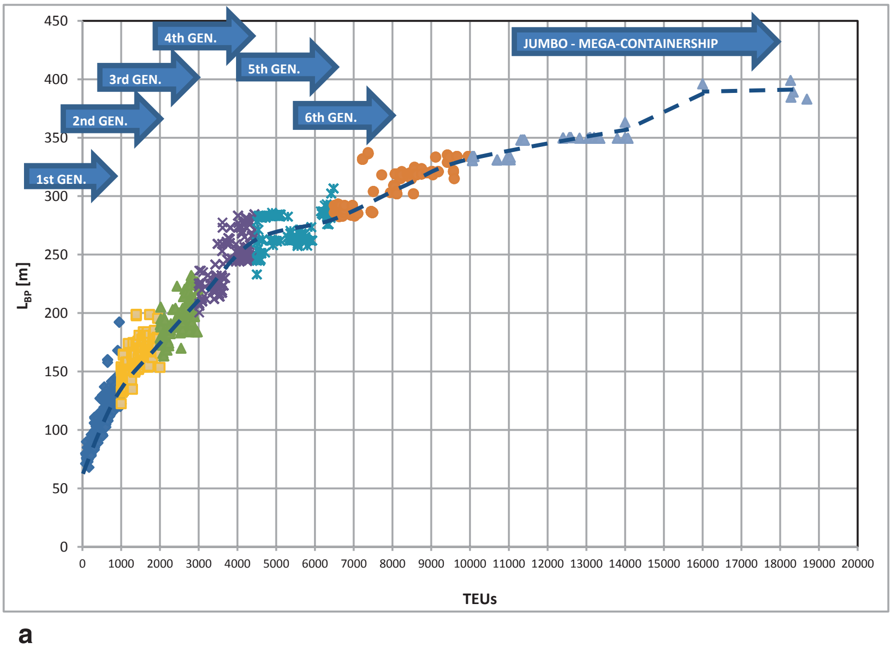
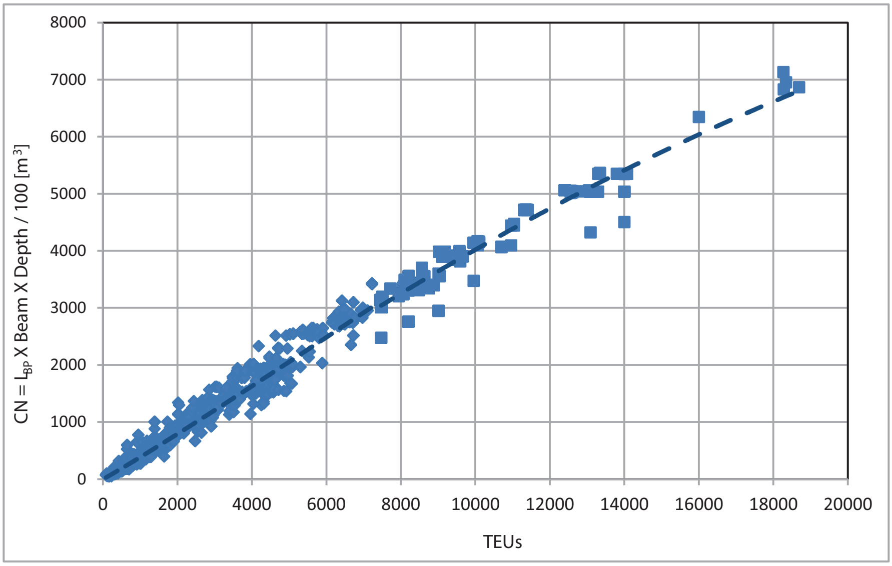
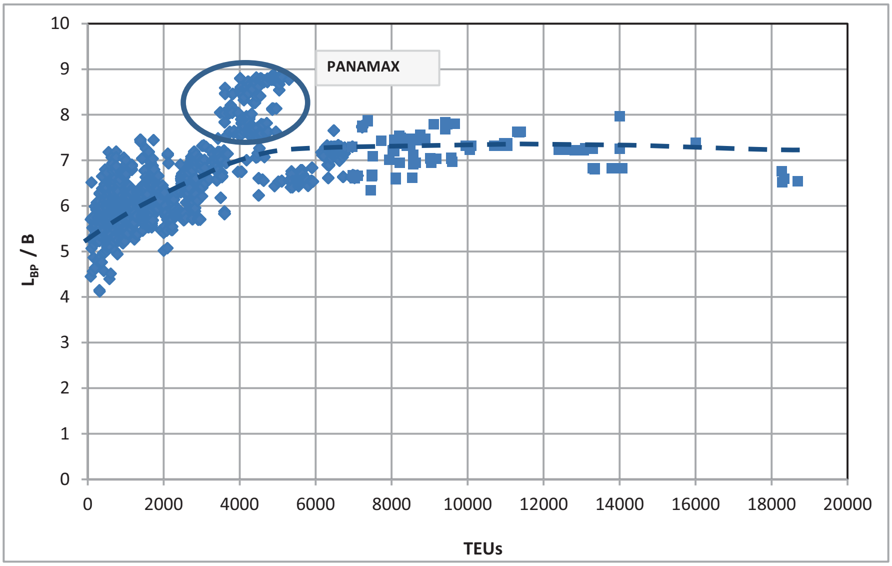


Fig. 2.27 Relations of (a) length L_{PP}, (b) volumetric numeral $L{\cdot}B{\cdot}D$ and (c) the ratio L_{PP}/B to the total number of transported TEU containers for containerships. (Papanikolaou 2014)



b



c

Fig. 2.27 (continued)

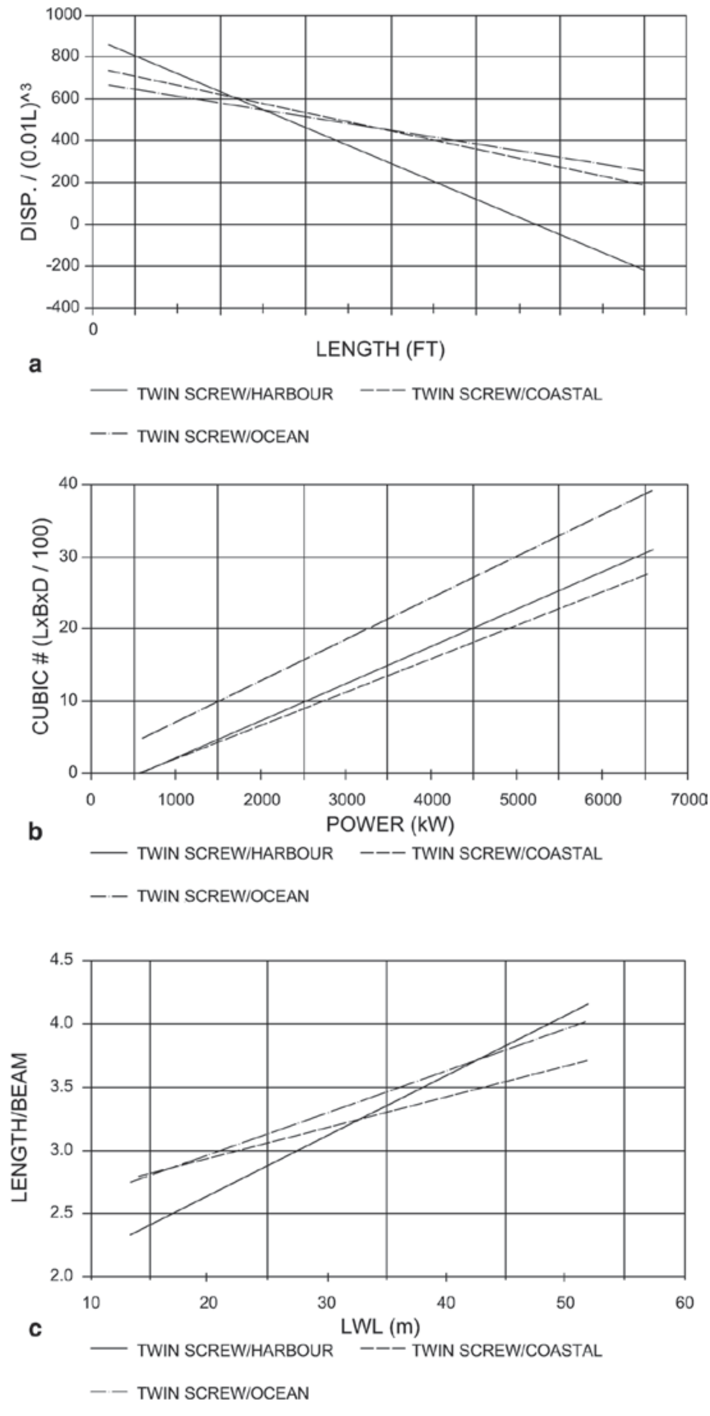


Fig. 2.28 (a) Relation of displacement with the length L_{PP}, (b) the volumetric numeral $L{\cdot}B{\cdot}D$ with the installed power and (c) the ratio L/B with the waterline length L_{WL} for tugboats. (Lamb 2003)

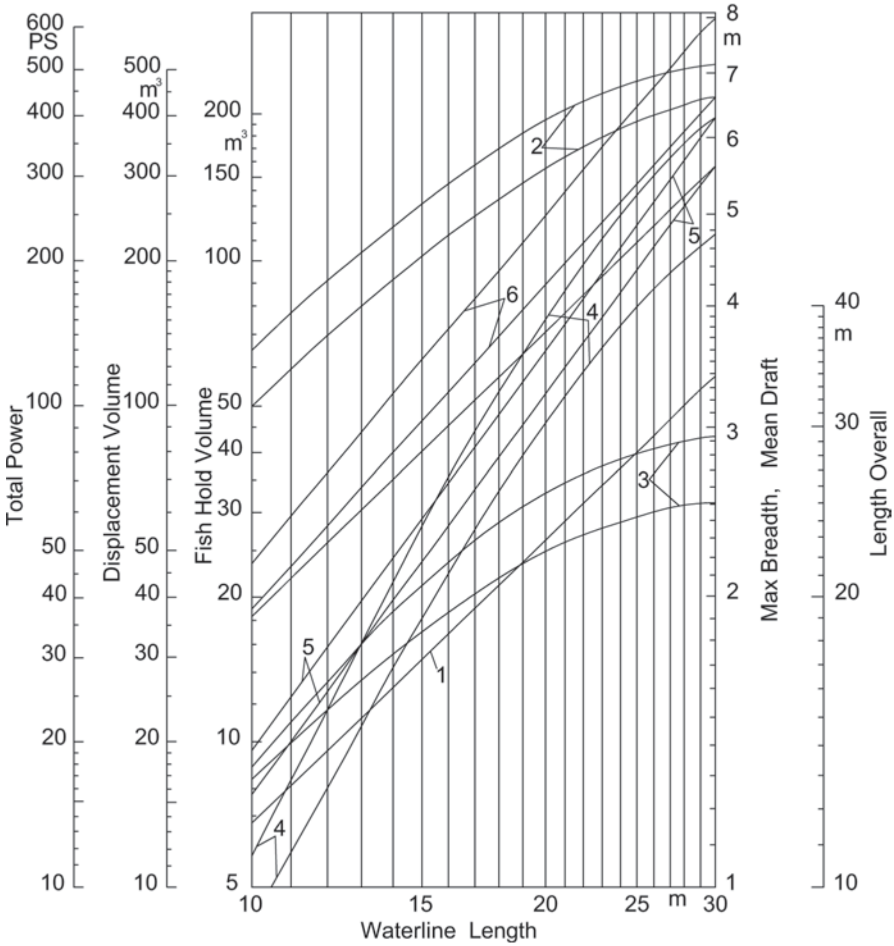


Fig. 2.29 Relationships of the length L_{WL} to other dimensions and basic characteristics for North Sea fishing vessels. (Henschke 1964). (*1*. Overall length, *2*. Beam (maximum), *3*. Average draft, *4*. Fish hold volume, *5*. Displaced volume, *6*. Installed engine power)

7. ~~Figure 2.30: Relation of L_{PP}, B, and D to the refrigerated hold capacity for fishing ships (Lamb 2003).~~
8. ~~Figure 2.31: Relation of L_{OA}, B, and T to deadweight for Chemical Tankers (Lamb 2003).~~
9. ~~Figure 2.32: Statistical averages of slenderness coefficients of oceangoing ships~~ according to Völker (1974).

e. Recommended procedure for the determination of length

   e1. Approximation of L based on the slenderness coefficient (see procedures (a) and (c))

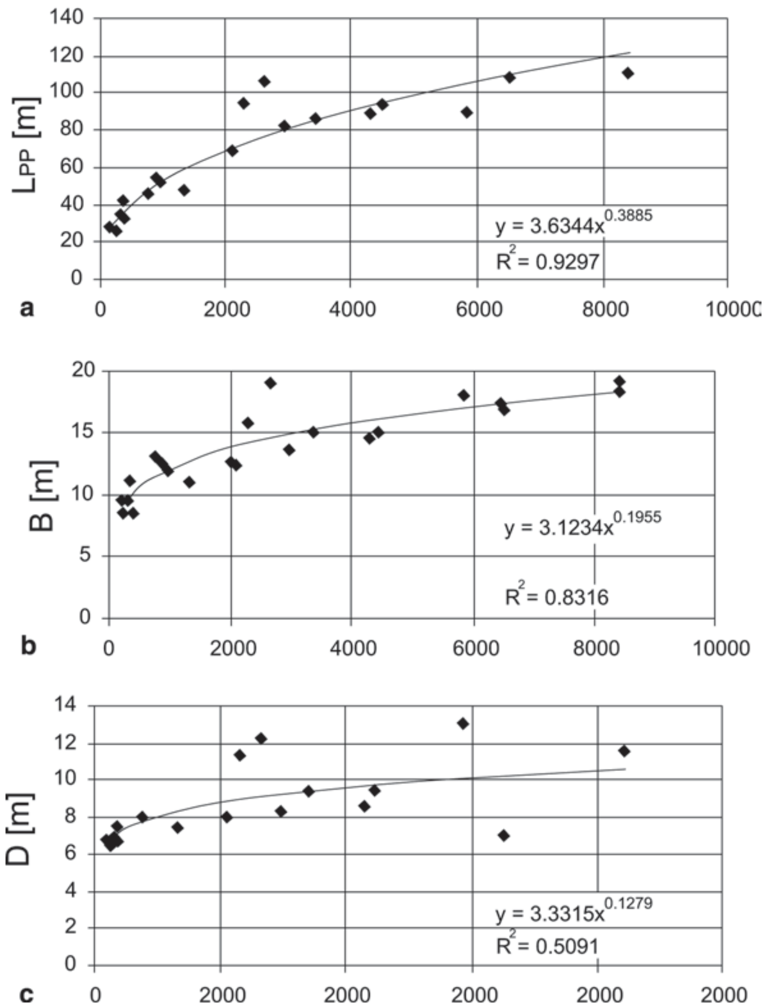


Fig. 2.30 Relationships of length L_{PP}, beam B, and side depth D to refrigerated hold capacity for fishing vessels. (Lamb 2003). (length (m) (**a**), beam (m) (**b**), side depth (m) (**c**))

e2. Examination of the resultant L based on the "least cost" formula according to Schneekluth (b)
e3. Examination of the resultant L based on the empirical diagrams (d)
e4. Examination and adjustment of L with regard to the physical, passing constraints: physical limits of channels, canals, ports, slipways, or docks of the shipyards

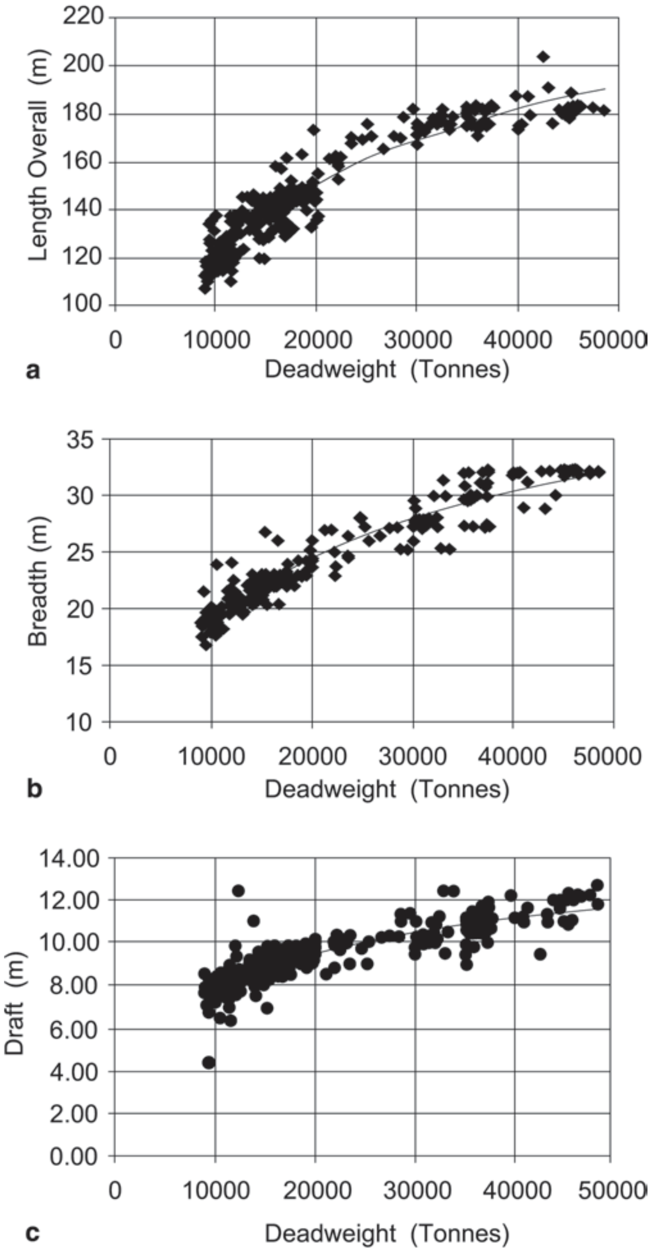


Fig. 2.31 Relationships of length L_{OA} (**a**), beam B (**b**), and draft T (**c**) to deadweight for chemical tankers. (Lamb 2003)

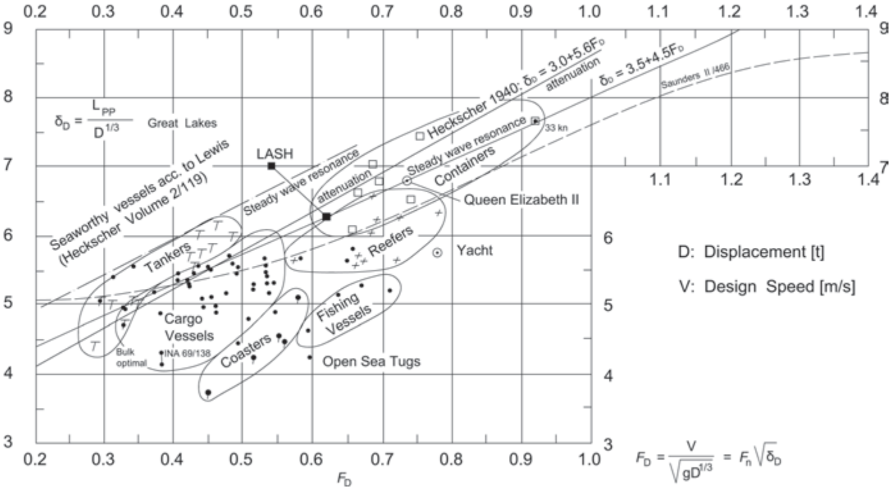


Fig. 2.32 Average slenderness coefficients of ocean-going ships according to Völker (1974)

e5. Examination of L with respect to the required number of transverse bulkheads according to the specifications of a recognized classification society[9]; possible adjustment of the length in cases of marginal exceedance of the limit for certain required number of bulkheads (bulkhead/steel weight savings)

e6. Examination of L, in conjunction with side depth D, regarding the ratio of (L/D) that needs to be below certain limit according to the rules of specific classification society

e7. Examination of L with respect to the possible occurrence of resonance of ship motions in typical waves in the region of operation (to avoid $\lambda_W \sim L$); this only applies to vessels with special requirements in terms of seakeeping, such as passenger ships and naval ships in general

e8. Examination of L with respect to the superposition of the generated bow wave, stern wave and shoulder waves for certain speeds of the ship due to possible excessive increase of wave resistance; indirectly, examination of the appropriateness of the operational Froude number

In the preliminary design stage, the above process is limited to the first six steps only (1–6).

[9] Every ship must have at least one collision bulkhead, one after peak bulkhead, and one bulkhead at the fore and aft boundaries of the engine room. In case the engine room is placed astern, the after-peak bulkhead coincides with the aft bulkhead of the engine room. The total number of bulkheads as a function of ship's length L in accordance with the regulations of, for example, Lloyd's Register is as follows:

$L \leq 65$ m, $N=3$ (4); 65 m $< L \leq 85$ m, $N=4$ (4); 85 m $< L \leq 90$ m, $N=5$ (5); 90 m $< L \leq 105$ m, $N=5$ (5); 105 m $< L \leq 115$ m, $N=5$ (6); 115 m $< L \leq 125$ m, $N=6$ (6); 125 m $< L \leq 145$ m, $N=6$ (7); 145 m $< L \leq 165$ m, $N=7$ (8); 165 m $< L \leq 190$ m, $N=8$ (9); $L > 190$ m, N as appropriate.

The above applies to ships with engine rooms placed astern (in parenthesis the corresponding number of bulkheads for the engine room placed amidships).