Example 1: Bulk Carrier Dimensioning

Problem:

- Optimize the main dimensions and service speed of a bulk carrier in order to minimize the Annual Unit Cargo Transportation Cost (US$/ton)

Assumptions:

- The round trip voyage distance is assumed to be 5,000 miles
- The fuel oil cost is assumed to be 100 US$/t
- The cargo handling rate in port is assumed to be 8,000 t/day

NOTE:
These assumptions represent design parameters.
They should be clearly stored in cells, NOT hidden in formulas!

Example 1: Computation Model

- The simplified Model used on the example is based on the one presented in Xuebin (2009)

Annual cost = capital costs + running costs + voyage costs
Capital costs = 0.2 × ship cost
Ship cost = $1.3 \times (2{,}000 \times W_s^{0.85} + 3{,}500 \times W_o + 2{,}400 \times P^{0.8})$
Steel weight = $W_s = 0.034 \times L^{1.7} \times B^{0.7} \times D^{0.4} \times C_B^{0.5}$
Outfit weight = $W_o = 1.0 \times L^{0.8} \times B^{0.6} \times D^{0.3} \times C_B^{0.1}$
Machinery weight = $W_m = 0.17 \times P^{0.9}$
Power = P = displacement$^{2/3} \times V^3/(a + b \times F_n)$
Displacement = $1.025 \times L \times B \times T \times C_B$
Froude number = $F_n = V/(g \times L)^{0.5}$
V (m/s) = $0.5144 \times V_k$; $g = 9.8065$ m/s^2
$a = 4{,}977.06 \times C_B^2 - 8{,}105.61 \times C_B + 4{,}456.51$
$b = -10{,}847.2 \times C_B^2 + 12{,}817 \times C_B - 6{,}960.32$
Running costs = $40{,}000 \times DWT^{0.3}$
Deadweight = DWT = displacement-light ship
Voyage costs = (fuel cost + port cost) × RTPA
Fuel cost = 1.05 daily consumption × sea days × fuel price
Daily consumption = $0.19P \times 24/1000 + 0.2$

Sea days = round trip miles/$(24 \times V_k)$
Round trip miles = 5,000 (nm)
Fuel price = 100 (£/t)
Port cost = $6.3 \times DWT^{0.8}$
Round trips per year = RTPA =350/(sea days + port days)
Port days = 2 × [(cargo deadweight/handling rate) + 0.5]
Cargo deadweight = DWT-fuel carried-miscellaneous DWT
Fuel carried = daily consumption × (seadays + 5)
Miscellaneous $DWT = 2.0 \times DWT^{0.5}$
Handling rate = 8,000 (t/days)
Vertical center of buoyancy = $KB = 0.53 \times T$
Metacentric radius = $BM_T = (0.085 \times C_B - 0.002) \times B^2/(T \times C_B)$
Vertical center of gravity = $KG = 1.0 + 0.52 \times D$

Light ship weight = $W_s + W_o + W_m$ (t)
Annual cargo = cargoDWT * RTPA

Objective Function → **Minimize:** Transportation cost = annual costs/annual cargo

Example 1: Physical Limitations and Constraints

- The following set of 14 constraints is applied:

$$L/B \geq 6$$
$$L/D \leq 15$$
$$L/T \leq 19$$
$$T \leq 0.45DWT^{0.31}$$
$$T \leq 0.7D + 0.7$$
$$25{,}000 \leq DWT \leq 500{,}000$$
$$0.63 \leq C_B \leq 0.75$$
$$14 \leq V_K \leq 18$$
$$L \leq 274.32$$
$$F_n \leq 0.32$$
$$GM_T = KB + BM_T - KG \geq 0.07B$$