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Published Papers (1988-1993)

on Fishing Vessels Design and Economics

by

Prof. Dr. M. A. Shama

1- "Factors Affecting Productivity of Coastal Fishing Vessel", AEJ, April, (Egypt-1988), Shama, M. A., (100%)
2- "Factors Affecting Fishing Voyage Expenses and Efficiency", AEJ, April, (Egypt-1988) , Shama, M. A., (100%)
3- "Operational Cost Analysis of Coastal Fishing Vessel", AEJ, July, (Egypt-988), Shama, M. A., (100%)
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6- "Appraisal of Fishing Vessel Economics Using Risk Analysis", AEJ, Jan., (Egypt-1990), Shama, M. A., 100%)
7- "A Rational approach to the Determination of Principal Dimensions of Coastal Trawlers", AEJ, Jan., (Egypt-1993), Shama, M. A., Eliraki, A. M., and Atwa, K. I. (33%)
8- "A Computer Based design Model for Coastal Stern Trawlers", AEJ, Jan., (Egypt-1993), Shama, M. A., Eliraki, A. M., and Atwa, K. I. (33%)
9 - "Appraisal of Fishing Vessel Economics Using Risk Analysis", ISUMA93, April. (USA-1993), Shama, M. A., (100%)
10 - "An Integrated Rational Approach for Improving the Economics of Coastal Stern Trawlers", AEJ, April. (Egypt-1994), Shama, M. A., (100%)

A RATIONAL APPROACH TO THE DETERMINATION OF THE PRINCIPAL DIMENSIONS OF COASTAL TRAWLERS

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ABSTRACT

The importance of the determination of the principal dimensions for the economic operation of trawlers is mentioned. A rational approach is proposed for the determination of the length between perpendiculars. The determination of breadth, depth and draught according to different design criteria is presented. These design criteria include fish hold capacity, stability and ship motions. A computer program (DPD) is developed to determine the principal dimensions of coastal stern trawlers using the proposed approach. A case study is presented to demonstrate the procedure of determining the principal dimensions for coastal trawlers operating in the Red Sea.

NOMENCLATURE

B	breadth moulded in m
B_{AP}	breadth at aft perpendicular, in m
b_e	brake specific fuel consumption, in t/bhp hr
B_{ER}	average breadth of engine room, in m
BM	metacentric radius, in m
D	depth moulded in m
Δ	displacement, in tonnes
DWT	total dead weight, in tonnes
$\overline{GM}$	metacentric height, in m
I_T	transverse moment of inertia of the load water line, in m^4
$\overline{KB}$	vertical position of center of buoyancy above keel, in m
$\overline{KG}$	vertical position of center of gravity above keel, in m
L_{AC}	length between aft perpendicular and aft peak PHD, in m
L_{AP}	length between aft perpendicular and aft peak bulkhead, in m
LBP	length between perpendicular, in m
L_{ER}	length of engine room, in m
L_{FH}	length of fish hold, in m
L_{FP}	length between fore perpendicular and fore peak bulkhead, in m
L_{ME}	length of main engine, in m
N_{cr}	number of crew
P	brake hose power
P_{fr}	shaft horse power of the main engine
Q	fishing rate per day, in tonnes/day
R_N	net drag, in kN
R_T	total resistance of the ship in towing condition, in kN
ρ	density of water, in tonnes/m^3
T	draught, in m
T_{AL}	Time allowance, in days
T_{FA}	time in fishing area, in days
T_{OV}	time of outgoing voyage, in days
T_{RV}	time of return voyage, in days
T_{Φ}	rolling period, in sec.
V_T	Towing speed, in knots
V_{FH}	fish hold capacity, in m^3
W_{AL}	weight allowance, in tonnes
W_{LS}	light ship weight, in tonnes
$W_{M/C}$	machinery weight, in tonnes
W_{OU}	outfitting weight, in tones
W_{ST}	hull steel weight, in tonnes
c	rolling period coefficient
C_b	block coefficient
C_{FH}	fish hold capacity coefficient
C_{IT}	coefficient of transverse moment of inertial of load water line
C_w	water plane area coefficient
η_p	propulsion efficiency
η_g	coupling efficiency
η_m	mechanical efficiency

INTRODUCTION

Design of coastal trawlers requires in the first place, the determination of the principal dimensions. These principal dimensions have a great effect on the economics of fishing vessels. The length of the vessel has the major effect on its economics. As the length increases. The building cost increases. The other principal dimensions, breadth, depth and draught affect the fish hold capacity, stability and ship motions.

The principal dimensions of trawler could be determined using the conventional method [1]. This method depends on the analysis of relationship between design parameters of similar ships. Figure (1), shows the scatter range of length between perpendiculars as related to the fish hold capacity [1]. Therefore this method may give overestimated, or underestimated, values for the length which may have an adverse effect on the economy of the vessel.

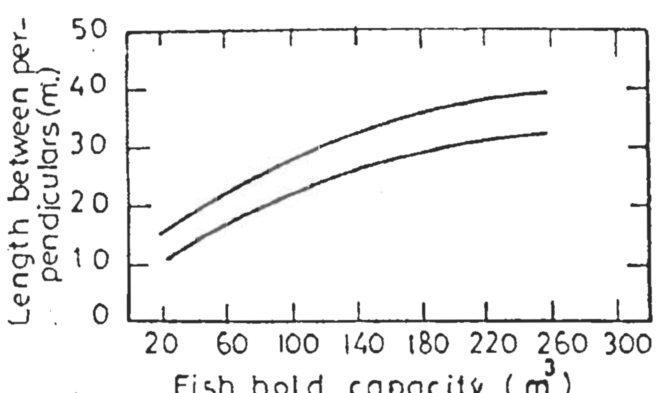

Figure 1. Length between perpendiculs versus releted to fish hold capacity.

As we are dealing here with coastal trawlers with length from 20 to 35 m. a slight change of length will have a proportional effect on the building costs and the operational cost of the ship.

The proposed approach of aggregated length is based on the decomposition of the total length of the fishing vessel into the length of the different sections of the hull. The individual lengths of each section is determined according to the factors affecting the design parameters of each section. The total length of the vessel is the sum of these lengths. The breadth and the depth are determined according to the ratios of B/T and B/D, fish hold capacity, stability and ship motions requirements. The draught is determined according to the displacement equation.

2- THE PROPOSED APPROACH OF AGGREGATED LENGTH FOR STERN TRAWLERS

In this approach, the length of a stern trawler is decomposed into the length of the main hull sections which include the fish hold, accommodation, engine room, aft peak and fore peak. The design procedure could be summarized as follows:

i Determination of the individual length of each hull section related to the relevant design parameters effecting it.

ii- Determination of the length between perpendiculars by summing the individual lengths of hull sections.

iii- Determination of breadth and depth according to the following factors:

- Fish hold capacity
- Stability and ship motions requirements
- (B/D) ratio

iv- Determination of draught from displacement equation.

A general flow chart, Figure (2) shows the entire design procedure for the determination of the principal dimensions.

This approach, therefore, is based on a known general arrangement plan. Figure (3) (a,b) shows the two proposed general arrangement plans of a coastal fishing vessel where the accommodation is located under or above the main deck.

These arrangements have the following advantages:

1- Locating the fish hold in the midships region gives greater capacity to the fish hold.

2- The ship has no serious trimming problem when changing from unloaded to loaded conditions as center of gravity of fish hold is close to the center of floatation of the vessel (nearly amidships).

3- Torsional stress and distortion of the propeller shaft is minimized as the shaft length is decreased.

4- Fish hold capacity is not reduced by the presence of a shaft tunnel.

The target now is to determine the individual length of each section in the hull for the general arrangement plan. The length of each section is determined from the design parameters affecting each section as follows:

Length of fish hold depends on the amount of catch i.e. the fishing days, fishing rate per day and the catch type [2].

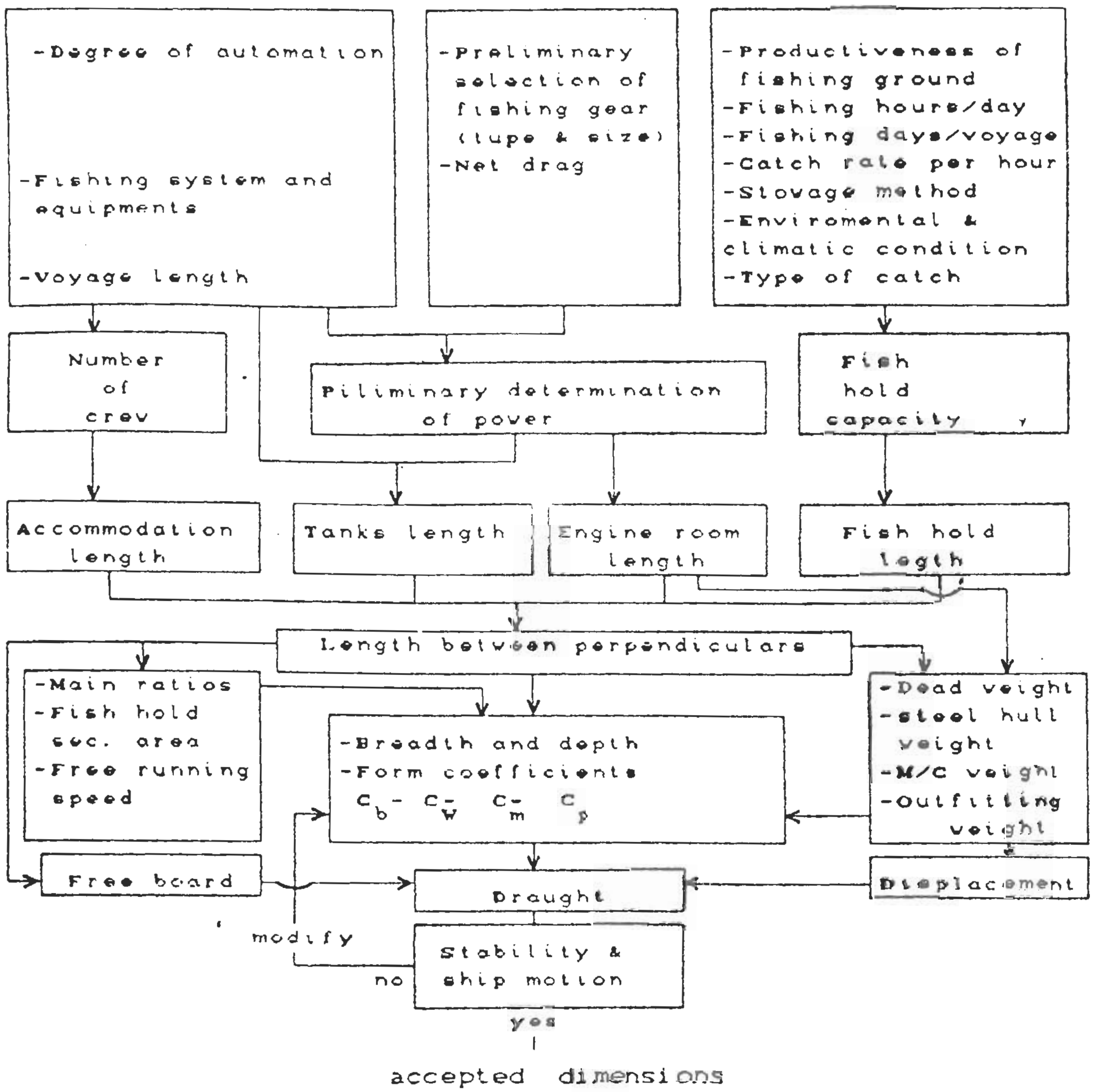

Figure 2. General flow chart for the determination of principal dimensions of the coastal stern trawler.

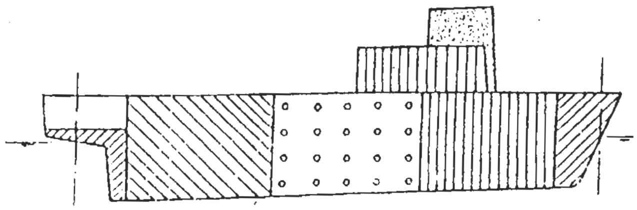

Figure (3-a)

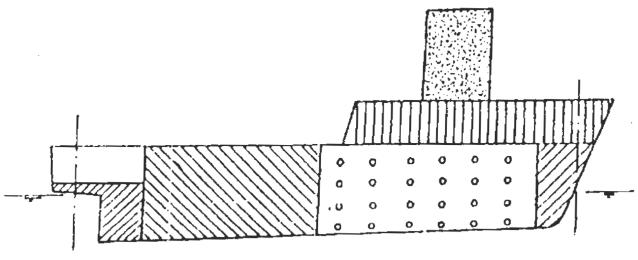

Figure (3-b)

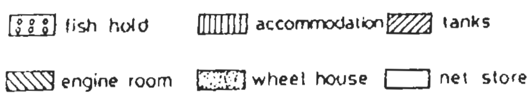

Figure 3. Proposed general arrangement plans for coastal fishing vessels.

Length of engine room depends on the installed engine power which must satisfy net towing requirements (towing speed and trawl net drag) [3].

Length of accommodation depends on the number of crew, fishing voyage duration, size and arrangement of furniture, etc.

Length of fore and aft peaks depends on the required size of stores and amount of ballast required [3] and regulations concerning location of fore and aft peak bulkheads.

The aggregated length between perpendiculars is composed of the main hull sections length shown in Figures (4a, 4b) as follows:

$$\text{case a } LBP = L_{AP} + L_{ER} + L_{FH} + L_{AC} + L_{FP}$$

$$\text{case b } LBP = L_{AP} + L_{ER} + L_{FH} + L_{FP}$$

Particulars of some coastal trawlers Table 1 have been analyzed to give the following formulae:

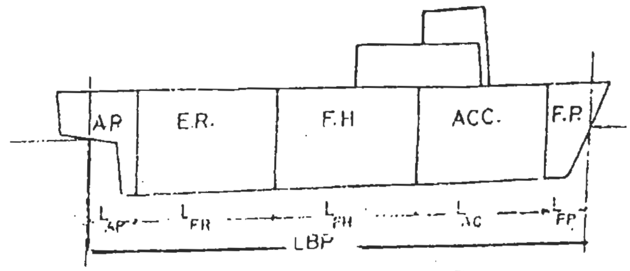

Figure (4a)

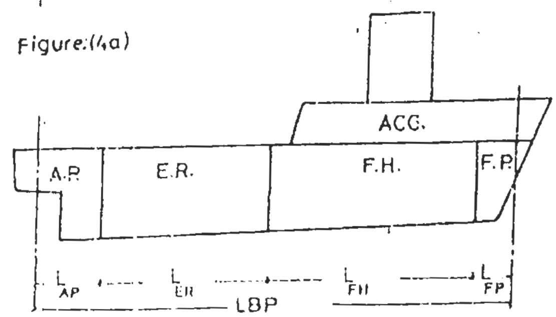

Figure (4b)

Figure 4. Composition of length between perpendicular for proposed general arrangements of trawlers.
a- $LBP = L_{AP}+L_{ER}+L_{FH}+L_{AC}+L_{FP}$
b- $LBP = L_{AP}+L_{ER}+L_{FH}+L_{FP}$.

Table 1. Input data sheet for DPD PDP (Determination of Principal Dimensions).

Data sheet	
duration	Fish data
T_{ov} = 7 day T_{rv} = 7 day T_{fa} = 10 day	Q = 12 Ton/day
Type of General Arrangement j = 1 Accommodation Above main deck 1 Accommodation Under main deck 2	Stowage method = i = 3 Frozen fish single 1 Frozen fish in single 2 Frozen fish fillets 3 Frozen fish in ice Salted fish 5 Canned Fish 5
Ncr = 15 V_T = 4 knots	Fish hold capacity k = 1 specified k = 2 unspecified k = 2

2.1 length of fish hold L_{FH}

Analysis of data collected from several fishing vessels could be used to obtain the relationship between the fish hold length and the fish hold capacity, as shown in Figure (5). Using statistical analysis, the following relationship is developed, which could be used to estimate the length of the fish hold when the fish hold capacity is known:

$$L_{FH} = 2.54 * V_{FH}^{1/3} - 2.1 \text{ m}$$

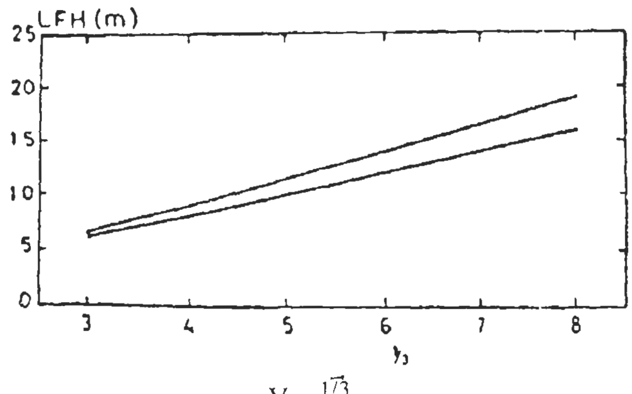

Figure 5. LFH Versus VFH.

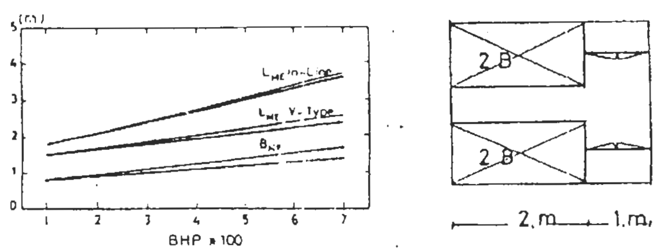

Figure 6. Dimensions of main engine.

2.2 *Length of engine room* L_{ER}

The length of engine room is related to the required power of main and auxiliary engines. Figure (6) illustrates the length and breadth of different engines for both In-line and V-types. This gives a guide for determining the principal dimensions of the engine room after allowing for the required clearances around the main engine as shown in Figure (7). These clearances are found to be suitable for operation and maintenance work. The main engine power could be estimated as a function of the net drag at a certain towing speed. This power is considered as a reference for the required shaft horse power for the free running speed as follows [3]:

$$P_{fr} = (1.4 - 1.5) P$$

$$P = V_T * (R_N + R_T) / \eta_D$$

The brake horse power of the main engine could be determined as follows [3]:

$$PHP = P_{fr} / (\eta_m * \eta_g)$$

The dimensions of the main engine could be determined from the analysis of available data of engine power and engine width and length as follows:

$$L_{ME} = 1.7 + PHP / 500 \text{ m} \quad \text{In-line}$$

$$L_{Me} = 1.4 + BHP / 500 \text{ m} \quad \text{V type}$$

$$B_{ME} = 0.35 + BHP / 700 \text{ m}$$

Having determined the dimensions of the main engine, the engine room length and breadth could be determined by adding the clearances required around the main engine in the engine room:

$$L_{ER} = 4.2 + BHP / 500 \text{ m}$$

$$B_{ER} = 3.85 + BHP / 700 \text{ m}$$

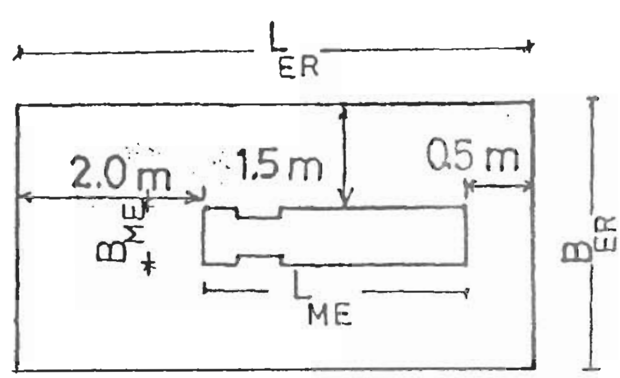

Figure 7. Engine rooms dimensions.

2.3 *Length of aft peak and fore peak* L_{AP}, L_{FP}

The combined length of aft peak and fore peak for most of the vessels analyzed are found not to exceed 20% of the length between perpendiculars.

$$\text{i.e. } L_{AP} + L_{FP} = 0.2 \text{ LBP}$$

2.4 *Length of a accommodation* L_{ACC}

For the general arrangement, type (a), where accommodation is located under the main deck, the number of crew commonly is ranges from 4 to 6 persons, the length of accommodation compartment could be taken from 3 to 5 m. In Figure (8), two typical arrangements for crew accommodation are shown.

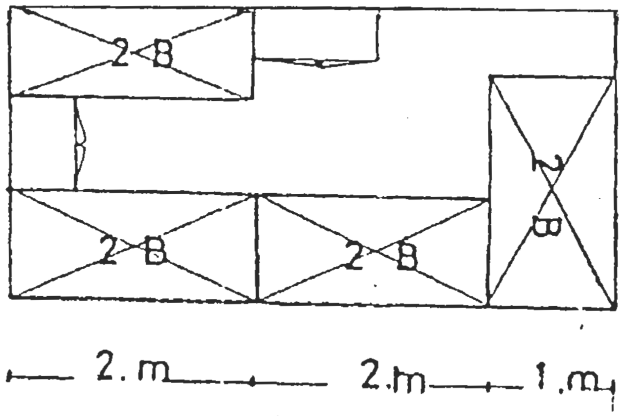

Figure 8. Typical accommodations length for different number of crew.

2.5 *Total aggregated length* L_{BP}

The length between perpendiculars could be obtained from the summation of the aggregated length as follows:

$$\text{In type a: } LBP = L_{ER} + L_{FH} + L_{ACC} + L_{AP} + L_{FP}$$

$$\text{In type b: } LBP = L_{ER} + L_{FH} + L_{Ap} + L_{FP}$$

3- BREADTH AND DEPTH

The breadth and depth of a coastal trawler could be determined from the following factors, which could be determined from the analysis of data collected from several vessels:

1- Volume of fish hold
2- Transverse stability and rolling motion.
2- (B/D) ratio

3.1 *Volume of fish hold*

This could be expressed in the form of a fish hold coefficient (C_{FH}) which is related to the ship breadth and depth as follows:

$$C_{FH} = V_{FH} / (L_{FH} * B * D)$$

where C_{FH}: ranges from 0.4 to 0.6 according to the floor height

3.2 Transverse stability and rolling motion

Ship breadth should satisfy the requirements of stability and rolling motion as given by [3]:

$$T_{\Phi} = B * c / (\overline{GM})^{1/2} \text{ (sec.)}$$

Detailed calculation for the transverse metancentric height is given in Appendix (1)

The breadth and depth could be checked knowing LBP using statistical data from trawlers as shown in Figure (9), where B and D are plotted against length between perpendiculars . The following formulae are developed to give the breadth and depth in terms ship length:

$$B = 4.0 + 0.1 * LBP \text{ m}$$

$$D = 2.5 + 0.05 * LBP \text{ m}$$

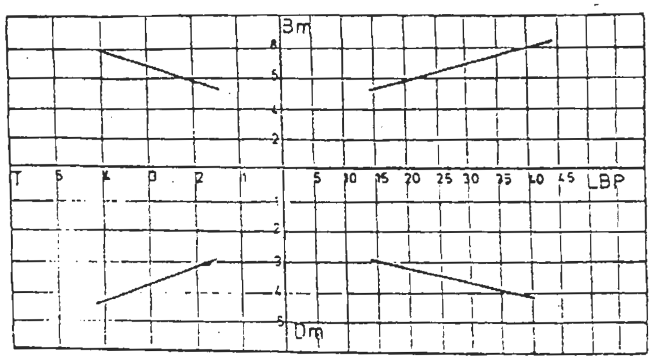

Figure 9. Main dimensions of some small trawlers.
$B = 5.5 + 0.1 (L-15)$
$D = 3.2 + 1.2 (L-15)/25$
$T = 1.13 + 2.24 (B-5) 1.25.$

4- DRAUGHT T

The draught could be obtained using the weight equation,

$$T = \Delta / (LBP * B * C_B * \rho)$$

where:

- The block coefficient could be determined using the following formula which is derived specially for stern trawlers [3]:

$$C_b = \frac{1}{3} * (L\,BP)^{0.15} + 0.03$$

- Preliminary displacement could be determined using the statistical formula for group weight estimation;

$$\Delta = W_{LS} + DWT$$

where:

$$W_{LS} = W_{ST} + W_{OU} + W_{M/C} + W_{AL}$$

Detailed calculations for the displacement is given in Appendix (2)

A check on the draught could be achieved using Figure (10) which shows (for different fishing vessels) the relationship between propeller diameter, draught, engine power and the displacement.

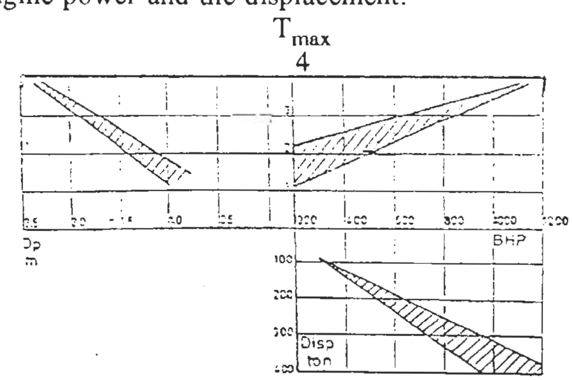

Figure 10. Propeller diameter related to T_{max}, BHP and disp.

It should be realized that the draught should accommodate the propeller diameter and allows adequate immersion for the empty ship condition. From the analysis of the principal dimensions of some existing fishing vessels, the (B/T) and (D/T) ratios are found to be according to the following developed ranges:

$$B / T = 2.5 - 3.5$$

$$D / T = 1.3 - 1.6$$

5- THE COMPUTER PROGRAM (DPD) FOR DETERMINATION OF PRINCIPAL DIMENSIONS

A computer program is developed to determine the ship principal dimensions. The main information required for the (DPD) are:

i- Time duration, in days
ii- Voyage duration, in days
iii- Trawling speed, in knots
iv- Fishing rate per day
v- Number of crew
vi- Free running speed, in knots
vii- Location of accommodation (under or above main deck)

The output of the (DPD) is given in the following form:

i- Length between perpendiculars, in m
ii- Individual length of each hull section, in m
iii- BHP
iv- Block coefficient C_b
v- Displacement Δ
vi- Set of breadths, depths and draughts and the corresponding values of $\overline{GM}$ available and $\overline{GM}_{max}$

The designer can select the optimum principal dimensions from the set of results given by the computer.

6- CASE STUDY

A case study is worked out to demonstrate the capability of the developed computer program DPD. The proposed coastal fishing vessel is required to meet the following requirements;

1- the vessel is required to operate in the Red Sea.
2- the fishing time not exceed 7 days
3- the vessel is to have it's full bunkers in Alexandria to cover the return voyage.

The set of data required for the DPD is given in Table (2).

Breadth, depth and draught could be determined according to the requirements of stability and ship motion [3]. This is illustrated in Figure (11).

The optimum dimensions and characteristics of the required fishing vessel are given in Table (2).

$LBP = 29.95$ m $\quad L_{FH} = 12.427$ m

V_{FH} = 232.5 m^2 L_{ER} = 8.244 m
BHP = 790 hp, C_b = 0.490
Trawling Speed = 4. Knots
Cruising Speed = 9.5 Knots
Displacement = 343 ton
$\overline{GM}$min = 0.35 m

Table 2. Set of principal dimensions.

Breadth m	Depth m	Draught m	GM m	GMmax m
10.53	3.95	2.42	2.1	1.28
10.09	3.09	2.15	2.71	1.76
9.65	3.23	2.24	2.15	1.07
9.21	3.38	2.35	1.63	0.89
8.77	3.55	2.47	1.16	0.89
8.33	3.47	2.60	0.73	0.80
7.90	3.95	2.74	0.34	0.72
7.46	4.18	2.90	-0.02	0.64
7.02	4.44	3.09	-0.35	0.57

Selected breadth, depth and draught
Breadth molded = 8.0 m, Depth molded = 3.8 m
Draught = 2.8 m
D,T,GM (m)

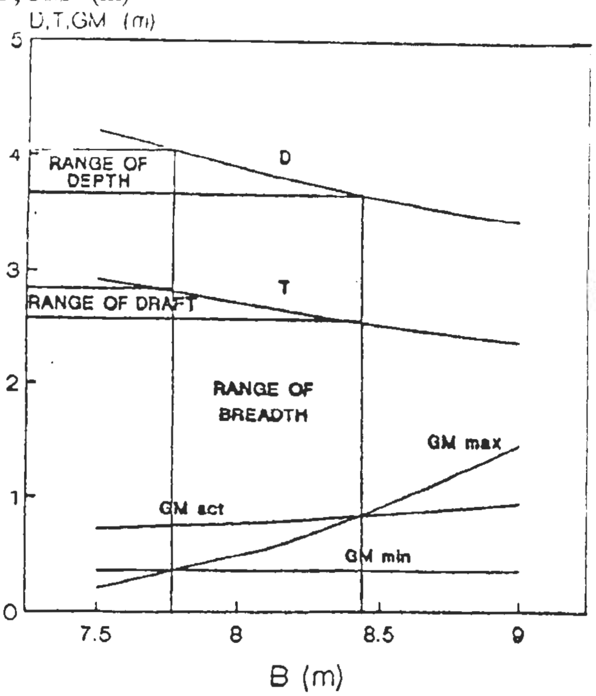

Figure 11. Determination of breadth and depth for stability and ship motion requirements.

7- CONCLUSIONS

- Determination of length between perpendiculars considering only the fish hold capacity gives an overestimated or underestimated values which may have adverse effects on ship economy.
- The determination of the optimum LBP should be based on the relationships between the different hull sections and the factors affecting them such as:

i- length of fish hold and fish hold capacity
ii- length of engine room and brake horse power
iii- length of accommodation compartment and number of crew and voyage duration.

- Determination of breadth, depth and draught should be based on the requirements of fish hold capacity, displacement, stability ship motions and propeller diameter simultaneously.

8- REFERENCES

[1] H. Benford and M. Kossa "An Analysis of U.S. Fishing Boats-Dimensions Weights and Coasts". *Fishing Boats of the World: 2* pp. 320-331, 1960.

[2] M.A. Shama "An Economical Evaluation Model for the Egyptian Coastal Fishing Vessel" *Alex. Eng. J.*, Alex. Univ., vol. 28. No., pp. 403-423, 1989.

[3] W. Stovhase "Aspects of Fishing Trawler Design", *Unpublished*.

[4] I. Calglayan and R.L. Storch "Stability of Fishing Vessels with Water on Deck: A Review" *Journal Of Ship Research*, vol. 26, No. 2, pp. 106-116. June 1982.

[5] J.F. Minee "New Trends in Stern Fishing" *Fishing Boats of the World:3* pp. 572-582.

[6] W.M. Reid "Small Stern Trawlers " *Fishing Boats of the World:3* pp. 572-582.

[7] A. Von Brandt and C. Birkhoff "Trawling Deck Design and Equipment" *Fishing Boasts of the World:2 (FAO)* 1960, pp. 102-113.

[8] C. Birkhoff "The Stern Trawler-A Decade's Development in A Trawl Handling" *Modern Fishing Cears of the World:2* 1984, pp. 147-152.

APPENDIX (1)

Stability and rolling motion requirements

The metacentric height $\overline{GM}$ is given by:

$$\overline{GM} = \overline{KB} + \overline{BM} - \overline{KG}$$

Detailed calculations for $\overline{KB}$, $\overline{BM}$, $\overline{KG}$ are given by the following formulae [3]:

For trawlers with small rise of floor:

$$\overline{KB} = (0.69 - 0.169 * C_b/C_w - 0.15 * C_m$$

$$+ 0.25 * C_w/(C_w + C_b)$$

For trawlers with greater rise of floor:

$$\overline{KB} = (0.858 - 0.37 * C_b / C_w) * T m$$

$$\overline{KG} = (0.92 - 0.033 * D \pm 0.03) * D \text{ full displacement (m)}$$

$$\overline{KG} = (0.92 - 0.025 * D \pm 0.03) * D \text{ empty ship (m)}$$

$$\overline{BM} = I_T * \rho / \Delta$$

$$\overline{BM} = C_{IT} * B^2 / (12 * C_b * T)$$

$$C_{IT} = 0.13 * C_w + 0.87 * C_w^2 + (1 - c_w) * B_{AP}/B \pm 0.005$$

The required value for $\overline{GM}$ in the different loading conditions varies from 0.08 B TO 0.10 B for small trawlers (10.-30. m long) and from 0.9 m to 1.1 m for larger trawlers (30.-50. m long). The rolling period of a fishing vessel could be determined from the following formula [3]:

$$T_\phi = B * c / (\overline{GM})^{1/2} \text{ (sec.)}$$

The metacentric height should not exceed the maximum value determined from the following equation, otherwise the vessel would be subjected to severe motions:

$$\overline{GM}_{max} = (B * c / T_\phi)^2 \text{ (m)}$$

where:

$$c = 0.78 - 0.84$$

$$T_\Phi = 8 - 12 \text{ (sec.)}$$

APPENDIX (2)

Determination of Displacement Δ

Displacement could be determined from the following equation [3]:

$$\Delta = W_{LS} + DWT$$

where:

$$W_{Ls} = W_{ST} + W_{OU} + W_{M/C} + W_{AL}$$

where:

$$W_{ST} = 0.13 * L_{BP} * B * D$$

$$W_{OU} = (0.36 \pm 0.04) * (L_{BP} * B)$$

$$W_{M/C} = 0.00075 * PHP^{1.66}$$

$$W_{AL} = .03 * W_{LS}$$

The deadweight is the sum of the weights of the catch, fuel, lubricating oil, fresh water, crew and provisions.

where:

$$DWT = WFISH + = \frac{1}{2}(W_{FUEL} = W_{FW} + W_{LO} + W_{CREW})$$

where:

$$W_{SIDH} = Q * T_{FA}$$

$$W_{FUEL} = BHP * b_e * (T_{OV} = T_{RV} + T_{AL})$$

$$W_{LO} = 0.1 * W_{FUEL}$$

$$W_{FW} = 0.15 * NCR * (T_{OV} + T_{RV} + t_{FA} + T_{AL})$$

$$W_{CREW} = 0.15 * NCR$$

The maximum dead weight for fishing vessels occurs at the departure from the fishing area with full fish hold and tanks are nearly 50 per cent. full.