AN INTEGRATED RATIONAL APPROACH FOR IMPROVING THE ECONOMICS OF COASTAL STERN TRAWLERS

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SUMMARY

This paper presents an integrated rational approach for improving the economics of coastal stern trawlers. Particular emphasis is placed on the rationalisation of investment costs so as to take account of initial and operational expences and to be compatible with available resources (capabilities of current and potential fishing grounds, realistic fish catching rates), average market fish prices of different species, competency of currently available crew, etc. The rationalisation process of investment costs is based on a statistical decision making approach as well as the following main items:

i - the interaction among the operational characteristics of the stern trawler, fishing gear and fish catching rates.
ii - the main factors impairing the average annual production and revenue.
iii- the main factors having deleterious effects on the average annual expenditures.
iv - the main factors affecting the magnitude of the investment cost and average cost of capital.
v - the various elements of uncertainties associated with the basic items of annual expenditures, production and revenues.
iv - the risk of investment in a stern trawler to operate in uneconomical and uncertain fishing conditions.

A numerical example is given to illustrate and clarify the application of the statistical decision making approach to an investment in a projected coastal stern trawler.

THE MARINE COASTAL FISHING INDUSTRY

The present condition of the Egyptian marine coastal fishing industry suffers significantly from traditionalism [1], poor working conditions, poor design and fittings of fishing vessels, improper matching among main dimensions of fishing vessel, engine power, propeller, fishing gear, [2], etc. The natural and logical consequences of this irrational and unsatisfactory condition of this important industry are very well demonstrated by the increased operational costs, reduced annual production and revenues and in general by the reduced fishing vessel effectiveness, productivity and profitability. In order to improve and develop this highly needed industry, technically and economically, it is important to study and examine the main elements of the marine coastal fishing system which have direct as well as indirect impact on the economics of the marine coastal fishing industry at large and on the economics of coastal fishing vessels in particular. This could be achieved as follows:

i - Protection and rational exploitation of the currently available coastal resources.
ii- Exploration of new resourceful fishing grounds.
iii- Improving competency of the crew.
iv- Minimisation of annual operational costs.
v- Maximisation of annual production and revenues.
vi- Rationalisation of investment costs so as to be compatible with available resources, annual expenditures and annual revenues.
vii- Introducing modern fishing vessels compatible with capabilities of fishing grounds (available type, size and quality of resources, realistic catching rates), crew experience, etc.

viii- Introducing more efficient fishing gear (trawl nets and otter boards).
ix - Improving navigational and fish detection equipment.
x - Improving catch preservation methods and equipment.
xi- Improving fishing vessel safety.
xii- Improving fishing vessel maintenance and repair strategies, planning and methods.
xiii- Improving fishing port facilities and services.
xiv- Improving fishing fleet management

The realisations of all or most of these targets require proper long and short term planning with identification of priorities, investment capital, training of crew, examination of main parameters affecting both revenues and expenditures, etc. This could be achieved by proper study of the main elements of the marine coastal fishing system [1].

THE MARINE COASTAL FISHING SYSTEM

The marine coastal fishing system is composed of several basic items, namely:
i- The marine resources
ii- The fishing vessel
iii- The crew
iv- The fishing gear
v- The fishing equipment
vi- The fishing port and shore facilities.

Figure (1) illustrates the interrelation and interaction among these basic items of the marine coastal fishing system. The interrelation and interaction among the fishing vessel, the fishing gear and the fishing equipment should be especially considered, as this interaction affects the economics of the fishing vessel.

ECONOMICS OF COASTAL STERN TRAWLERS

The economics of coastal stern trawlers is based totally on the estimate of the expected annual profit. The annual profit could be assessed and evaluated when both annual revenues and expenditures are predictable [3]. However, in order to estimate annual revenues and expenditures, it is important to examine and analyse the main factors affecting the magnitude and fluctuation of both.

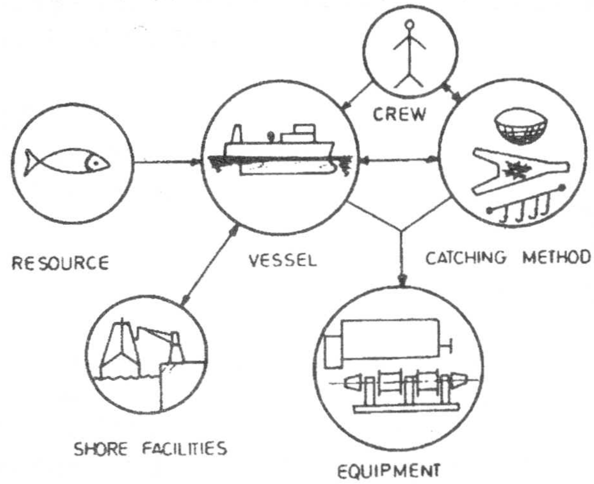

Figure 1. Fishing system.

Using the Net Present Value (NPV) formulation of annual cash flows [4,5], the economics of coastal stern trawlers could be evaluated as follows [5], see Figure (2).

$$NPV = R - E = \sum_{J=0}^{N} \frac{(R_j - E_j)}{(1+i)^j} \geq 0$$

where

R_j = annual revenue in year "j"
E_j = annual expenditure in year "j"
R = Present value of all annual revenues
E = " " " expenditures
C_S = Present Value of ship investment cost
Y = Present Value of all Annual operational costs
i = rate of interest
N = expected life of ship, years.

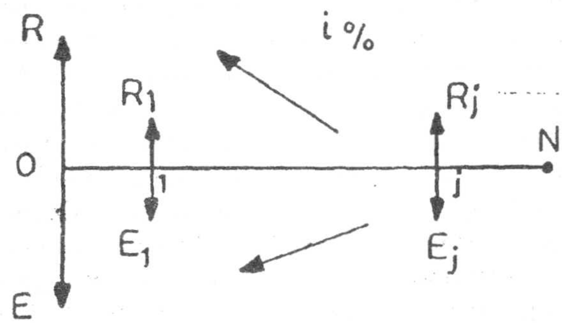

Figure 2. NPV of R_j and E_j.

The present value of all annual expenditures is given by, see Figure (3):

$$E = C_s + Y$$

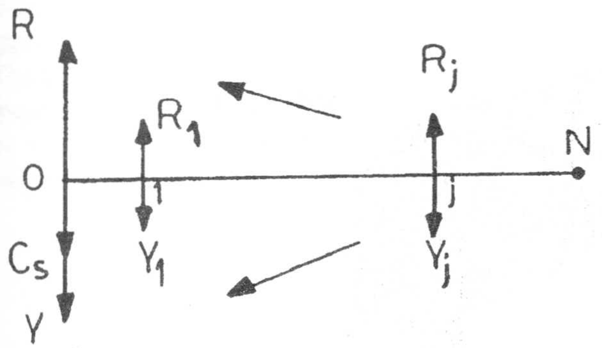

Figure 3. NPV of R_j nd Y_j.

FACTORS AFFECTING AVERAGE ANNUAL EXPENDITURES

The main factors affecting the average annual expenditures of a coastal stern trawler, among other factors, are: the annual cost of capital and the annual operational cost.

The annual operational cost depends directly and indirectly on the following main factors:

- power of main and auxiliary engines
- degree of mechanisation and automation of the stern trawler
- type and size of fishing gear
- number of crew, degree of skill and experience
- etc.

The average annual operational cost of a stern trawler, therefore, is composed basically of the crew share, fuel and oil consumptions, maintenance and repair cost, among several other cost elements. Figure (4) shows a typical example of the breakdown of annual operational costs for a stern trawler. Figure (5) shows an example of the breakdown of consumable expences of a stern trawler. Figure (6) shows an example of the breakdown of maintenance and repair costs of a coastal stern trawler.

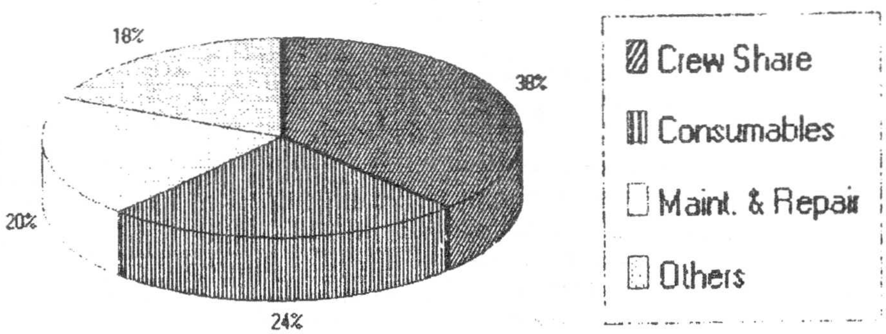

Figure 4. Breakdown of operational costs.

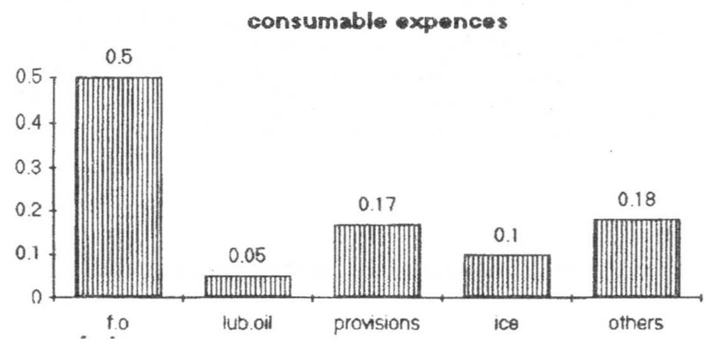

Figure 5. Breakdown of consumable expenses.

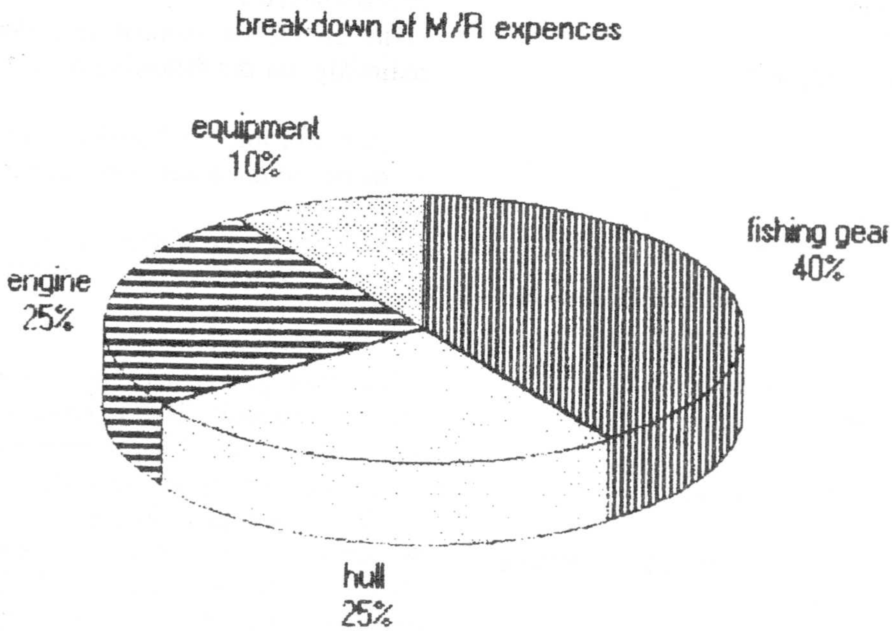

Figure 6. Breakdown of M/R. Expences.

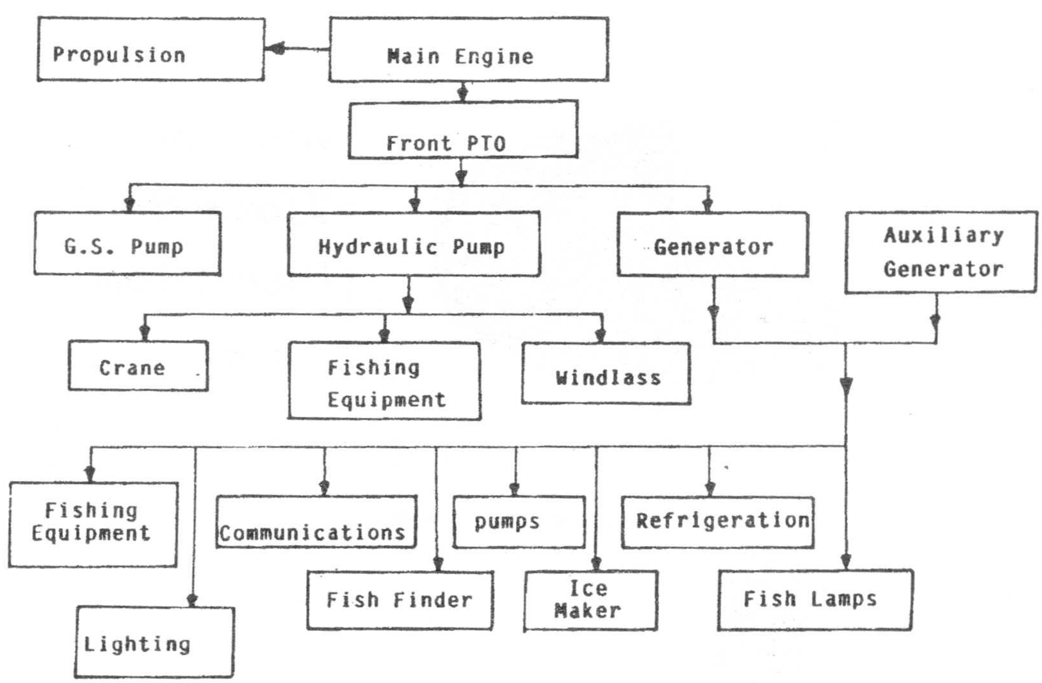

Figure 7. Fishing vessel power requirements.

The average annual fuel consumption depends on the power requirements over the fishing voyage cycles. The required power of the main and auxiliary engines depends on the main dimensions of the stern trawler, type and size of the fishing gear, degree of mechanisation and automation of the vessel, etc, see Figure (7).

The annual cost of capital of a coastal stern trawler depends on the magnitude and type of investment cost. The investment cost of a stern trawler depends on several factors among them are;

- i - stern trawler type and size
- ii- type of propulsion system (main engine, propeller, shafting)
- iii - degree of mechanisation and automation of the vessel and the fishing opertations
- iv- quality and capacity of fishing equipment
- v- size and quality of crew accommodation
- vi- type, quality and capacity of fish preservation equipment
- vii- quality and versatility of hull and engine room equipment, auxiliaries and fittings
- viii- quality and variety of navigational, electronic and safety equipment.
- ix- etc.

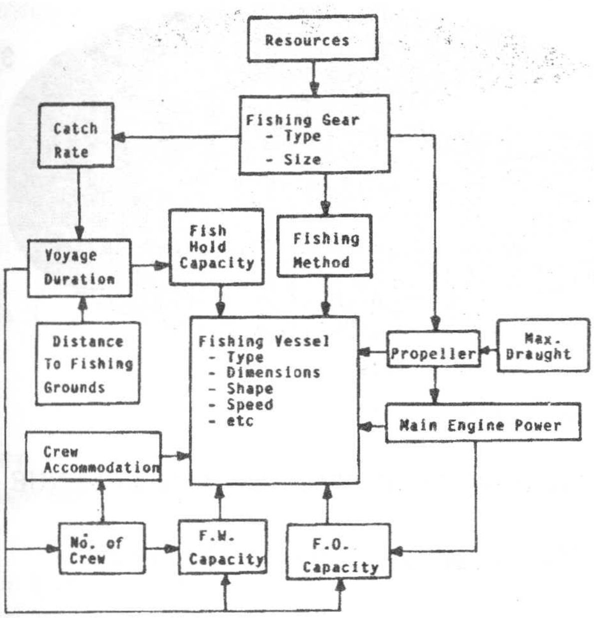

Figure 8. Fishing vessel design procedure.

The main parameters affecting stern trawler type, design, dimensions, speed, equipment, outfittings, etc. are shown in Figure (8). It is evident from Figure (8) that the design of a coastal stern trawler is a very complex problem [7]. The design process should take account of such parameters as type of resources, distance to fishing grounds, catch rate, type and size of fishing gear, size of crew, etc.

The interaction among the hull, main engine, propeller, fishing gear and trawl winch is shown in Figure (9). The selection of propeller type and size depends on the operational requirements for free-running and towing conditions [2]. The selection of towing winch depends on fishing gear type, size and hauling speed, see Figure (9).

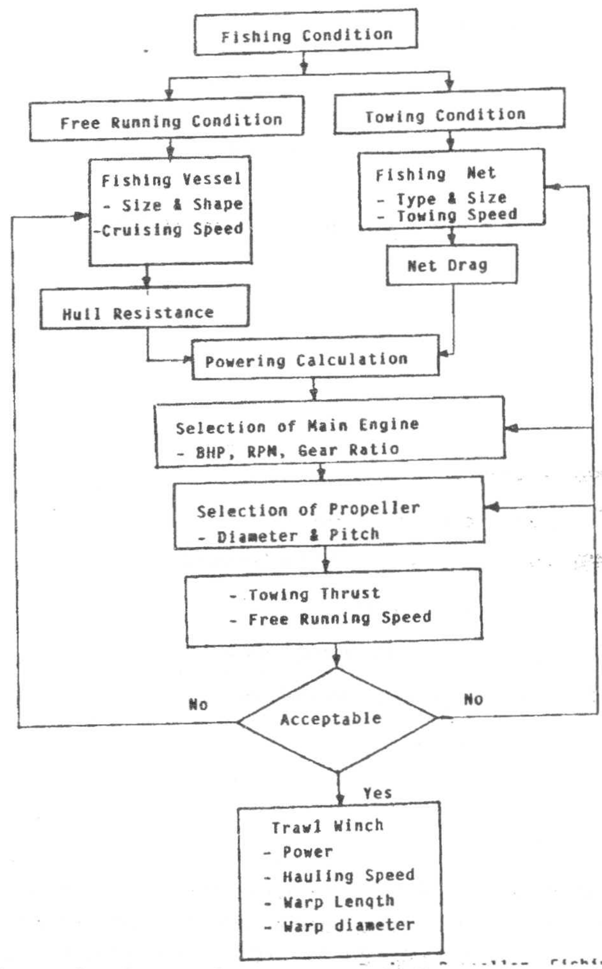

Figure 9. Interaction among hull, main engine, propeller, fishing gear and trawl winch.

It should be realised that the magnitude of the investment cost has a significant effect on the economics of coastal stern trawlers. High values of investment costs increase significantly the average annual expenditures through the increased annual cost of capital. Therefore, an upper limit of the cost of capital should be estimated from the average annual production, the current average fish prices and the expected annual operational costs. Figure (10) shows the variation of the upper limit of the investment cost C_S with average fish price, for certain fishing conditions. Figure (11) shows an example of the breakdown of investment cost of a coastal stern trawler.

Appendix (1) gives a detailed analysis of the cost of capital for coastal stern trawlers. It is shown that the upper limit of the present value of the investment cost P_C is given by:

$$P_C \leq \frac{\sum \frac{A_j}{(1+i)^j}}{(1+i)^g}$$

where: A_j = average annual cost of capital

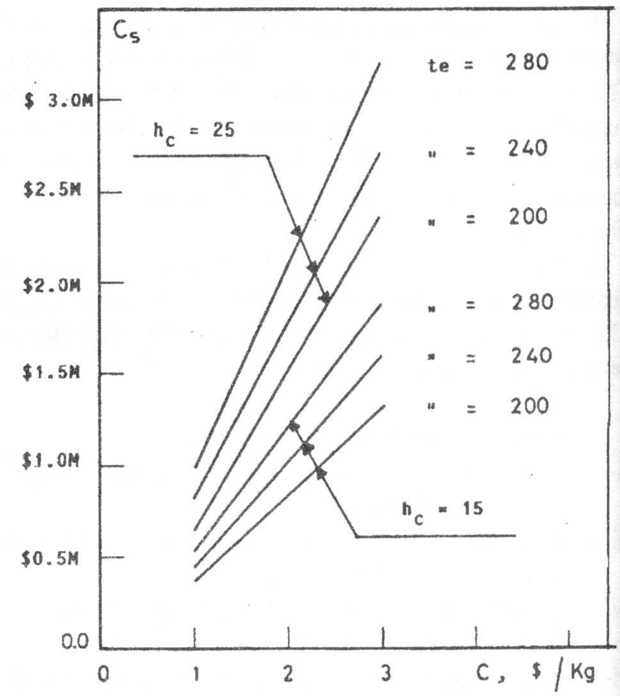

Figure 10. Variation of "C" with C_S.

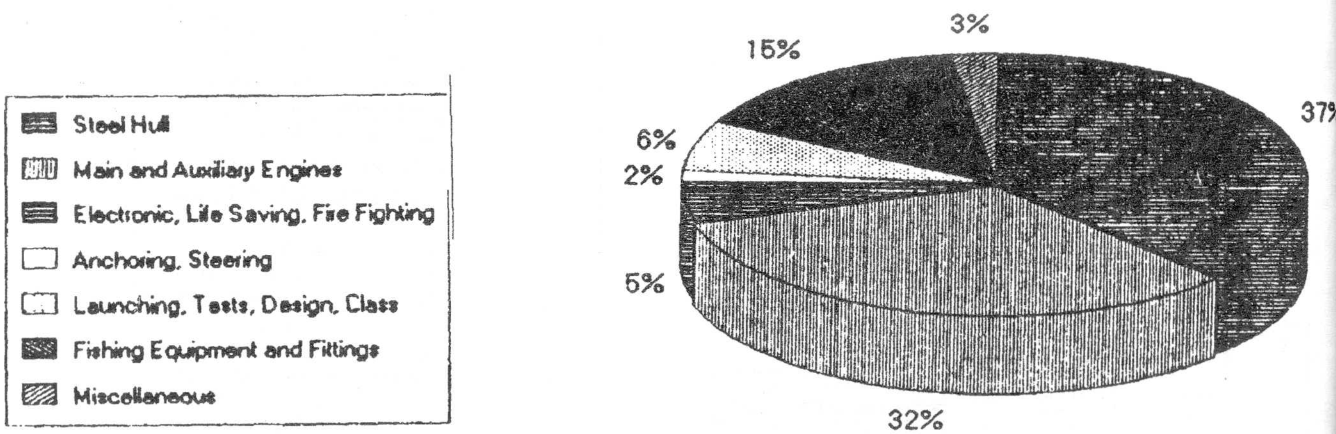

Figure 11. Investment cost data.

Appendix (2) gives the effect of initial as well as the maintenance and repair costs on the average annual cost of capital. It is shown that lower initial cost of capital may require high annual maitenance and repair costs, and therefore may not give lower average annual cost of capital.

FACTORS AFFECTING ANNUAL REVENUE

The average annual revenue is given by;

$$R_j = Q_j \times C_j$$

where: R_j = average annual revenue of year j
Q_j = average annual production of year j, tonnes
C_j = average fish price/tonne of year j

The average annual revenue is time dependent as it varies from year to year over the vessel's service life by virtue of the variation of annual production and associated prices of the different fish species, annual and seasonal weather fluctuations, maintenance, repair and off service non-productive times, etc. It is shown in Appendix (1) that the lower limit of the average annual revenue is given by:

$$R_j \geq (CRF) \cdot R$$

where: CRF = capital recovery factor
R_j = average annual revenue

FACTORS AFFECTING ANNUAL PRODUCTION

The average annual production is time dependent as it varies seasonally and from year to year. Figure (12) shows an assumed scenario for the expected variation of average annual production over the expected ship service life. This scenario could be represened by the following equation:

$$Q = \frac{3\,Q_o + (7+N)Q_3 + (N-10)Q_N}{2\,N}$$

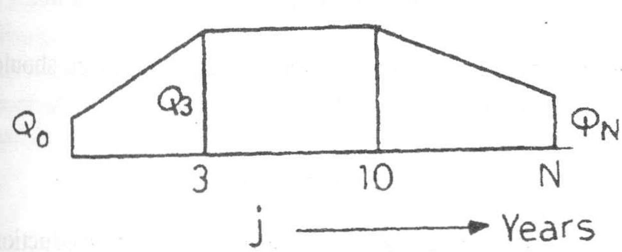

Figure 12. Assumed scenario of the variation of average annual production.

This scenario is based on the assumption that the annual production increases during the first three years of operation, by virtue of learning and grasping all the capabilities of the stern trawler and her equipment, reaches a steady state of production for seven years and decreases steadily after year 10 due to wear and tear, frequent breakdowns, and increased maintenance and repair time and costs.

The average annual production of coastal stern trawlers depends on several factors among them are [1]:

i- Fish catching rate (h_C)
ii- exploitation time per year (t_e)
iii- competency of the crew
iv- distance to fishing grounds
v- number of fishing voyages/year
vi- number of hauls/fishing voyage
vii- etc.

The fish catching rate represents one of the major factors affecting fish annual production and in general is influenced by;

i- type and characteristics of fishing grounds
ii- type, size and behaviour of fishing species
iii- method of catching
iv- effectiveness of fishing gear and equipment
v- competency of the crew
vi- engine power
vi- etc.

Figure (13) illustrates the various factors affecting the expected catch per haul.

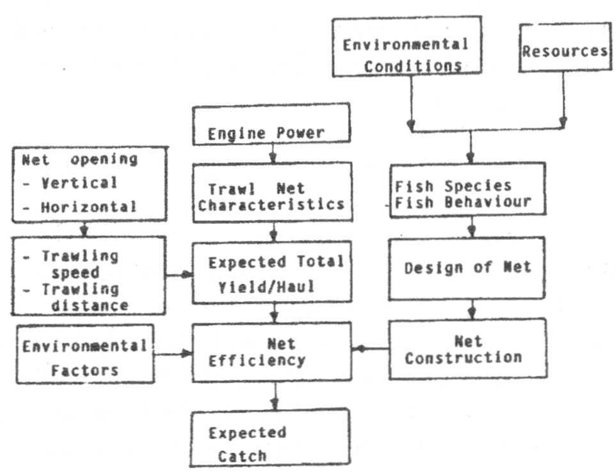

Figure 13. Various factors affecting expected catch/haul.

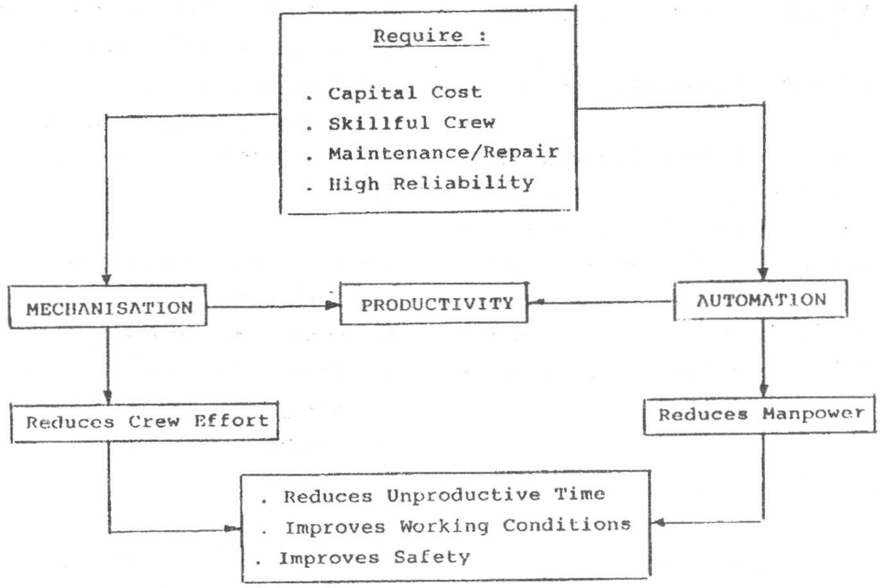

Figure 14. Impact of machanisation & automation on productivity.

The number of hauls/fishing voyage depends on several parameters, among them is the degree of mechanisation and automation of the stern trawler, see Figure (14). Improving the mechanisation and automation of a fishing vessel will improve working conditions and will reduce required crew effort and manpower, reduce unproductive time, and increase number of fishing hours/day. However, this will require additional investment, skillful crew, improved and increased maintenance and repair strategies, etc. This necessitates the selection of the optimum degree of mechanisation and automation so as to be compatible with the local fishing conditions and the capabilities of the fishing grounds.

FACTORS AFFECTING AVERAGE FISH PRICE

The average fish price depends on the average annual expenditures and average annual fish production, among several other factors. Figure (15) shows the variation of average fish price with fish catching rate and investment cost. It is evident that the investment cost and fish catching rate could affect the average selling price of the different species of the catch.

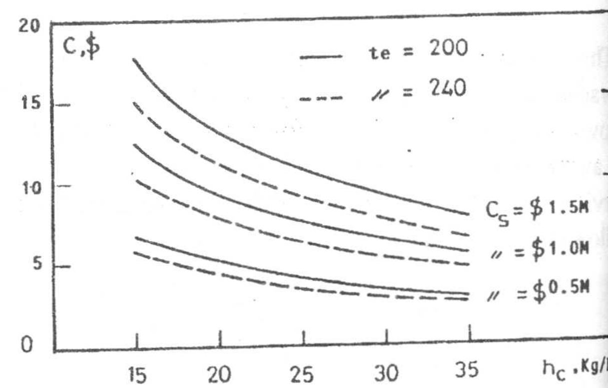

Figure 15. Variation of fish price with catch rate.

The minimum value of the average fish price shou satisfy the following condition:

$$C \geq R/Q$$

where: Q = expected average annual fish producti
R = expected average annual revenue

This average fish price should be compatible with t average price obtained from the composition of t catch and the price of each species, as given by:

$$C = \sum_{j=1}^{n} P_j . C_j$$

where: C_j = price of species "j"
P_j = proportion of species "j" in the catch
n = number of species in the catch.

It would be reasonable and practical to assume that the catch is composed of three categories only, namely: high, medium and low quality species, i.e., n = 3.

Assuming also that:
p_h = proportion of high quality species = 20%
p_m = " " medium " " = 40%
p_l = " " low " " = 40%
C_j = price/kg of species "j", j = h, m, l
C_h = 6 C_l
C_m = 3 C_l
Then: $\mathbf{C = 0.466\ C_h}$

These assumptions are based on market prices of the commonly available species and data obtained from the annual production of several local stern trawlers over the last few years.

STATISTICAL APPROACH TO THE ECONOMICS OF COASTAL STERN TRAWLERS

It is evident that both annual Revenues and Expenditures of coastal stern trawlers are not Deterministic quantities. They are subject to various elements of operational and economical uncertainties and therefore should be treated statistically [6].

Assuming statistical independence and normal distribution, for both annual Revenue and Expenditure of coastal stern trawlers, the profit margin is also normally distributed, having the following statistical parameters :

$$\mathbf{M = N(\bar{M}, \sigma_M)}$$

where $\bar{M} = \bar{R} - \bar{E}$

$$\sigma_M^2 = \sigma_R^2 + \sigma_E^2$$

Then: $\beta = (\gamma - 1)/\{ \gamma^2 . v_R^2 + v_E^2 \}^{1/2}$

and $\mathbf{P_L = P(R \le E) = 1 - \Phi(\beta)}$

where:
σ_X = standard deviation of X, X = R, E and M
v_X = coefficient of variation of X, X=R,E and M
β = Profitability index
γ = Profitability Factor = R/E
P_L = Risk = Probability of making a loss
$\Phi(x)$ = cumulative distribution function.

The relation between $\mathbf{P_L}$ and β is shown in Figure (16) for:

$$\mathbf{X = N(\bar{X}, \sigma_X),\ X = R, E.}$$

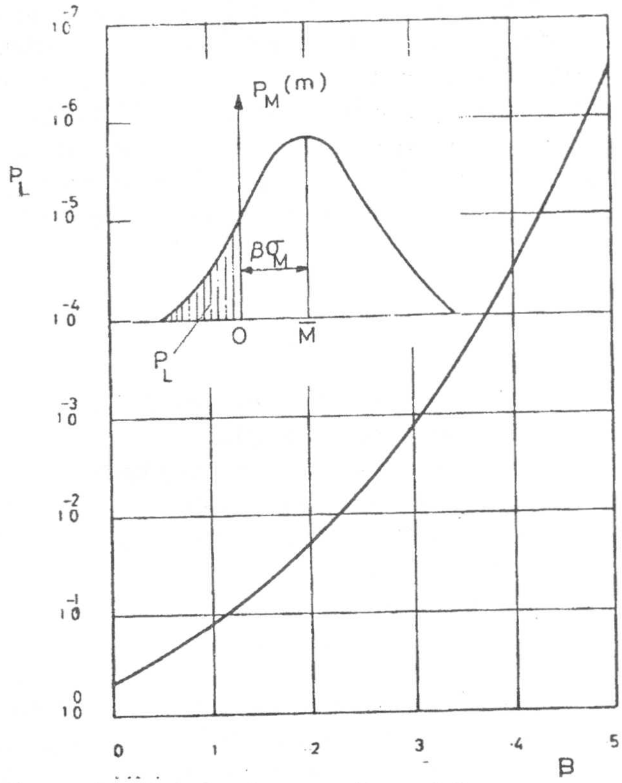

Figure 16. Relation between P_L and β.

FACTORS REDUCING RISK OF INVESTMENT

The magnitude of the risk of investment in a coastal stern trawler to operate in a fishing environment subjected to numerous sources of uncertainties could be significantly reduced by:

i- Increasing the Mean Value of the Profit Margin (M) by increasing the average annual revenue R and reducing the average annual expenditures E.

ii- Decreasing Standard Deviation of the profit margin,

σ_M by reducing the variabilities of both annual revenue R and annual expenditure E.

INVESTMENT DECISIONS

Because of the various elements of uncertainties associated with both annual revenues (R) and annual expenditures (E), decisions on investment in a projected coastal stern trawler or a fleet of stern trawlers should be based on an acceptable risk value for investment **(P^*)**.

Figure (17) shows a flow diagram for a procedure for calculating the expected fish catching rate based on an acceptable risk value (P^*) and some statistical data from the currently operating fleet. If the estimated required fish catching rate is larger than the capability of the fishing grounds, either of the fishing grounds, main engine type and power or type and size of fishing gear should be changed. The calculations to be repeated until the following condition is satisfied:

$$h_C \geq h_C^*$$

This procedure could be illustrated and clarified by the following numerical example:

EX.	Required fish catching rate (h_c) kg/h	= 50
	Exp. number of voyages/year	= 20
	Exp. number of fishing days/voyage	= 7
	acceptable risk (P_L)	= 0.001
	C.O.V. of expenditures v_E	= 0.04
	C.O.V. of Revenue, v_R	= 0.06
	Profitability factor, γ	= 1.275
	Expected annual expenditures, E	= $400,000
	Expected annual Revenue, R	= $510,000
	Exp. price of high quality species	= $8.0
	Exp. price of medium quality species	=$4.0
	Exp. price of low quality species	= $1.0
	Exp. proportion of high quality specie	= 20%
	Exp. proportion of medium quality species	= 50%
	Exp. proportion of low quality species	= 30%
	Exp. average fish price/tonne	= $3900.0
	Exp. average annual production, tonnes	= 130.77
	Exp. production/voyage, tonnes	= 6.538
	Exp. fish catching rate, hc, kg/h,	= 58.37

$$\text{Then } h_C^* \geq h_C$$

It is necessary, therefore, either to change type and size of fishing gear (bigger and more efficient) or to a more resourceful fishing ground to satisfactory value of fish catching rate.

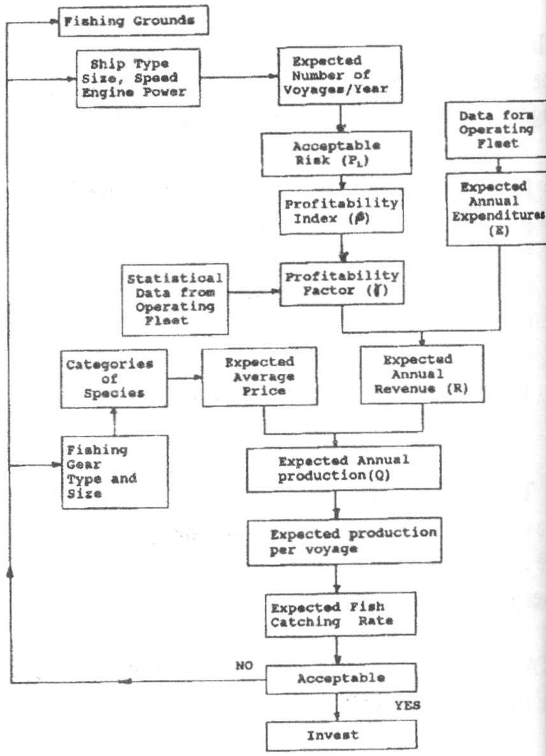

Figure 17. Investment decision making model

CONCLUSIONS

From the foregoing presentation and analysis, evident that the development of the marine co fishing industry could only be realised through pr examination and rationalisation of the Marine Co Fishing System. The latter involve several elements that are directly and indirectly interrelate spite of the apparent differences of the scientific engineering backgrounds of these elements. This be clarified and illustrated by one element only fishing system such as the fish catching rate that r from the indirect combined effects of type of fi ground, engine power, type and size of propeller type and size of fishing gear.

It is obvious that the design, equipment, fitting degree of mechanisation and automation of the trawler have direct and indirect impacts on her operation and economics. The design of a stern tr cannot be carried out from naval architectural aspects only but should take account of all elements of the marine fishing system such as type and size of fishing gear, resourcefulness of fishing grounds, number and degree of skill of crew, distance to fishing grounds, etc. Lower initial costs coupled with higher maintenance and repair costs may impair the economics of fishing vessels. Therefore, the average annual cost of capital that takes account of initial as well as annual operational cost elements dependent on the intial cost of the vessel should be considered as the annual cost of capital.

In order to obtain best economic results, without violating the biological balance of the marine resources, it is important to consider the main elements of the total fishing system as well as the uncertainties of all the major factors affecting annual revenues and expenditures.

Using the statistical decision making approach and the economic model given in this paper, proper decisions could be made for investing in projected coastal stern trawlers to operate in certain fishing conditions. This statistical decision making approach will certainly give much better and more reliable economical results than the commonly used traditional and deterministic approach.

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Appendix (1)

The Cost Of Capital

The aquisition of a coastal stern trawler could be financed either by a borrowed capital or from awn resources. The cost of capital in both cases could be evaluated as follows:

i- borrowed capital

Assuming that:

rate of interest = r

loan period = n years

grace period = g years

The upper limit of the present value of the investment cost P_C is given by see Figure (1A):

$$P_C \leq \frac{\sum \frac{A_j}{(1+i)^j}}{(1+i)^g}$$

where: A_j = the annual cost of capital and is given by:

$$A_j = \frac{C_S\{1+r(n-g-j)\}}{(n-g)}$$

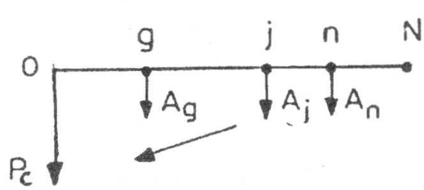

Figure 1-A. NPV of A_j.

The upper limit of the average value of the annual cost of capital, X_j, is given by see Figure (2A):

$$X_j \leq (CRF) \cdot P_C$$

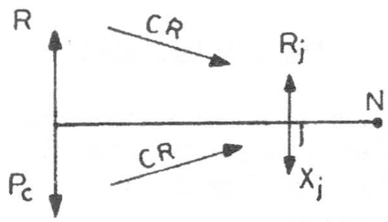

Figure 2-A. CR of R and P_c.

The present value of the average annual expenditures is given by, see Figure (3A):

$$E = \sum \frac{(X_j + Y_j)}{(1+i)^j}$$

where: Y_j = average value of the annual operational cost in year j and is given by:

$$Y_j = \frac{i(1+i)^N}{(1+i)^N - 1} \cdot Y$$

$$(CRF) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

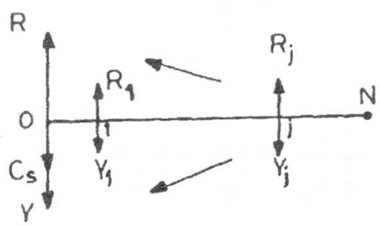

Figure 3-A. NPV of R,Y and X_j.

The lower limit of the present value of annual revenue is, therefore, given by, see Figure (4A):

$$R \geq Y + P_c$$

The corresponding minimum value of the average annual revenue is given by, see Figure (2A):

$$R_j \geq (CRF) \cdot R$$

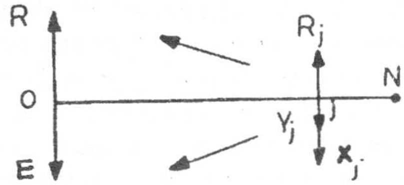

Figure 4-A. NPV of R_j and Y_j

The variation of the ratio of the limiting value of th average annual cost of capital to the investment cost a stern trawler is shown in Figure (5A), for th following conditions:

projected ships' life, N =16 years
rate of interest, i =15%, 20%
grace period, g =2 and 3 years
loan period, n =8 to 16 years
rate of interest of loan, r =3%, 6%, 9%

It is evident from Figure (5A) that the upper limit the average annual cost of capital of a stern trawl increases significantly when the loan rate of intere and period increase for the same ship's life an nominal rate of interest. Increasing the grace perio also reduces the limiting value of the average annu cost of capital.

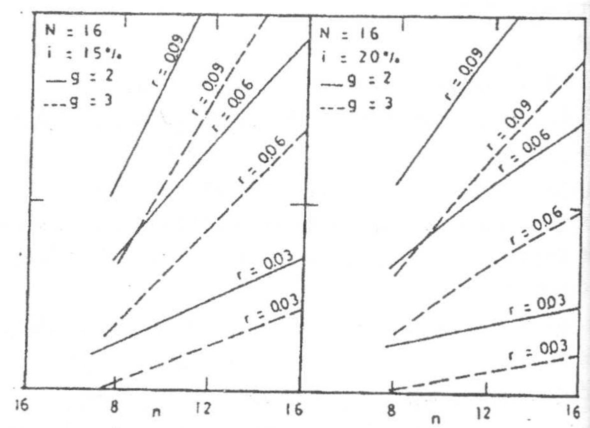

Figure 5-A. Variation of average annual cost capital/C_s with N,n,i,g,r.

ii- Non-borrowed capital

The upper limit of the investment cost, in this ca is given, by see Figure (4A):

$$C_S \leq R - Y$$

where:

C_S = Present Value of investment cost of stern trawler
Y = Present Value of annual operational cost
R = Present value of annual Revenue

The lower limit of the present value of revenue is given by:

$$R \geq C_S + Y$$

The minimum average annual revenue, $\mathbf{R_j}$, is, therefore, given by:

$$R_j \geq (CRF) \,.\, R$$

The upper limit of the average annual cost of capital, X_j, is given by:

$$X_j \leq (CRF) \,.\, C_S$$

APPENDIX (2)

Effect of Initial, Maintenance and Repair Costs On The Average Annual Cost Of Capital

The average annual cost of capital, A, is composed ot two main parts:

i - The annual cost, Ap, of the initial cost of the vessel, P_C
ii- The average annual cost of maintenance and repair, A_{MR}

Hence,

$$A = Ap + A_{MR} \qquad (1)$$

Let:

ν = initial cost factor
α = maintenance and repair cost factor
(CRF) = capital recovery factor

The initial cost factor " ν" is a factor associated with the quality of and the initial cost of the vessel. The lower the factor "ν" is, the higher the probability that the vessel is of lower quality, and may require higher costs for maintenance and repair.

The maintenance and repair factor "α" is a factor representing the proportion of the cost of maintenance and repair with respect to the initial cost of the vessel. High values of "α" indicate indirectly lower quality of vessel and higher maintenance and repair costs.

Therefore, there is an interrelation between "α" and "ν." The following values of "α" and "ν" are proposed".

ν	1.2	1.4	1.6
α	.04	.03	.02

From equation (l), we have:

$$A = \nu.(CRF).P_C + \alpha.\nu.P_C$$
$$= \nu.P_C\,.[(CRF) + \alpha\,]$$

Therefore, $A/\nu.P_C = Y = \alpha + (CRF)$ (2)

The variation of "$A/\nu.P_C$ " with "ν" is shown in Figure (1B). It is evident from Figure (1B), that the average annual cost of capital is significantly influenced by the initial cost factor " ν," ships' life, N and the rate of interest"i." Higher initial investment costs and lower annual maintenance and repair costs could have a pronounced beneficial effect on the average annual cost of capital. Therefore, lower initial cost of coastal stern trawlers does not necessarily mean lower annual cost of capital and better fishing vessel economy unless the annual costs of maintenance and repair are reasonably and economically proportioned to the initial cost of the vessel.

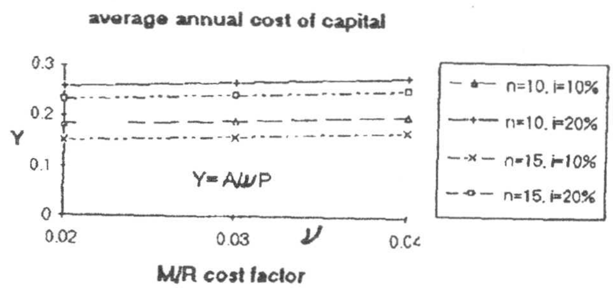

Figure 1-B.