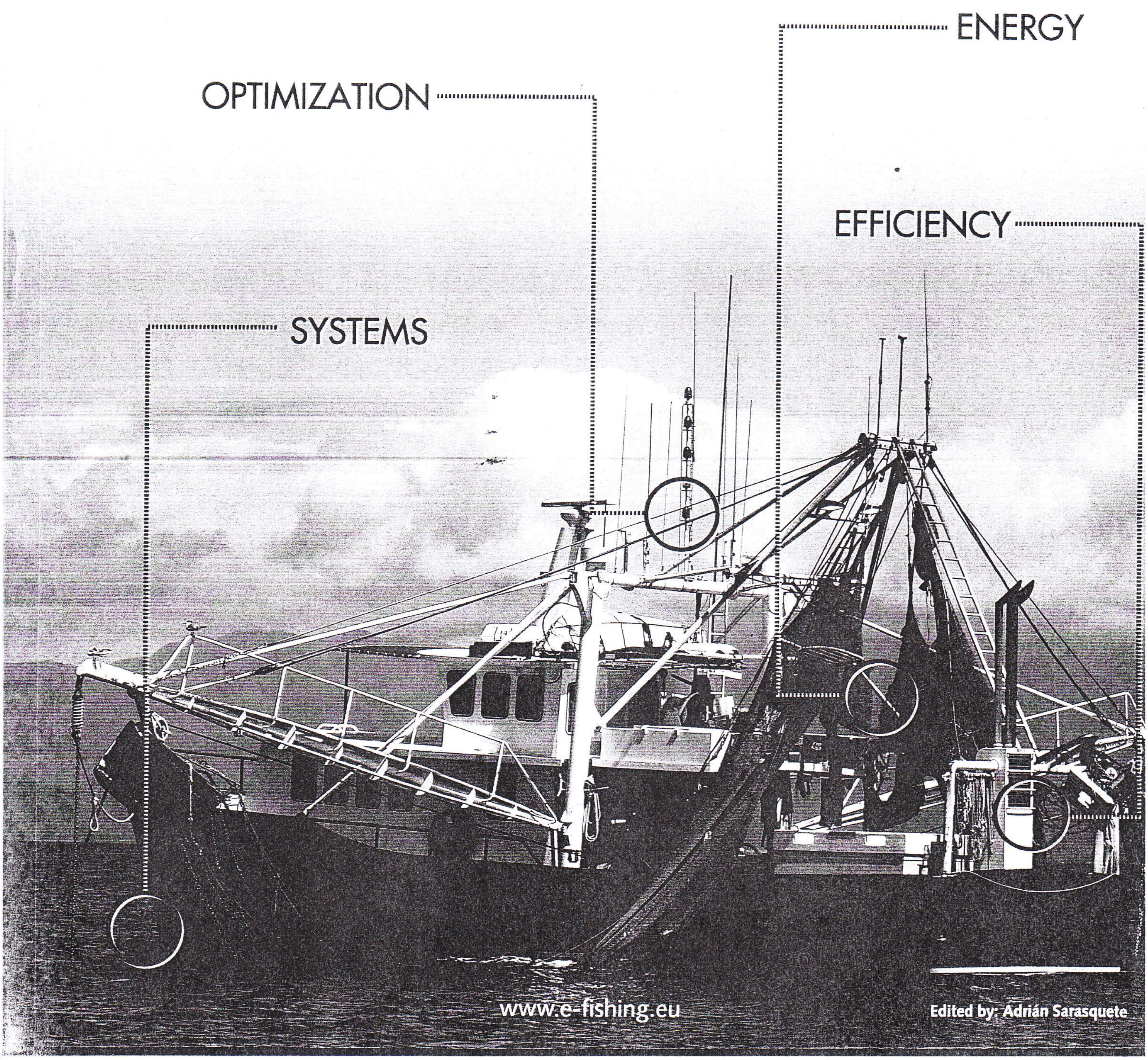
1st International Symposium on Fishing Vessel Energy Efficiency

e-fishing

FISHING VESSEL ENERGY EFFICIENCY

Vigo, Spain, 18th - 20th of May 2010



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List of Papers

SkySails - New energy for fishing trawlers. Using clean wind power to trawl more profitably
Mr. Fabian Jures, SKYSAILS (GERMANY)

Coriolis Fuel Mass Flow Metering for Fishing Vessels
Dr. Antonello Sala, INSTITUTE OF MARINE SCIENCES (ISMAR) (ITALY)

Fuel optimisation in the Faroese fishing fleet
Mr. Bjarti Thomsen, FAROE MARINE RESEARCH INSTITUTE (FAROE ISLANDS)

An Overview of Fishing Vessel Energy Efficiency Work in Newfoundland and Labrador, Canada
Mr. Christian Knapp, MEMORIAL UNIVERSITY OF NEWFOUNDLAND (CANADA)

Influence of the trawling gear on the drag force
Dr. Ana Ivanovic, UNIVERSITY OF ABERDEEN (UNITED KINGDOM)

The Next Generation Stern Trawler
Mr. Birger Enerhaug, SINTEF FISHERIES AND AQUACULTURE (NORWAY)

Intelligent Engineering Options for Highly Fuel-Efficient Fishing Vessels
Dr. Volker Bertram, FUTURESHIP (GERMANY)

The use of a Generic Energy Systems (GES) model for fishing vessels
Mr. B. van Marlen, IMARES (HOLLAND)

Low-Carbon Fishing Gear Design using Numerical Methods
Mr. Chun-Woo Lee, PUKYONG NATIONAL UNIVERSITY (KOREA)

Routing optimization using neural networks and oceanographic models from remote sensing data
Dr. Jesus M. Torres Palenzuela, UNIVERSITY OF VIGO (SPAIN)

Numerical Method for Energy Optimisation of Bottom Trawl
Dr. Daniel Priour, IFREMER (FRANCE)

Trawl-Gear Innovations to Improve the Energy Efficiency of Australian Prawn Trawling
Mr. Steve Eayrs, GULF OF MAINE RESEARCH INSTITUTE (USA)

First International Symposium on Fishing Vessel Energy Efficiency
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Design requirements vs. real operational needs in fishing vessels.

Economical Effects of Oversizing.

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Abstract—**During the last years two facts have drastically affected the profitability of fishing fleets: the reduction of fish catches and the continued increase of fuel prices. These two circumstances have led to a critical situation of fishing fleets, which are nowadays trying to improve their efficiency in order to maintain their economical profitability.**

Fishing fleets are characterized by the heterogeneity and overestimation of ship characteristics and their equipment. These considerations have become hard barriers to improve their efficiency. Despite this some elements have been significantly improved: new hull configurations, better hydrodynamic performance of rudders and propellers, electronic control based engines, co-generating systems, etc. However the design requirements and parameters have not changed although environmental, legal, operational conditions have drastically been modified and design parameters are still based on maximum sales criteria. Those criteria involve minimizing navigation times and to be able to catch, store and process as much captures as possible in the worst sea conditions.

In this paper the characteristic parameters of a fishing vessel are evaluated in order to determine the feasibility project and the variables with more influence in the economical results. Therefore, new design parameters will be proposed taking into account the real operational needs and the current economical framework. Finally the economical profitability of two ship models is compared in order to define efficient design criteria.

The aim of this paper is to define the design parameters for a fishing vessel in order to increase its economical profitability. To achieve this target, the sensitivity of each variable has been evaluated through the application of Monte Carlo simulation. Thus, the quantification of the influence of the fuel consumption, the ship building cost, the amount and price of catches has lead to the determination of the economical result of a current fishing vessel for the last 7 years. On the other hand this study identifies the real operation needs of fishing vessels and the real trend of the fishing market.

The analysis of those parameters shows the high influence of initial investment on the final economical profitability of the ship. For this reason, to adjust its main dimensions, power and systems to the real operational needs it becomes essential to secure the profitability of the vessel.

Keywords-component feasibility plan for fishing vessels; operational needs in fishing vessels; design requirements for fishing vessels.

I. INTRODUCTION

Fishing vessel design has been guided by the requirements of the ship-owner of a multipurpose vessel due to the inherent uncertainty of this sector. Thus, the target design has been one capable of dealing with different scenarios and with the largest dimensions and power that their licenses permit. That is, the design criterion has been maximal cached capacity.

Therefore, this attempt for improving ship profit has derived into an inefficient fleet because it is not optimized for its real operation during most of its life cycle. An example is an ocean going trawler designed for fishing in distant grounds, that changes its operation into a coastal tandem trawler with a daily catch limit.

In Europe, ship dimensions and propulsive power are limited by the EU laws, which establish a maximum effort for each country. The vessel fishing effort is based on its tonnage and propulsive power, that is, hold capacity and speed, and its fishing time, and is stated on its fishing license. This fishing effort can be transmitted from one ship to another and in case of a new building, a ship of similar capacity should be decommissioned.

Fish catches in all European waters are also controlled by the EU; for each species and fishing ground, a "total allowable catch" (TAC) is annually specified, which determines the maximum quantity of that species that can be captured in that ground for a whole year. Those TAC´s are then distributed between all European countries (EU responsibility) and afterwards between the different fleets of that country (national authorities).

The amount of national TAC that corresponds to each vessel depends on the fishing effort that is approved in the fishing license, the fishing ground or the fleet. National authorities can also determine a fishing calendar or daily maximum catches depending on the species or fishing grounds.

The search for the maximum sales, maximizing fish catches in all conditions and minimizing voyage times, has derived in large and powerful vessels, sometimes built after the decommissioning of two or more older vessels and the adding of their capacities. This is usually done without considering the maximum permitted/available catches for each vessel, and that in most cases will be much less than its hold capacity.

Due to this fact, incomes from fish catches are clearly under expected, decreasing the benefits. Moreover uncontrollable and non long term predictable variables, as fuel prices, affect profit and the capacity of the owner to correct the situation is highly constrained.

According to these points several research projects to improve the technological efficiency in fishing ships have been carried out. It is necessary to mention studies in the field of hydrodynamics, as the effects of different bows or propeller nozzles among others [1,2] and the optimization of the propellers and its integration in the engine room [7,8]. All technical advances try to respond to the fuel savings demanded by ship owners through efficiency improvements.

However, many technical studies are based on design operating requirements that are different from of its real operational requirements. At the same time, usually hydrodynamic or equipment improvements are focused on a particular scenario in the fishing activity, but not considering the complete cycle of the operation of the vessel. Thus, the process to improve the economical profitability must consider all aspects of the fishing exploitation.

According to the previous points, in this work the fishing vessel profitability is presented as the main design criteria. Thus fuel savings are considered as a controllable variable among others that affect the profitability of the vessel. Its relative importance will also be determined.

For that, the exploitation of the ship is considered from the point of view of the business feasibility. Therefore, the most important variables have been analyzed in order to determine their affect on the activity profit.

Once determined, these variables have been evaluated according to their influence on the economical results in order to take design decisions. Then, different solutions that led to improvements in the expected profit have been compared. One important point of this analysis is to determine which can be controlled or not by the ship owner and how affect on the economical result.

II. DATA AND FRAMEWORK

To estimate the fishing market trend, the evolution of the catch amount of the Celeiro port (one of the most important fishing ports in Galicia, Spain) has been considered. Thus, the extrapolation to the total catches has been carried out through the analysis of main species caught in this port. The total amount of species caught since 2001 to 2009 [10] were: hake (47,669,663 kg), whiting (31,281,569 kg) and mackerel (13,489,354 kg).

As shown the figure 1 hake amount was quite stable, mackerel catches had a significant increase and whiting catches decreased. However, the total amount of catches has been quite stable during the last years.

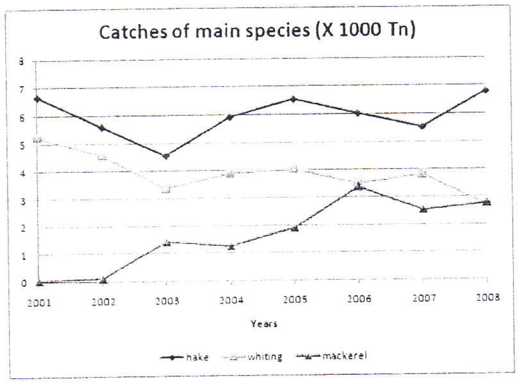


Figure 1. Catches of main species [10]

On the other side, their price has been continuously falling during last decade, especially in the case of mackerel whose price dropped in 2003 (see figure 2).

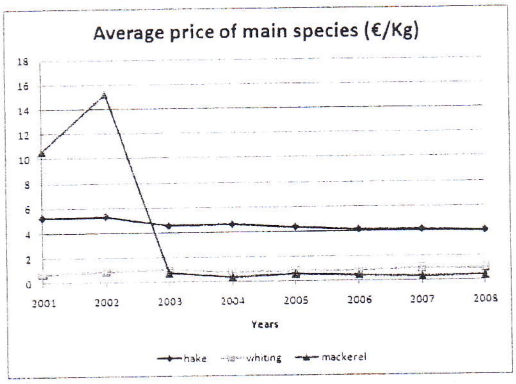


Figure 2. Average price of main species [10]

A drastically reduction of the incomes occurred in the first third of the decade as result of trends of the catches and prices (see figure 3). After these years, the incomes have been stabilized.

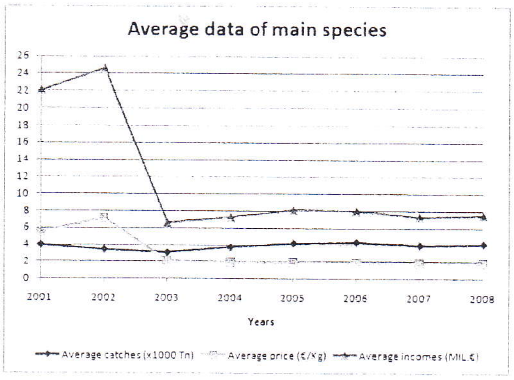


Figure 3. Average data of main species [10].

In spite of the incomes decrease from fishing activity, fishing ships built in last years have reached larger cargo capacity per unit; this trend is showed in the figure 4. These new vessels reach higher speeds despite their larger dimensions (see figure 5) due to their higher propulsive power. For example, in the case of longliners, their service speed has increased from 8 kn to 12 kn.

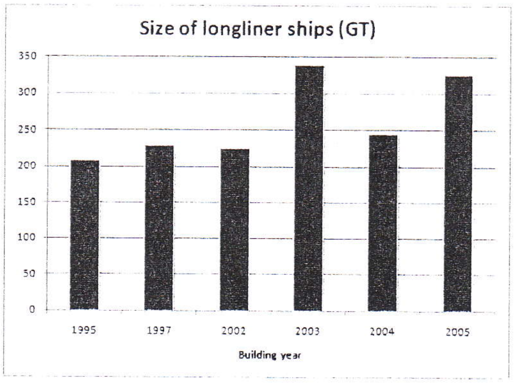


Figure 4. Size of longliner ships in Gross Tonage (data from fleet of Celeiro port, Spain)

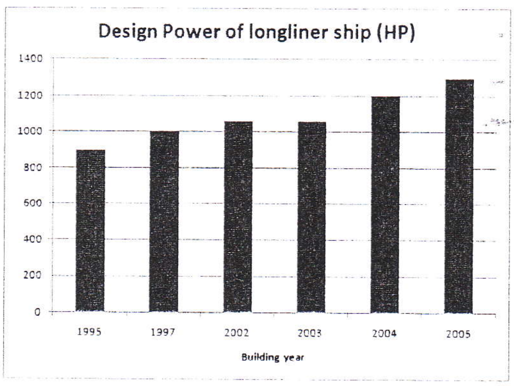


Figure 5. Design power of longliner ship (data from fleet of Celeiro port, Spain)

Although this higher speed means a higher fishing opportunity since it allows a greater available time for operation, the catches amount has been quite constant in the last years and incomes have finally decreased because of the fish prices.

These systems and configuration would lead to minimize the operational costs per caught tone and the consumption costs due to their technological improvement. However and due to constant catches and rising of ship dimensions, the expected reduction of costs per caught tone has not been carried out. In addition to this the fuel price has been increased for the last years (see figure 6). The advantage of the technology improvements and the effects of economy of scale due to greater ships have not had the expected results.

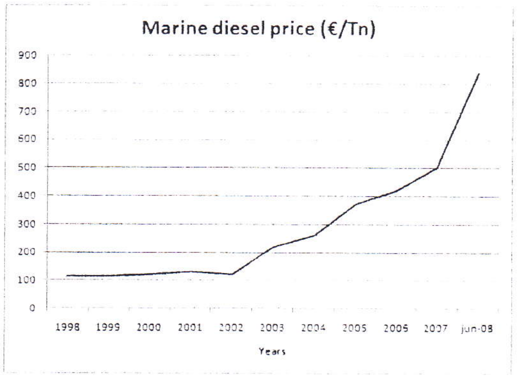


Figure 6. Marine diesel price.

Once analyzed the evolution of the fishing market and their fleet, the next step has been to define the real operating features of the fishing vessel. The aim of this analysis has been to define the necessary dimensions of the vessels and their power in order to cover their real needs per trip and to increase their profitability.

The current average dimensions for those fishing vessels in Galician ports can be seen in table I, moreover their operating features which are showed in the table II. According to these operational needs, power requirements are defined by transfer voyage needs, as only in certain conditions trawling request the maximum power. Taken into account the total time for every operating condition, the higher total consumptions take place in voyage time for longliners and in trawling for trawlers, but the consumptions for pair trawling are similar for voyage and trawling operation. In this point, it is necessary to take into account that the voyage speed is a free variable that is defined by the master.

Although in trawlers, the differences between propulsion needs in each operational condition are well known, each trawler is designed to reach its better efficiency under only one drag condition. However, if this trawler is employed to work in different conditions (for example from working alone to operate in pair), its efficiency will decrease during most of its fishing time. This necessarily means a higher consumption in this operating condition.

TABLE I. CURRENT FEATURES OF FISHING VESSELS

Current Features of Fishing Vessels						
Vessels	*Lpp (m)*	*Lo (m)*	*B (m)*	*D (m)*	*Hold Capacity (m3)*	*Power (HP)*
Longliner	28	36	8.0	3.8	119	1200
Trawler	37	31	8.6	3.7	175	1500
Coastal trawler	24	30	8.0	3.5	134	1200

TABLE II. OPERATIONAL FEATURES OF FISHING VESSELS PER KIND OF SHIP.

Operational Features per kind of ship					
Coastal Trawler					
Distance to fishing point (miles)	33	*Average pull capacity (Tn)*	9	*Hours per trip*	22.5
operating conditions		*% trip in time*		*speed (kn)*	
transfer voyage		31.11		9.2	
letting out		6.67		2.0	
picking up		4.44		1.5	
trawling		57.78		2.0	
Trawler					
Distance to fishing point (miles)	315	*Average pull capacity (Tn)*	9	*Days per trip*	18
operating conditions		*% trip in time*		*speed (kn)*	
transfer voyage		14.44		11.0	
letting out		7.56		2.0	
picking up		7.56		1.5	
trawling		67.39		2.0	
Longliner					
Distance to fishing point (miles)		315		*Days per trip*	18
operating conditions		*% trip in time*		*speed (kn)*	
transfer voyage		21.39		11.0	
letting out		12.11		8.0	
picking up		52.06		1.7	

The necessary fuel capacity to perform the fishing activity under the previous operating conditions for every trip is showed in table III. In this table the fuel capacity in tanks for current vessels is also showed. Range oversizing is very important in all cases, but table IV also shows an important oversizing in hold capacity regarding the maximum amount of catches per trip. Therefore, in the studied fleet, an important over capacity has been found out both in holds and in fuel tanks even considering the most demanding operation modes.

TABLE III. CAPACITY OF FUEL TANKS VERSUS NECCESARY CAPACITY PER TRIP

Capacity of Fuel Tanks versus Necessary Capacity per Trip				
Vessel	*Available capacity (m3)*	*Necessary capacity (m3)*	*Capacity excess (m3)*
longliner	125	51.23	73.77
coastal trawler	70	3.40	66.60
trawler	120	61.00	59.00

TABLE IV. HOLD CAPACITY AND FILLING HOLDS PER TRIP

Hold Capacity and Filling Holds per Trip				
Vessel	*Hold capacity (m3)*	*% max. Full/ trip*	*% average full/trip*	*Hold capacity for max. catches per trip (m3)*
longliner	119	74	37	88.06
trawler	175	71	41	124.25
coastal trawler	134	60	6	81.05

III. THE METHOD

The main variables which determine the profitability of a fishing vessel will be defined in the next paragraphs, on the basis of the analysis of an economical model. This model will be based on a fishing vessel feasibility project from the point of view of an investor.

First, the operation of a fishing vessel will be evaluated considering the investment profitability of a current vessel in the last seven years, according to the average catches per trip and the market evolution in prices. In order to do this, a coastal trawler operating in tandem will be taken as example. The economical results will be evaluated according to the net present value (NPV) together with the internal rate of return (IRR).

To obtain the influence of the main variables in the economical results of the project, a MonteCarlo simulation will be carried out using Crystal Ball.

This will also make possible to determine the certainty rate of the achieved NPV value, as the MonteCarlo simulation takes its inputs according to a probability distribution [11], which represents the uncertainty of different scenarios. The simulation is able to take values of various variables at the same time according to the probability distribution.

In this case, a triangular probability distribution with a variation of 20% between most and least probable values has been chosen (see figure 7) for all selected inputs. This distribution is the most suitable for our case, because the model is analyzed as a past project where all variables are right now met, although their influence level on the NPV has not been determined yet.

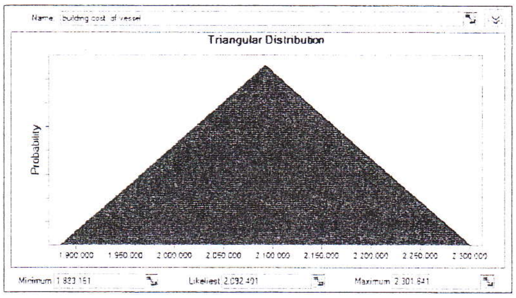


Figure 7. Probability distribution for the controllable variable 'building cost of vessel'

The selected variable in the simulation can be divided in two groups. Some of them are defined as external, such as catches per trip, catches price or fuel prices. The other group is integrated by ship owner selected variables such as number of trips per year, percentage of time in each operation mode, main engine consumption or building cost of the vessel.

Although the residual value of the ship can be considered as an external variable (as it depends on the market situation), we will consider it as a controllable variable because it specially depends on the building cost and the sale moment and these parameters are determined by the ship owner.

After 1.600.000 trials the obtained results show a main NPV with a certainty level of 99.65% (see figure 8). The most influential variables on NPV are listed according to their sensitivity on the forecast in percentages (see figure 9), both in positive and negative direction.

It can be seen that, for all the studied years, the most important variable is the fish price (39.95%) and the total catches per trip (39.77%), although its importance depends on the considered year (higher in first years when fish prices were also higher).These variables are determined by the market or by the Administration in most cases, and so ship owners are not able to control them.

The other influential input is the number of trips per year (19.47%). However, as fish catches are limited by Administration during most of the yearly fishing time, a higher number of trips will not necessarily mean a higher catches amount. Thus the trip number a year will be considered as a no controllable input. In the sensitivity simulation, the rest of the variables only influence a 0.8 % on the NPV, although these ones are the controllable parameters.

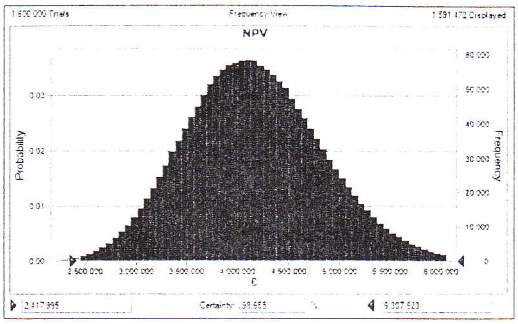


Figure 8. Simulation results for NPV of a project of current trawler evaluated since 2001 to 2008.

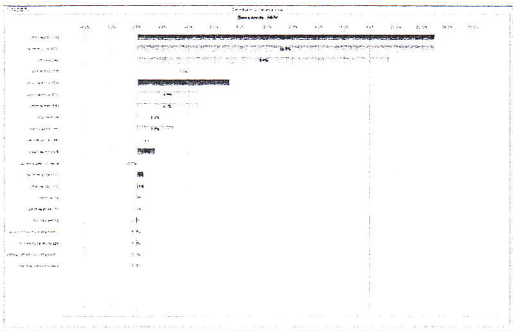
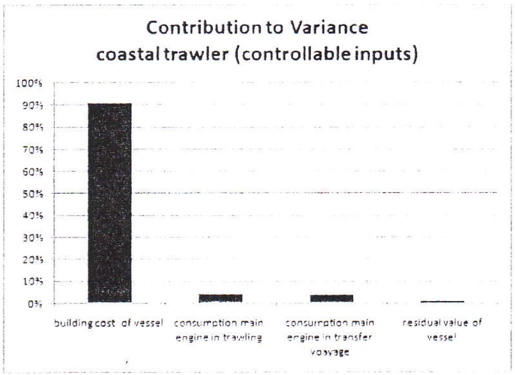


Figure 9. Contribution from considered assumptions to variance in NPV values in the simulation for a project of a current trawler evaluated since 2001 to 2008.

If we only considerer in the simulation the controllable inputs, these can be listed according to their influence on the sensitivity of the result as shown in figure 10. The most influential variable is the building cost (90.85%), followed by consumption while trawling (4.33%) and the consumption in the transfer voyage to the fish grounds (3.76%) with very similar importance. The least influential variable is the residual



value of the vessel (0.94%).

Figure 10. Contribution to variance. (in the simulation for a project of a current trawler evaluated since 2001 to 2008).

Taken the aforementioned results in account, an alternative vessel that improves the profitability of the analyzed current trawler shall have its fuel consumption and building cost minimized.

To achieve both goals, the new vessel must be smaller. On one hand, a smaller ship can maintain the transfer times equal with less propulsive power and so also reduce specific fuel consumption. On the other hand, the building cost of a smaller ship will also be reduced, as steel weight and main engine power are less than in the current vessel case (in this kind of ships, both items together represent about the 30% of the cost of the vessel).

According to the previous operation data of current vessels (such as hold occupancy and fuel consumptions per trip), the necessary cargo capacity for a new optimized vessel can be determined.

This proposed vessel should have enough capacity as to carry up to 90 m3 of cargo. With this hold capacity, it will also be able to operate in other further fisheries (as Great Sole grounds), as it would have enough capacity to carry the average catches amount per trip in these areas (about 72 m3 of cargo per trip).

Regarding its range, to operate in coastal waters, a maximum of 3.4 m3 of fuel would be necessary. If the proposed vessel is also intended to operate in further fisheries, the range should be enough to cope with a 20 days trip.

Given this fact, the proposed vessel will have a 33% less of hold capacity and 33% less of propulsion power, but maintaining the same operational capacity, range and service speed (see table V).

Coastal Trawler Features						
Vessels	*Lpp (m)*	*Lo (m)*	*B (m)*	*D (m)*	*Hold Capacity (m3)*	*Power (HP)*
Proposed trawler	20.7	26	6.8	3.2	90	800
Current trawler	24.0	30	8.0	3.5	134	1200

TABLE V. COASTAL TRAWLER FEATURES

This new vessel leads to approximate reductions of 13 % in building cost and 11% in fuel consumption. Carrying out the feasibility simulation for this new vessel in the same conditions as the current trawler, the new NPV value is a 3.8% higher and its IRR is a 19% higher.

If we also analyze the variable sensibility in the new model we can find out that after 1.600.000 tests, this NPV value has a certainly level of 99.6%.

Listing in this case all the influential variables regarding their sensibility influence on the forecast value, we find out that the order of the variables is the same as in the current trawler. Carrying out the simulation again, but considering only the influence of the controllable variables, we can appreciate that the importance of the trawling consumption and transfer voyage consumption have not changed (see table VI). This is so because the impact from the reduction of the dimensions on the transfer voyages consumption is low and in trawling the ship resistance (especially viscous resistance) has less relative weight in the total resistance than the net induced resistance. Only the sensitivity regarding the building cost has been significantly reduced.

TABLE VI. CONTRIBUTION TO VARIANCE FROM CONTROLLABLE VARIABLES IN THE VESSELS

Contribution to Variance from Controllable Variables in Vessels		
Variables	*Proposed vessel*	*Current vessel*
building cost of vessel	89.17%	90.85%
residual value of vessel	1.60%	0.94%
consumption engine in transfer voyage	4.44%	3.76%
consumption engine in trawling	4.64%	4.33%

IV. CONCLUSSIONS

In this study we have reviewed the fishing scenario for the last years, including not only the trade variables as fish and fuel prices but also the variables controllable by the shipowners, as their vessel main dimensions and propulsion power.

The results show a trend towards increasing both propulsive power and hold capacity in the last years, in spite of the decrease of the fish price and the increase of the fuel price.

The operation of the main types of fishing vessels has also been analyzed. In this sense, we can note that the average occupation of holds per trip is very low. It can also be stated that the more powerful propulsion engines help reducing transfer times, increasing the available fishing time. Despite the increase in power, fuel tanks are still oversized regarding the operative range.

From this, it can be concluded that the majority of the current vessels are too large for the activity they are performing and at the same time were designed in order to be as versatile as possible. This fact makes vessel optimization impossible, especially regarding the working point of the propeller. Fishing vessels result very dependent on the operation mode (alone, in pair, speed, etc).

To obtain the economical consequences of fishing with an oversized vessel, we have modeled the feasibility of a current trawler for the last 7 years, considering its operational conditions and the environment variables.

The model calculated the NPV value of this project and the most influential variables on it. In order to do this, a MonteCarlo simulation was carried out considering both the variation in the shipowner controllable inputs and in the no controllable ones.

Thus, for the simulation of a current coastal trawler we find out that the most influential parameters on its profitability were the catches per trip and the fish price and that the total sensitivity of the controllable parameters on NPV is only 0.8%. Among the controllable inputs, the most important ones are building cost and fuel consumption. As expected, catches price is very important in the fishing profitability. However, the expectations about the fuel price influence were not met, since it showed a very little sensibility on economical results in comparison with other variables.

According to the previous results, a new trawler vessel was studied, which was able to operate in the same conditions as the current trawler but adapted to their real needs.

The proposed vessel was a smaller ship in order to reduce building cost and fuel consumption. Despite this decreasing, the ship still has enough hold capacity for the maximum occupation registered and even for operating in further fisheries.

These two parameters which have been minimized are the most sensitive controllable variables, and so the results of the feasibility model for the proposed ship showed better NPV value than in the previous case. In addition, the new vessel feasibility is less depending on the controllable parameters than the current one and therefore, the profitability of the fishing activity with this vessel will be more sensible to the market. In the analysis of the influence of controllable parameters in the new vessel profitability, the importance of the investment has decreased compared to the fuel consumption.

It is necessary to note that the reduction in consumption due to the reduction of the main dimensions for the coastal trawler is not as significant as expected. This is so because the real reduction was mainly due to the reduction of wet surface and to the increase of the slenderness of the ship forms and also due to that the most important resistance of the ship in free sailing, wave resistance, is not modified as speed has not changed.

On the other hand, the main component of the resistance in trawling is the viscous resistance, which mainly depends on the dimensions. Net induced resistance is as important as viscous resistance in this condition, and did not change in this new case.

Therefore, the main consequence of the substitution of a current coastal trawler by a smaller one is the reduction of its building cost. That is the main reason of the 3.8 % improving of the profitability in the feasibility analysis.

It can also be concluded that in order to obtain better economical results it will be necessary to carry out variations in the operational parameters, as the reduction of the service speed in transfer voyage. However, reducing the consumption in trawling would be more complicate because the main ship resistance is given by the catches, therefore no controllable. In this point, only the correct working of the propeller would lead to less consumption. The correct definition of the operational conditions will be very important to get a good efficiency in the propeller.

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