Operational Requirements on Fishing Vessel Design and their Economical Results

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Abstract

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.

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 current fishing vessels 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 large importance of market parameters in the economical results and the high influence of initial investment on the final economical profitability of the ship.

Keywords

Feasibility plan for fishing vessels; operational needs in fishing vessels; design requirements for fishing vessels.

Introduction

Fishing vessel design has been guided by the requirements of the ship-owner for to get 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 catches capacity. Therefore, this attempt for improving ship incomes has derived into an inefficient fleet because it is not optimized for its real operation during most of its life cycle

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 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, or the maximum available time per trip to sale fresh fish in port. The consequence is that in most cases the necessary cargo capacity 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 (Gómez.1998, Papanikolaou.2009) and the optimization of the propellers and its integration in the engine room (Hugel.1992; Pike.1992). All technical advances try to respond to the fuel savings demanded by ship owners through efficiency improvements.

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 in 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.

Data and framework

The market and fishing fleet trend

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 (Consellería do mar. 2009). were: hake (47,669,663 kg), whiting (31,281,569 kg) and mackerel (13,489,354 kg).

The 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.

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

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 1). After these years, the incomes have been stabilized.

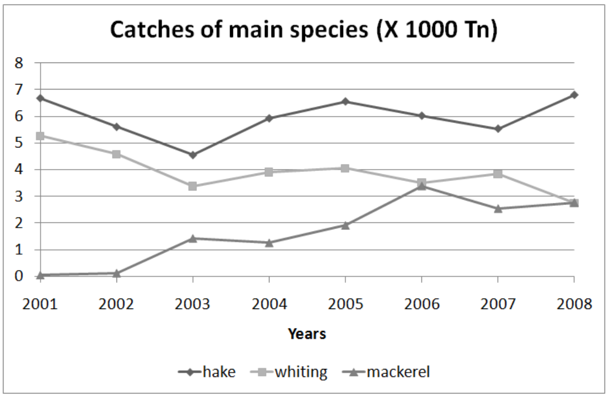

Fig. 1: Average data of main species

In spite of the incomes decrease from fishing activity, fishing ships built in last years have reached larger cargo capacity per unit. These new vessels reach higher speeds despite their larger dimensions (see figure 2) due to their higher propulsive power. For example, in the case of longliners, their service speed has increased from 8 kn to 12 kn.

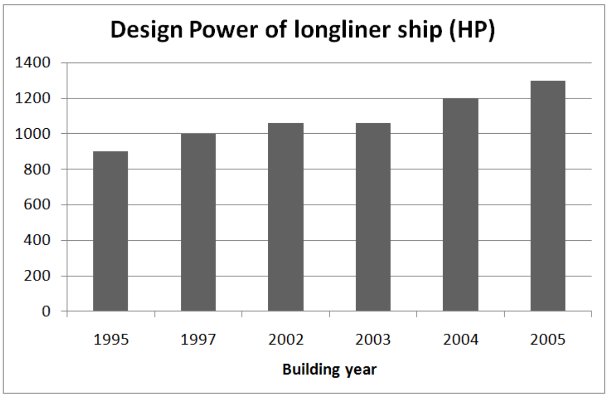

Fig. 2: Design power of longliner ships (data from fleet of Celeiro port, Spain)

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. The advantage of the technology improvements and the effects of economy of scale due to greater ships have not had the expected results.

Operating features of the fishing vessel

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 capacity of the vessels and their power in order to cover their real needs per trip and to increase their profitability.

The operating features for current fishing ships are showed in the table 1. 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.

Table 1: Operational features of fishing vessels per kind of ship.

<table>
<tr><th colspan="4">Operational Features per kind of ship</th></tr>
<tr><th colspan="4">Coastal Trawler in Tandem</th></tr>
<tr><td>Distance (miles)</td><td>33</td><td>Hours/trip</td><td>22.5</td></tr>
<tr><td>operating conditions</td><td>% trip in time</td><td colspan="2">speed (kn)</td></tr>
<tr><td>transfer voyage</td><td>31.11</td><td colspan="2">9.2</td></tr>
<tr><td>letting out</td><td>6.67</td><td colspan="2">2.0</td></tr>
<tr><td>picking up</td><td>4.44</td><td colspan="2">1.5</td></tr>
<tr><td>trawling</td><td>57.78</td><td colspan="2">2.0</td></tr>
<tr><th colspan="4">Trawler</th></tr>
<tr><td>Distance (miles)</td><td>315</td><td>Days/ trip</td><td>18</td></tr>
<tr><td>operating conditions</td><td>% trip in time</td><td colspan="2">speed (kn)</td></tr>
<tr><td>transfer voyage</td><td>14.44</td><td colspan="2">11.0</td></tr>
<tr><td>letting out</td><td>7.56</td><td colspan="2">2.0</td></tr>
<tr><td>picking up</td><td>7.56</td><td colspan="2">1.5</td></tr>
<tr><td>trawling</td><td>67.39</td><td colspan="2">2.0</td></tr>
<tr><th colspan="4">Longliner</th></tr>
<tr><td>Distance (miles)</td><td>315</td><td>Days/ trip</td><td>18</td></tr>
<tr><td>operating conditions</td><td>% trip in time</td><td colspan="2">speed (kn)</td></tr>
<tr><td>transfer voyage</td><td>21.39</td><td colspan="2">11.0</td></tr>
<tr><td>letting out</td><td>12.11</td><td colspan="2">8.0</td></tr>
<tr><td>picking up</td><td>52.06</td><td colspan="2">1.7</td></tr>
</table>

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.

The necessary fuel capacity to perform the fishing activity under the previous operating conditions for every trip and ship is about a 50% of the current capacity of fuel tanks. Range oversizing is very important in all cases, but table 2 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 2: Hold capacity and filling holds per trip.

Vessel	*Hold (m3)*	*% max. full/ trip*	*% average full/trip*
longliner	119	74	37
trawler	175	71	41
coastal trawler	134	60	6

The method and the analysis

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 the current vessels 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, a trawler working alone and a longliner will be taken as examples. The economical results will be evaluated according to the net present value (NPV).

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.

The MonteCarlo simulation has been selected in front of others sensitivity models and multidimensional analysis because while the last ones just allow a discrete evaluation the MonteCarlo simulation evaluates the impact of each variable whose value varies according to a probability distribution which represents the uncertainty for different scenarios (Sapag .2001)‘.

In this case, a triangular probability distribution with a variation of 20% between most and least probable values has been chosen (see figure 3) 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.

Therefore this simulation will also make possible to determine the certainty rate of the achieved NPV value moreover others statistical parameters (see figure 4) , as it takes its inputs according to a probability distribution (Sapag.2001), which represents the uncertainty level for this variable. The simulation is able to take values of various variables at the same time according to their probability distributions.

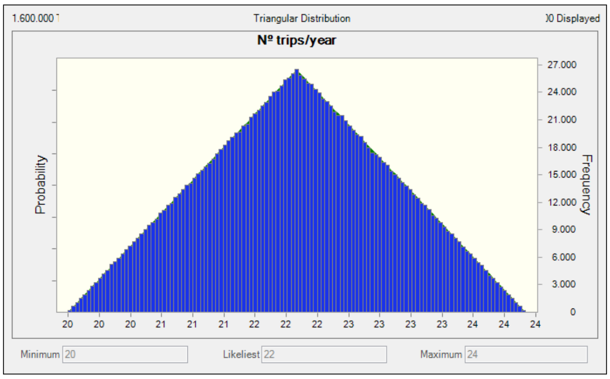

Fig. 3: Probability distribution used for the input 'Nº trips/year' in the simulation of a longliner.

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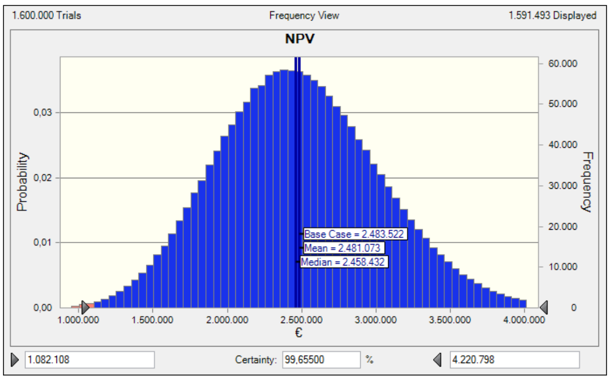

Fig. 4: NPV values in the simulation of a longliner.

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 NPV values with a certainty level of 100% for all vessels except for the longliner whose certainty level is of 99.65% (see figure 4).

The most influential variables on NPV are listed according to their sensitivity on the forecast in percentages (see figure 5), both in positive and negative direction. These percentages account for the contribution from each variable to the NPV variance.

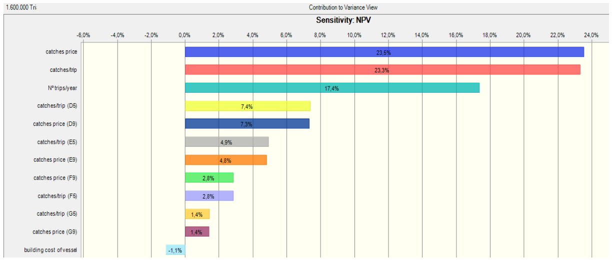

Fig. 5: NPV sensitivity in the simulation of a longliner.

For all current vessels, the most influent variables in the NPV are the fish price and the total catches per trip (see table 3), 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. In the table 3 can be noted that its influence is higher in coastal trawler than in the other vessels. In spite of the fact that coastal trawler perform more trips a year than the others its total consumption a year is less because it operates in tandem

However. due to 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 variables only represent between 0.81 % and 1.47% on the NPV although these ones are the controllable parameters. Therefore, since the studied data, the most depending vessel on the market is the coastal trawler and the ship with higher improvement range is longliner.

Table 3: Contribution to the variance from all inputs for each vessel .

Contribution to the variance from all inputs			
Inputs	***Coastal trawler***	***Trawler***	***Longliner***
Catches Price	39.59%	40.53%	40.61%
Total catches/trip	39.58%	40.47%	40.54%
Nº trips/year	20.02%	17.94%	17.38%
Controllable inputs	0.81%	1.06%	1.47%

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 6, 7 and 8 for each type of vessel.

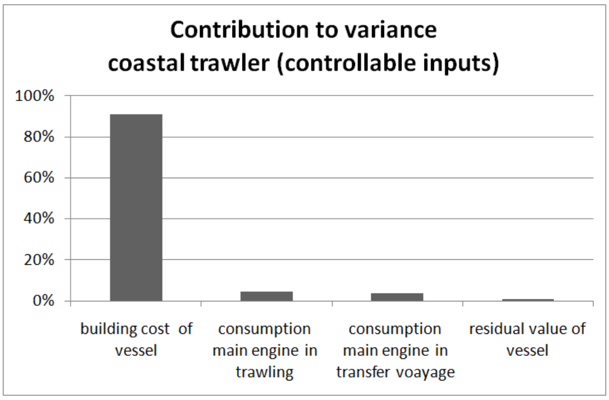

Fig. 6: Contribution to variance in coastal trawler

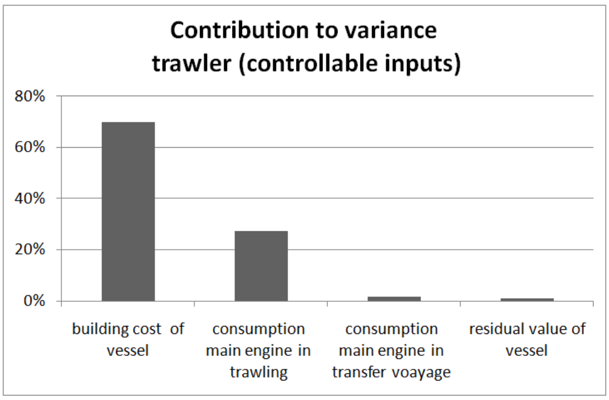

Fig. 7: Contribution to variance in trawler.

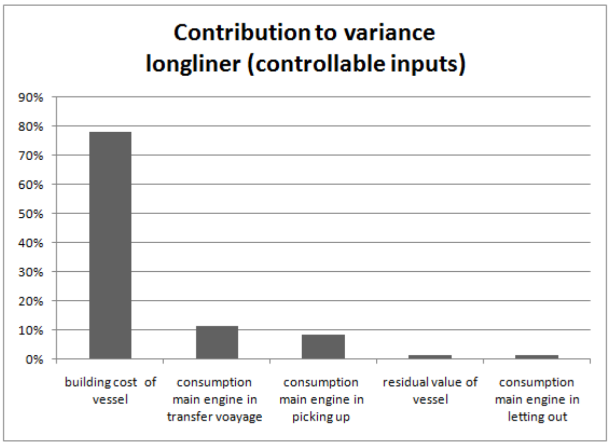

Fig. 8: Contribution to variance in longliner.

The most influential variable on NPV in all cases is the building cost (between 70% and 91 % among all controllable variables). This input reaches the highest value in coastal trawler however its influence is larger in the longliner.

Proposed vessels

Taken the previous results in account, the profitability of a fishing vessel (for all types studied of vessels) is very depending on the market variables. Therefore the improving range regarding controllable inputs is very limited.

The proposed vessels have to be directed to act on controllable inputs of the feasibility project; mainly, reducing the fuel consumption and the initial investment of the ship owner.

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 (hold occupancy and fuel consumptions per trip), the necessary cargo capacity for a new optimized vessel can be determined as seen in table 4.

Table 4: Features of fishing vessels.

Vessels	*Lpp (m)*	*B (m)*	*D (m)*	*Hold Capacity (m3)*	*Power (HP)*
Proposed coastal trawler	20.7	6.8	3.2	90	800
Current coastal trawler	24.0	8.0	3.5	134	1200
Proposed Trawler	23	7,13	3.2	124	1100
Current Trawler	31	8,6	3,7	175	1500
Proposed longliner	22	6,93	3,28	90	800
Current longliner	28	8	3,8	119	1200

The proposed vessels have enough capacity to carry up their maximal filling of holds but the proposed coastal trawler have an overcapacity of hold (90 m3 of cargo) to cover the possibility of operation in 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.

If we also analyze the variable sensibility in the new models we can find out that after 1.600.000 tests, this NPV value has a certainly level of 100% for all type of vessels.

Listing in this case all the influential variables regarding their sensibility influence on the forecast value, we find out that the variables order is the same as in the current vessels.

As shown the table 5 the sensitivity of all controllable inputs on the NPV has decreased on all vessels as expected because the fuel consumption and the building cost of the vessels have been reduced while the no controllable inputs are the same, as result the relative weight of controllable inputs on the variance is less.

The most important reduction in the sensitivity of controllable inputs is for the longliner, this is so due to that the impact of fuel consumption in this ship was larger than the trawlers because for trawling the ship resistance (especially viscous resistance) has less relative weight in the total resistance than the net induced resistance.

Table 5: Comparison between contributions from controllable inputs to the variances

Comparison between contributions from controllable inputs to the variances		
Kind of vessels	***Contribution***	***Reduction***
Proposed coastal trawler	0.63%	22.22%
Current coastal trawler	0.81%	
Proposed trawler	0.81%	23.58%
Current trawler	1.06%	
Proposed longliner	1.09%	25.85%
Current longliner	1.47%	

Carrying out the simulation again, but considering only the influence of the controllable variables on the result, we can appreciate that, despite variables order is the same, there are differences with regard to previous vessels (see table 6 and 7).

Table 6: Contribution to Variance from Controllable Variables in Trawlers

Variables	*Proposed Coastal Trawler*	*Current Coastal Trawler*	*Proposed Trawler*	*Current Trawler*
Building cost of vessel	89.17%	90.85%	66.84%	69.72 %
Consumption trawling	4.64%	4.33%	29.97%	27.46 %
Consumption voyage	4.44%	3.76%	1.83%	1.58%
Residual value of vessel	1.60%	0.94%	0.88%	0.88%

Table 7: Contribution to Variance from Controllable Variables in Longliners

Variables	*Proposed Longliner*	*Current Longliner*
Building cost of vessel	77.40%	77.78%
Consumption voyage	13.90%	11.32%
Consumption picking up	5.80%	8.26%
Consumption letting out	1.60%	1.32%
Residual value of vessel	1.30%	1.33%

For the proposed vessels, the sensitivity of building cost on the NPV is less due to the important reduction in the initial investment on the proposed vessels and its impact on the economical results.

Despite of the reduction in fuel consumption in all proposed vessels, this has had a very low impact, as can be seen in the previous tables.

Only the reduction in fuel consumption in longliners for picking up was important enough in order to reduce its sensitivity. In front of this, the reduction in fuel consumption for trawling has been so low than its sensitivity has been even increased.

Conclusions

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. 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.

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

The models for different types of fishing vessels calculated the PNV values 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 current vessels we find out that the most influential parameters on their profitability were the catches per trip and the fish price in all cases and that the total sensitivity of the controllable parameters on PNV is between 0.81% and 1,47%. In according to this, the most depending vessel on the market is the coastal trawler. 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, new fishing vessels were studied as which were able to operate in the same conditions as the current vessels but adapted to their real needs.

The proposed vessels were smaller ships in order to reduce building cost and fuel consumption. Despite this decreasing, the ships still have enough hold capacity for the maximal 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, specially, for longliners. In addition, the new vessels feasibility is less depending on the controllable parameters than the current ones and therefore, the profitability of the fishing activity with these vessels will be more sensible to the market. In the analysis of the influence of controllable parameters in the new vessels 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 fishing vessels is not as significant as expected, especially for trawlers. This is so, because the dimensional reduction mainly influences on the resistance of the ship at low speed (viscous resistance) while that at high speeds the most important resistance of the ship is wave resistance and this is mainly depending on speed. Thus, in free sailing, if the speed is kept as the current vessels the dimensional reduction only influence on the resistance though the reduction of wet surface and the slenderness of the ship forms therefore its impact is very limited.

On the other hand, the main component of the resistance at low speeds as trawling or picking up nets is the viscous resistance, which mainly depends on the dimensions. But trawling the net induced resistance is as important as viscous resistance in this condition, and did not change in this new case. However the reduction of fuel consumption for longliners in the picking up operation is important due to smaller dimensions of the ship.

Therefore, the type of ship with most important improvements in its economical results due to the dimensional reduction is the longliner as that in addition to reduce the capital cost, it significantly reduce consumption fuel. Thus, in according to previous results, for this type of ship a reduction of hold capacity of 25% could have represented an improvement on NPV of 11% in last 7 years.

It can also be concluded that in order to obtain better economical results in trawlers 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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