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Design-optimized and operational features to improve the economic results of fishing vessels

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Abstract

The main objectives of this paper are to define the design parameters and operational features for new fishing vessels in order to increase their economic profitability. Thus, an economic model of their activity has been developed by taking into account the activity of the Galician fleet (Spain) for the last 7 years. Subsequently, the influence of each variable has been evaluated through the application of Monte Carlo simulation for each type of fishing vessel. Once the controllable and market variables in the model have been identified, the quantification of their influence on the economic result has been carried out. From data provided by the shipowners using the Port of Celeiro, this study also identifies a large oversize both in the hold and in the fuel capacity of the current fleet.

According to the results obtained, new main dimensions and operational features for the vessels are proposed, with the objective of improving the economic feasibility of these vessels.

The analysis shows the great importance of the market parameters and the initial investment in the final economic results. The longliner is the vessel that is the most sensitive to the solutions proposed, obtaining the largest improvements through smaller vessels operating at a lower speed during the trip.

Keywords

Feasibility plan for fishing vessels, improvements in fishing vessels, design requirements for fishing vessels

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Introduction

In Europe, ship dimensions and propulsive power are limited by the European Union (EU) regulation that establishes a maximum fishing effort for each country. This value is based on tonnage and propulsive power and is stated on the ship fishing licence. The fishing effort can be transmitted from one ship to another and, in the case of a newly built ship, through the decommissioning of the older ship.

In addition to the above, 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 TACs are then distributed among all European countries (EU responsibility) and then among the different fleets of that country (national authorities).[1]

The amount of the national TAC that corresponds to each vessel depends on its fishing effort, 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 resulted in large and powerful vessels. Sometimes the construction of this kind of ship requires the decommissioning of two or more older ones and the sum of their capacities. Usually this design is achieved without considering the maximum permitted catch or the maximum available catch for each vessel, or the maximum available time per trip to sell fresh fish in port.

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The consequence is that, in most cases, the necessary cargo capacity will be much less than its real hold capacity.

Therefore, in this work the ship profitability is presented as the main design criterion.[2] Fuel savings are considered as a controllable variable among others that affect the profitability of the vessel, and their relative degrees of importance will also be determined. Subsequently, the different proposed solutions that led to improvements in the expected profitability will be compared.

Data and framework

The market and fishing fleet trend

The Port of Celeiro fleet is one of the most important fishing fleets in Galicia, northwest Spain.[3] In addition, it has a large number of types of vessel (with a wide range of cargo capacities) and various types of fishing activity.[4,5]

Because of these facts, data from the Port of Celeiro fleet were taken as the basis for the analysis carried out in this work.

The database used includes longliners between 200 gross tonnage (GT) and 378 GT, coastal trawlers between 174 GT and 292 GT operating in tandem, and trawlers between 297 GT and 415 GT.

In order to estimate the fishing market trend, the evolution of the most important ports in Galicia (nearly half of the Spanish fishing fleet and their workers are concentrated in Galicia) has been considered in reference.[3] Thus, the extrapolation to the total catches has been carried out through the analysis of the main species captured in these ports.[6]

On the one hand, the total amount of catches has been quite stable during the last few years mainly owing to the TAC. On the other hand, their price has been continuously decreasing during the last decade (Figure 1), especially in the case of mackerel, the price of which dropped in 2003.

In spite of the decreasing income from fishing activity, fishing vessels built in the last few years have larger cargo capacities[3] and also higher speeds (due to their higher propulsive power,[7,8] despite their larger dimensions (Figure 2)) than older fishing vessels have.

For example, in the case of longliners (data based on the Port of Celeiro fleet), their service speed has increased from 7 kn to 12 kn. Although this higher speed means a greater fishing opportunity,[4] since it allows a longer available operation time, the amount of catches has been quite constant in the last few years and income has finally decreased owing to the fish prices.

Therefore, it can be seen that the advantage of the technological improvements[9–12] and the effects of the economy of scale in larger ships have not obtained the expected results in fishing activity.

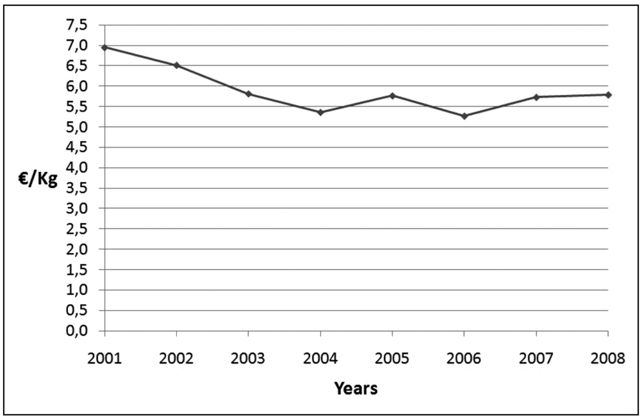


Figure 1. Average price of main species of fish in Galicia (produced from data from Pescadegalicia[6]).

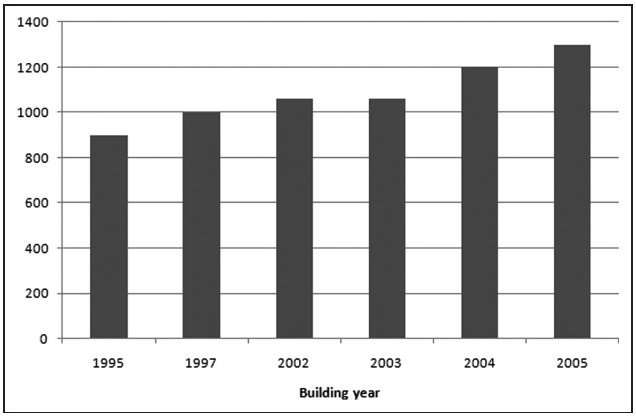


Figure 2. Design power of longliner ships (produced from data from technical specifications from the Port of Celeiro fleet, Spain).

Operating features of the fishing vessel

Once the evolution of the fishing market had been analysed, the next step was to define the real operational features of the fishing vessels. In order to do this, the analysis focused on determining the necessary capacity and power of the vessels, in order to cover their real needs per trip.

The operational features for current fishing ships (of average cargo capacity) are shown in Table 1. Two types of fishing ground were taken into account: first, coastal fishing grounds (33 miles from the coast) with daily trips (about 200 trips per year) and, second, fishing grounds further away (315 miles from the coast) with 18 days per trip (about 22 trips per year). Operational conditions included[4] the transfer voyage to the fishing grounds, fishing operations (the letting out and picking up of nets or lines), and standing-by situations in the fishing ground at much reduced speeds. In the case of longliners,[5] the free sailing condition in the fishing ground were included together with the transfer condition. In addition, the cargo hold occupancies were also registered and data were provided by the shipowners (Table 2). The fuel consumptions of the main and

Table 1. Current operational features of fishing vessels per type of ship.

Operating conditions	Percentage of the trip in time	Speed (kn)
Coastal trawler in tandem (22.5 h per trip)		
Transfer voyage	27.91	9.0
Letting out	6.97	2.0
Picking up	4.66	1.5
Trawling	60.46	2.0
Trawler (18 days per trip)		
Transfer voyage	12.79	11.0
Letting out	7.70	2.0
Picking up	7.70	1.5
Trawling	69.00	2.0
Standing by	2.81	≈ 0
Longliner (18 days per trip)		
Transfer voyage	19.72	11.0
Letting out	12.38	8.0
Picking up	53.11	1.7
Standing by	14.79	≈ 0

Table 2. Cargo hold capacities and cargo hold occupancies per trip.

Vessel	Hold (m^3)	Maximum cargo hold occupancy per trip (%)	Average cargo hold occupancy per trip (%)
Longliner	119	68	34
Trawler	175	61	35
Coastal trawler	134	54	6

auxiliary engines[13] were also measured for each ship and for each set of operational conditions, following a procedure similar to that described in reference.[14]

According to these operational needs, the power requirements are defined by the transfer voyage needs, as this condition requires the maximum power for all the evaluated types of vessel.

Considering the total time of each operating condition, the highest consumption takes place in the voyage conditions for longliners and in trawling for trawlers; in the case of tandem trawlers, the consumptions are similar during the voyage and the trawling operation.

The last points are very important, as the voyage speed is a free variable that is defined by the master.[15]

The necessary fuel capacity to perform the fishing activity under the previous operating conditions for each trip and ship is about 50% of the current capacity of the fuel tanks. According to Table 2, for all types of vessel a significant over-capacity is found, both in the holds and in the fuel tanks, even considering the most demanding operational modes.

Method and analysis

On the basis of the analysis of an economic model, the main variables which determine the profitability of a fishing vessel will be defined in the next few paragraphs. This model will be based on a fishing vessel feasibility project[16,17] which, from the viewpoint of an investor who has started to operate a new vessel in 2001, evaluates the economic results of the fishing business until 2008.[18]

This period of time has been selected to provide a test value for the shipowners. Therefore, they can compare their current profitability with the proposed model and incorporate these design criteria in their new fishing ships.

The economic results will be evaluated according to the net present value (NPV) and to the internal rate return (IRR), giving the cash flow (CF_n) of every year n according to the equations[16,17]

$$\mathrm{NPV} = -\mathrm{CF}_0 + \sum_{n=1}^{7} \frac{\mathrm{CF}_n}{(1+i)^n}$$

$$0 = -\mathrm{CF}_0 + \sum_{n=1}^{7} \frac{\mathrm{CF}_n}{(1+\mathrm{IRR})^n}$$

In order to obtain the CF_n, the results obtained in the previous analysis of the fishing market (for the incomes) for those years and the data from the analysis of the fleet[6] were incorporated in the economic model. In order to achieve this, a coastal trawler operating in tandem, a trawler working alone, and a longliner were taken as test cases.[4]

The necessary information to construct the model was provided by the shipowners of the vessels, except for the price of the catches, which were obtained from the Xunta de Galicia website[6] and the fuel prices (official information).

Therefore, for the first year

$$\mathrm{CF}_0 = \text{initial investment}$$

and, for the nth year

$$\mathrm{CF}_n = \text{revenue}_n - \text{operational costs}_n$$

$$\text{Revenue}_n = \text{catches}_n \times \text{average price}_n$$

The operational costs per year[18] were calculated by adding the annual fuel cost (from the main and auxiliary engines), the lubrication cost, the insurance cost, the port fees, the repair cost, the crew cost, and the taxes, where

$$\text{Fuel cost} = \text{fuel consumption} \times \text{fuel price}$$

To obtain the influences of the main variables in the economic results of the project, a Monte Carlo simulation was carried out using Crystal Ball (risk analysis software[19]).

Because the interest rate i for the NPV calculation is a constant (in this analysis a value of 6% was used), both the IRR and the NPV depend on the same variables.[17] Therefore, the sensitivity results for each parameter will be valid for both of them.

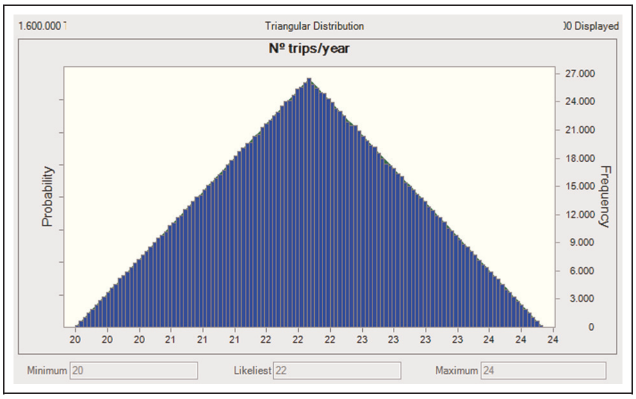


Figure 3. Probability distribution used for the input, which is the number of trips per year, in the simulation of a longliner.

To obtain the influences of the main variables, the NPV was selected as the economic result, making it easier to find the difference in the feasibilities of the different types of vessel.

However, and considering that the comparison of the IRR has a larger significance than that of the NPV, the percentages of the IRR for each vessel were used to evaluate the improvements obtained with the proposed solutions.

The Monte Carlo simulation was carried out using Crystal Ball. This simulation was selected instead of other analysis models because it allows the value of each alternative to be changed at the same time, according to a probability distribution that represents the uncertainty of the different scenarios.[17]

In this case, a triangular probability distribution with a variation of 20% between the most probable value and the least probable value was chosen for all the selected inputs (Figure 3). This distribution is the most suitable for this case, because the model is analysed as a past project where all variables are now known, although the degrees of their influence on the NPV has not yet been determined.

Therefore, this simulation allows determination of the certainty rate of the achieved NPV value next to other statistical parameters (Figure 4), as it takes its inputs from a probability distribution[16] that represents the uncertainty level of this variable.

The first results from the simulation (after 1,600,000 trials) are shown in Figure 4. The NPV values were obtained with a certainty level of 100%.

In the figures, it can be seen that the probability distribution of the NPV obtained is very close to a beta distribution. The differences between the base case and the mean are sufficiently small in all cases. In addition to this, the dispersion level in the simulation is low for the trawler (with a coefficient of variability of 22.10%) and the coastal trawler (with a coefficient of variability of 15.20%). This fact ensures that the assumed risk in the calculation of the NPV is quite low. However, in the case of the longliner, the coefficient of variability is quite high; therefore, the risk of the calculated NPV is important.

Taking into account the obtained results, it could be concluded that the most feasible vessel is the coastal trawler, followed by the trawler, and finally the longliner, with the reliability in the same order.

The variables selected in the simulation can be divided in two groups: the external variables (such as the catches per trip, the price of catches, or the fuel prices) and the variables that could be modfied by the shipowners (such as number of trips per year, the percentage of time in each operational mode, the specific main engine fuel consumption, or the ship dimensions and, therefore, the 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), it will be considered as a controllable variable, as it largely depends on the building cost and the sale time, which are controllable parameters.

The variables that have the most influence on the NPV are listed in percentages according to their sensitivities in the forecast, both in the positive and in the negative direction. These percentages account for the contribution of each variable to the NPV variance.

For all current vessels, the variables that have the most influence on the NPV are the fish price and the total catches per trip (Table 3). These variables are determined by the market or by the administration in most cases, and so the shipowners are not able to control them.

On the other hand, the most important variable with a negative influence is the building cost, with the greatest importance for the longliner and the least importance for the coastal trawler (Figure 5).

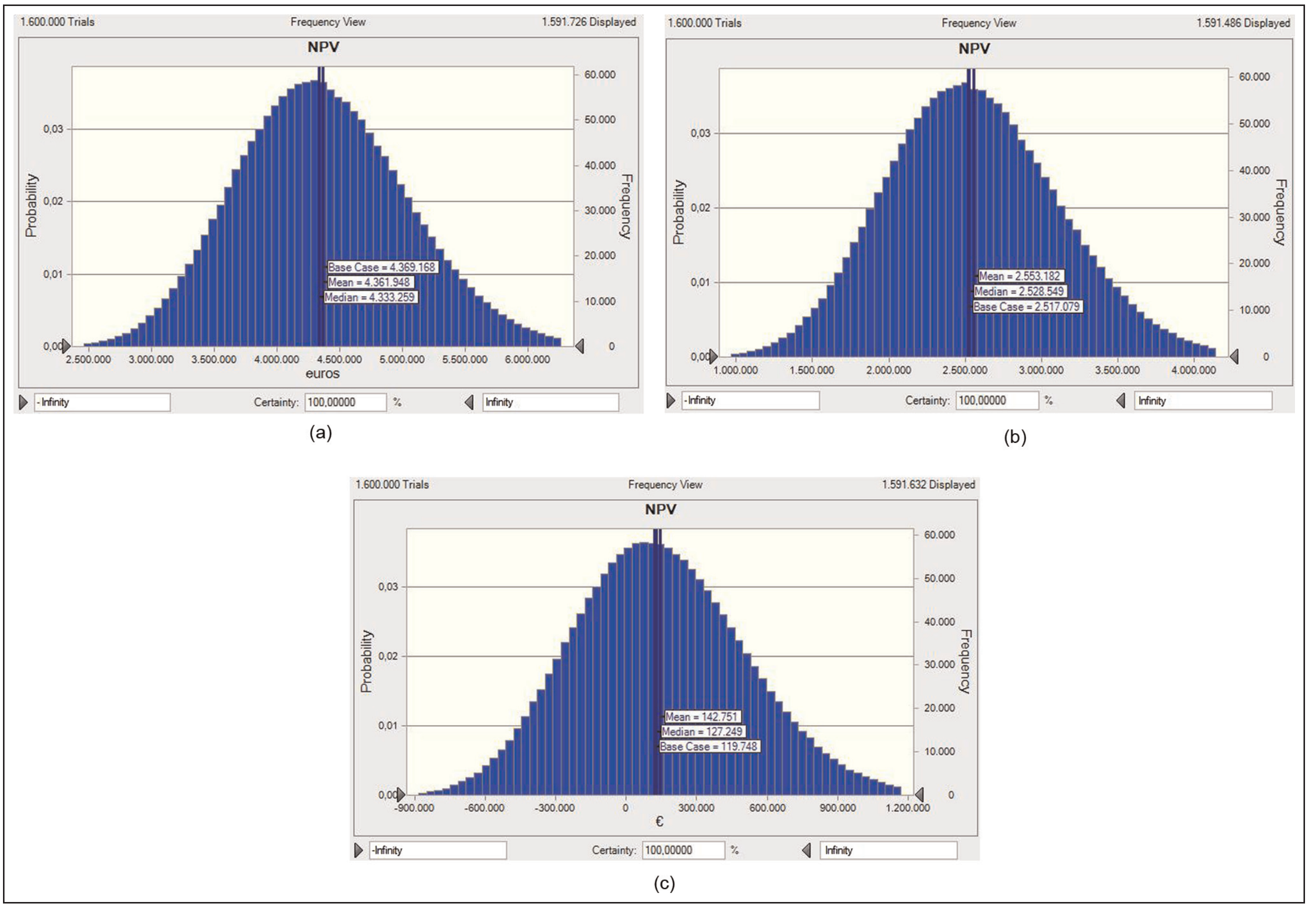
In Table 3, it can also be appreciated that the influence of the number of trips per year is higher in the coastal trawler than in the other vessels. This is because coastal trawlers perform more trips a year than the other vessels.[4] Despite this, its total fuel consumption per year is less than the other vessels because they operate in tandem.[20]

As fish catches are limited by administration during most of the fishing time, a higher number of trips will not necessarily mean a higher amount of catches. Thus, the number of trips per year was considered as a non-controllable input.

Therefore, from the results obtained from the simulation, the most market-dependent ship would be the coastal trawler, while the ship with the highest improvement range would be the longliner.

In the sensitivity simulation, the controllable variables represent only between 1 and 3.60% of the NPV in comparison with the rest of the variables (see Table 3). However, these are the only parameters that can be modified.

Despite the fact that the NPV has a low sensitivity to the controllable inputs, in order to improve the profitability of the vessels, it is necessary to determine which



(a)

(b)

(c)

Figure 4. NPV values for the fishing vessels: (a) in the simulation of a coastal trawler; (b) in the simulation of a trawler; (c) in the simulation of a longliner.

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

Input	Contribution (%) from the inputs to the variance for the following		
	Coastal trawler	Trawler	Longliner
Price of catches	39.50	41.00	41.80
Total catches per trip	39.40	40.90	41.70
Number of trips per year	20.10	16.10	12.90
Controllable inputs	1.00	2.00	3.60

controllable input is the most important, in order to act on it.

If only the controllable inputs are considered in the simulation, their relative influences on the result for each type of vessel are shown in Figure 6.

In this case, the controllable variable that has the most influence on the NPV for all vessels is the building cost (between 70.5 and 91% (see Figure 6)). This input reaches its highest value in the coastal trawler, although its total influence is larger in the longliner, as can be seen in Figure 6.

It is also necessary to note that the contribution of the fuel consumption of the main engine to the variance reaches the most significant level in the longliner.

Proposed new vessels

Taking into account the previous results, the profitabilities of all the types of fishing vessel studied are very dependent on the market constraints. Therefore, the improvement range through controllable inputs will be limited.

The aim is that the proposed vessels comply with the main controllable inputs of the feasibility project, namely a reduction in the main engine fuel consumption and the initial investment of the shipowner.

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

According to operational data on the current vessels (the hold occupancy and the fuel consumption per trip), the necessary cargo capacity for a new optimized vessel can be determined, as seen in Table 4.

The proposed vessels have sufficient capacity to carry their maximum hold occupancy (see Table 2). In

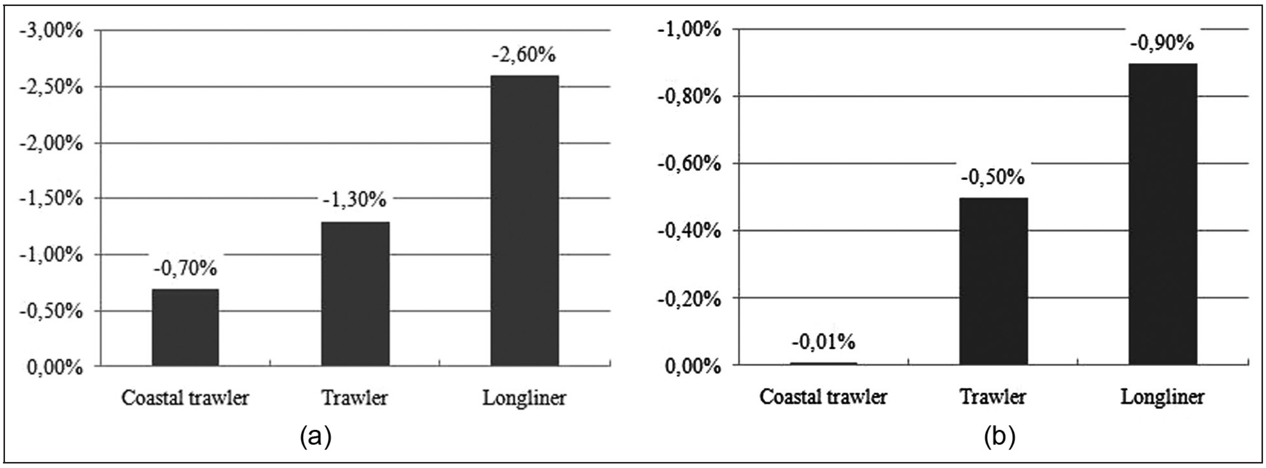


Figure 5. NPV sensitivity in the simulation of fishing vessels: (a) building cost contribution to the NPV variance; (b) main engine fuel consumption contribution to the NPV variance.

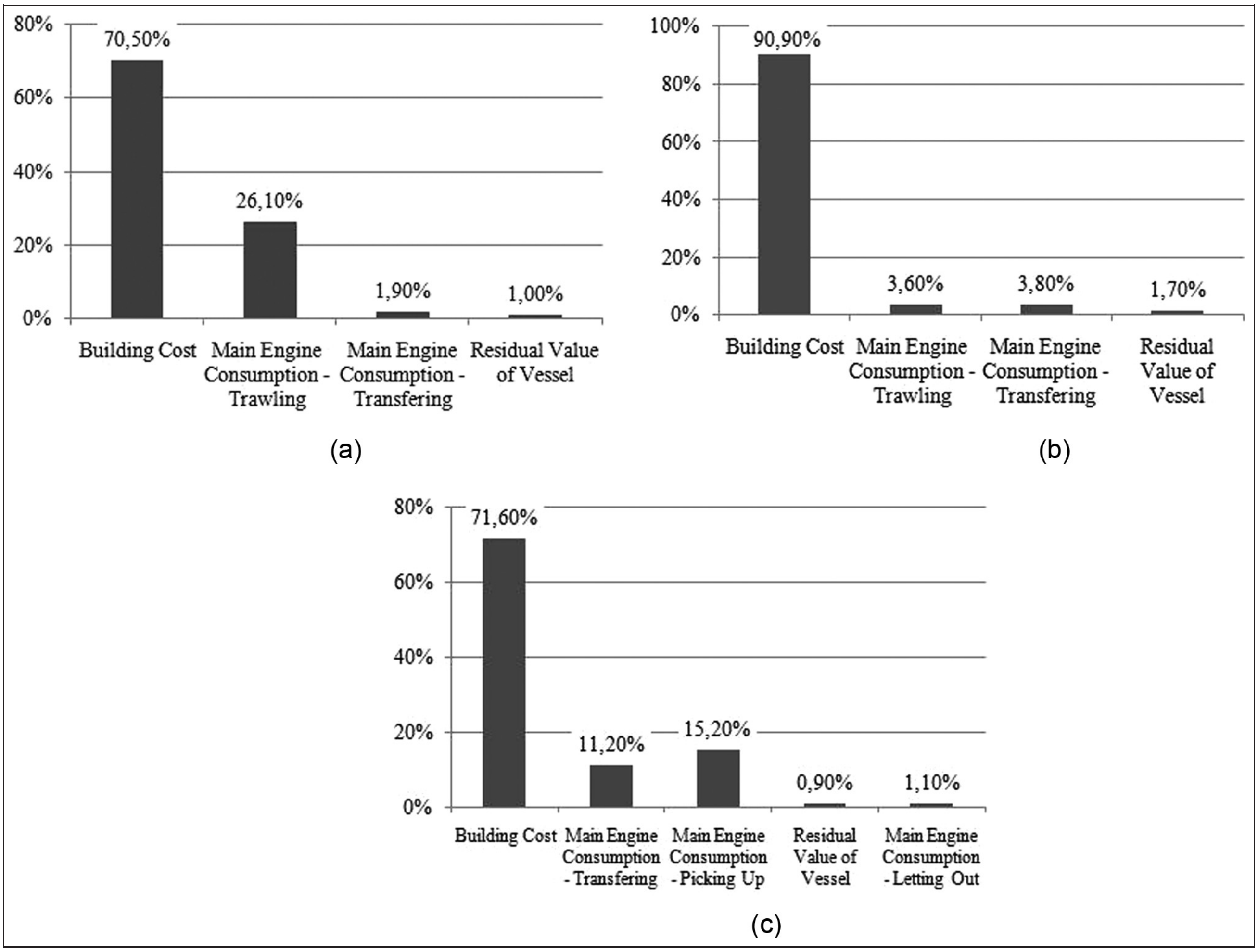


Figure 6. Contribution of the controllable inputs to the NPV variance in fishing vessels: (a) trawlers; (b) coastal trawlers; (c) longliners.

the case of the coastal trawler, the proposed alternative still has a hold overcapacity (90 m^3 of cargo), because it is necessary to cover the possibility of operation in fisheries further away (such as the Great Sole Bank fishing ground). Therefore, in this case, it would have sufficient capacity to carry the average amount of

Table 4. Features of the fishing vessels (Port of Celeiro fleet).

Vessel	L_{pp} (m)	B (m)	D (m)	Hold capacity (m^3)	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

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

Type of vessel	Contribution (%)	Reduction (%)
Proposed coastal trawler	0.60	14.28
Current coastal trawler	0.70	
Proposed trawler	1.40	22.22
Current trawler	1.80	
Proposed longliner	2.70	22.86
Current longliner	3.50	

catches per trip in these areas (about 72 m^3 of cargo per trip).

Vessels with the proposed features can be found in the Port of Celeiro fleet. Hence, the data provided by the shipowners of these smaller vessels (see Table 4) will be taken into account to build the new economic model.

Regarding the range of the proposed vessel, in order to operate in coastal waters, a maximum of 3.4 m^3 of fuel would be necessary. If the proposed vessel is also intended to operate in fisheries further away, the range should be sufficient to cope with a trip of 20 days.

In order to meet the variations in the influences of the variables on the NPV, the simulation was carried out again for all types of the proposed new vessel. Listing all the influential variables with respect to their influences on the forecast value, it was found that the order of the variables is the same as in the current vessels (Table 3).

As shown in Table 5, the sensitivity of the NPV to all controllable inputs (among all the inputs for the Great Sole Bank fishing ground) decreased as expected for all vessels, because the main engine fuel consumption and the building cost of the vessels were reduced, while the non-controllable inputs were still the same. As a result, the relative weights of the controllable inputs on the variance are less.

The most important reduction in the influences of the controllable inputs is for the longliner, because the impact of the fuel consumption for propulsion in this ship was greater than for trawlers. While trawling, the ship resistance (and, in particular, the viscous resistance) has a lower relative weight in the total resistance than does the net induced resistance which does not depend on the ship dimensions.[21] It should be mentioned that all vessels (both current vessels and smaller vessels) operate with very similar nets,[4,14] and so the net resistance could be considered to be equal in the two cases.

In order to obtain the influence of the reduction in the dimensions on the controllable inputs, the simulation was carried out again for the new vessels. In Tables 6 and 7, it can be appreciated that, for the proposed vessels, the influence of the building cost on the NPV is less owing to the important reduction in the initial investment.

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

Only the reduction in the fuel consumption for propulsion of longliners for the picking-up condition was sufficiently important to reduce its influence with respect to those of the other variables. In contrast with this, the reduction in the fuel consumption for trawling was so low that its influence even increased.

The main consequence of this can be seen in Table 8, where the improvements in the IRRs for the new vessels are shown with respect to the previous IRRs obtained from the current vessels.

As expected, the highest improvement in the economic feasibility is for the longliner (74.77% with respect to the current vessel). This is mainly because the overall effect on the NPV due to the reduction in the capital cost (i.e. the building cost (see Figure 5)) for this type of vessel is much larger than for the other ships.

Regarding the main engine fuel consumption, this has the greatest influence on the NPV in this type of vessel. In addition to this, owing to the operational characteristics of the longliner (without extra resistance due to the net at low speeds as in the case of the trawlers) the fuel reduction due to a smaller size is more important.

Modifications to the operational features

Because operational conditions are easily modifiable and related to the fuel consumption,[15] the following paragraphs attempt to obtain fuel savings through operational modifications to the navigation conditions.

In order to achieve this, the operational conditions with the largest fuel consumption for each type of ship will be determined and the possibility of acting on them will be defined.

The necessary power for the propulsion of the vessels depends on its total resistance R_t and speed $\boldsymbol{v}$ according to[7,21]

Table 6. Contributions from the controllable variables to the variances for trawlers.

Controllable variable	Contribution (%) from the controllable variable to the variance for the following			
	Proposed coastal trawler	Current coastal trawler	Proposed trawler	Current trawler
Building cost of vessel	90.10	90.90	68.00	70.50
Fuel consumption when trawling	4.50	3.60	28.70	26.10
Fuel consumption during voyage	4.10	3.80	2.20	1.90
Residual value of vessel	1.20	1.70	0.70	1.00

Table 7. Contributions from the controllable variables to the variances for longliners.

Controllable variable	Contribution (%) from the controllable variable to the variance for the following	
	Proposed longliner	Current longliner
Building cost of vessel	69.80	71.60
Fuel consumption during voyage	13.90	11.20
Fuel consumption when picking up	14.10	15.20
Fuel consumption when letting out	1.30	0.90
Residual value of vessel	1.00	1.10

Table 8. Feasible improvements in terms of the percentages of the IRRs for the proposed vessels.

Kind of vessel	Improvement (% current IRR)
Coastal trawler	20.25
Trawler	28.33
Longliner	74.77

$$\mathrm{EHP} = \boldsymbol{\nu} R_t$$

The total ship resistance consists of the wave resistance R_w and the viscous resistance R_v, according to

$$R_t = R_w + R_v$$

Both R_w and R_v are mainly dependent on the speed,[21,22] as given by

$$R_w = k\left[\frac{v}{(gL)^{0.5}}\right]^4 \frac{1}{2}\rho s v^2$$

$$R_v = r\frac{0.075}{\{\log[v(L/\nu)] - 2\}^2}\frac{1}{2}\rho s v^2$$

At low speeds, the most important resistance component is the viscous resistance R_v. At higher speeds, the dominant resistance component is the wave resistance R_w, mainly depending on the speed. In the case of trawlers in the fishing condition, the net resistance depends on the net parameters and also on the speed; this has to be added to the total resistance.

Up to this point, the speed has been taken to be constant; the reduction in the fuel consumption has only been due to the reduction in the resistance, which implies smaller ship dimensions (smaller length and smaller wetted surface).

As the resistance is also greatly dependent on the ship speed, fuel consumption savings were very small. Otherwise, if the speed is reduced, larger fuel savings could be achieved, as the reduction in the resistance would also be much larger. This alternative will be proposed in the next few paragraphs.

If Table 1 is considered, in trawlers, trawling is the more time-demanding condition. However, the trawling speed is defined by performance of the fishing method and so it was kept constant.

In the case of longliners, they spend half of the total trip time picking up at low speeds; in this case, the reduction in the fuel consumption due to the reduction in the speed will not be very significant, while the new vessels have a great advantage because of their smaller dimensions, which mean lower power needs.

According to Figures 1 and 2, concerning the evolution of the service speed and the volume of catches for the last few years, it can be assumed that in a speed range between 7 kn and 12 kn for the transfer voyage, the available fishing time is sufficient to maintain the catch capacity of the vessels per trip. On the other hand, reduction in the speed at higher speeds means large reductions in the fuel consumption (Figure 7).

Therefore, the proposed new operational features for the fleet (Table 9) are based on a reduction in the speed of 2 kn for the transfer voyage in all types of ship and reductions in the speed of 1 kn for the letting-out condition and of 0.7 kn for the picking-up condition in longliners.

In this new operational scenario, the fuel consumptions (of the main and the auxiliary engines) were obtained from real data on vessels with the dimensions shown in Table 4 sailing at the proposed speeds.

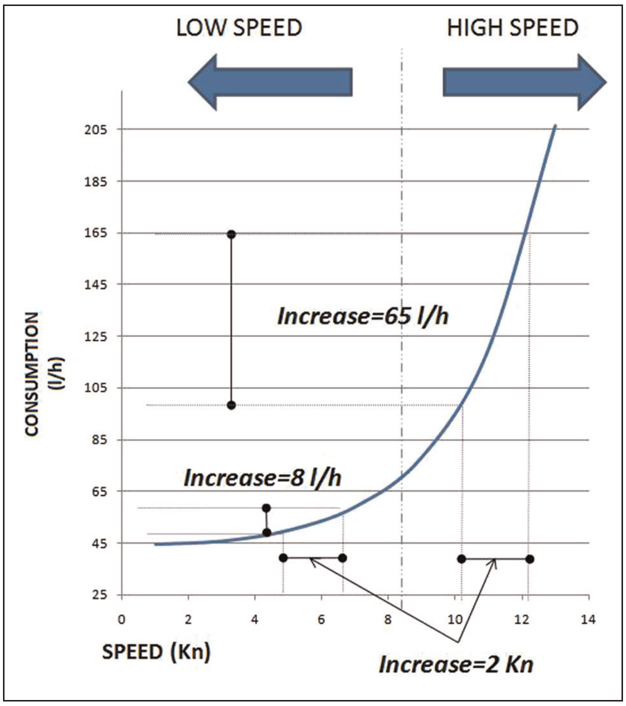


Figure 7. Increase in the propulsive power for a current trawler.

The feasibility models for the ships were adapted and the simulation results compared in terms of percentages of the IRR with the previous results of the current fleet (Table 10).

In comparison with the improvements in the IRR due to the proposed new vessels, the economic advantages shown in Table 10 are just significant for the longliners. This effect in longliners is due to the large fuel reduction during 37% of the trip and the great importance of this variable in the economical results for this kind of ship.

As a consequence of the conclusions obtained in the previous analysis, new vessels with the new dimensions and the new operational features will be studied. This last analysis will allow determination of the total improvement that could have been obtained by the vessel investors during the last few years.

The comparison in terms of improvement in the IRR with respect to the current values is shown in Table 11, where the largest improvement is for the vessel which is most dependent on the controllable variables (see Table 3).

In spite of the fact that the influences of these controllable parameters are very small in comparison with the influences of the non-controllable variables, great improvements can be obtained if they are sufficiently reduced.

In the case of the longliner, with this last alternative the IRR obtained would be nearly twice the current IRR.

Table 9. Operational features of the fishing vessels per type of ship with speed reductions.

Operating conditions	Percentage of the trip in time	Speed (kn)
Coastal trawler in tandem (22.5 h per trip)		
Transfer voyage	36.35	7.0
Letting out	6.13	2.0
Picking up	4.13	1.5
Trawling	53.33	2.0
Trawler (18 days per trip)		
Transfer voyage	15.61	9.0
Letting out	7.30	2.0
Picking up	7.30	1.5
Trawling	65.12	2.0
Standing by	4.67	≈ 0
Longliner (18 days per trip)		
Transfer voyage	21.39	9.0
Letting out	12.11	7.0
Picking up	52.06	1.0
Standing by	14.44	≈ 0

Table 10. Feasible improvements in terms of the percentages of the IRRs for the proposed operational features.

Type of vessel	Improvement (% current IRR)
Coastal trawler	1.61
Trawler	3.74
Longliner	36.37

Conclusions

It can be concluded that the majority of the current vessels are too large for the activity that they are performing and that they were designed in order to be as versatile as possible.

After modelling the feasibilities of current vessels for 7 years (from 2001 to 2008) and considering their operational conditions and the environmental variables, it can be concluded that the parameters which have the most influence on their profitability are the catches per trip and the fish price and that the total effect of the controllable parameters on the economical results is very low (between 1 and 3.6%). Among these controllable parameters, the building cost and the fuel consumption for propulsion are the most important inputs.

The expectations about the influence of the fuel price were not confirmed, as it was found that the fuel price had a very small effect on the economic results in comparison with other variables.

The vessel most dependent on the market is the coastal trawler and the least dependent is the longliner. This means that the longliner has the largest range for improvement. For these reasons, the longliner obtained the best results with the proposed reduction in dimensions and operational modifications.

Table 11. Feasible improvements in terms of the percentages of the IRRs for the proposed vessels and operational features.

Type of vessel	Improvement (% current IRR)
Coastal trawler	20.54
Trawler	30.37
Longliner	99.31

According to the results obtained, the feasibilities of the proposed smaller vessels are less dependent on the controllable parameters than are the current vessels and, therefore, the profitabilities of the fishing activity with these vessels will be more sensitive to the market.

The dimensional reduction has affected the profitabilities of vessels mainly through the reduction in the building cost. In particular for trawlers, this meant very low fuel savings due to the reduction in the wet surface.

In spite of their low impacts on the sensitivity analysis compared with other inputs, the proposed new vessels have led to improvements of up to 74.77% in the initial IRR for the longliners. In the case of the new operational features, the longliner would improve, by a factor of nearly 2, its current IRR (from an IRR of 13% to an IRR of 25% in absolute terms).

It is important to highlight that, despite the fact that only moderate improvements were obtained as a result of the modified speeds of the current vessels, this does not need any investment.

In addition to this, the information in Table 10 will be very useful to evaluate the feasibilities of the current vessels, as it shows the percentage of the current interest rate that was lost by an investor because the service speed had not been reduced during the last few years. In absolute terms, in the case of longliners, the lost IRR would be 4.6%.

Finally, it has to be highlighted that all the alternatives considered are based on operating ships; considerations in terms of ship stability or safety of fishermen at sea were not taken into account. These factors are regulated by the Spanish Maritime Administration. Keeping alternative sizes between the the considered limits permits safety and security effects to be neglected.

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Appendix

Notation

B	breadth
CF_0	initial cash flow
CF_n	cash flow in the nth year

D	draught
EHP	effective horse power
EU	European Union
g	acceleration due to gravity
i	annual interest rate
IRR	internal rate return
k	slenderness constant for wave resistance ($0 \leqslant k \leqslant 1.0$)
L	overall length
L_{pp}	length between the perpendiculars
n	number of years considered in the model = 7
NPV	net present value
r	slenderness constant for viscous resistance ($1 \leqslant r \leqslant 1.6$)
R_{t}	total resistance
R_{v}	viscous resistance
R_{w}	wave resistance
s	wet surface of the vessel
TAC	total allowable catch
v	speed
$\nu = \mu/\rho$	kinematic viscosity coefficient
ρ	water density