Design of an electric ferry for 260 passengers and 19 cars destined for Aveiro Port in Portugal

By: *Kevin Santiago Oña Rojas & Lissette Margarita Tenesaca Mendoza, January 2020*
Advisor: *Hugo José Jama Aveiga, Ing.*

SUMMARY

More than 90% of world trade is carried out by sea through some 90,000 ships. These use fossil fuels, emitting carbon dioxide, one of the main greenhouse gases, which contributes significantly to climate change, and maritime transport also continues to grow. Puerto Aveiro is the connection point between Sao Jacinto and Fort Da Barra, here the Cale de Aveiro ferry is operating, with more than 50 years of construction of a ship that uses fossil fuels. Portugal wants to join the environmental awareness campaign and requires reducing carbon dioxide emissions in this form of transport. The general scope of this work is to design an electric ferry for the transportation of passengers and cars by complying with the requirements of the shipowner, rules of the Classification Society and other regulations for sailing in said area of Portugal; achieving this through the identification of the shipowner's requirements for the development of the conceptual and preliminary design stages of the vessel, implementing solar energy with the use of panels to obtain design improvements and with the estimation of costs of design -construction, preventive maintenance and operation of the ship, leading to the appropriate decision-making by the owner.

Within the process the design spiral concept is used, which is a series of parameters for the number of stages required by the designer. In this work, three stages were considered, for which the conceptual and preliminary stage are the first two where their respective results were obtained, but using another return to the spiral, the product of this work is finally reflected with the improved stage.

Main features

Length overall	36.52 [m]
Moulded breadth	9.60 [m]
Depth to main deck	2.73 [m]
Design draft	1.50 [m]
Speed	9 [kn]

The design of an electric ferry of 36.52 [m] in length, 9.60 [m] in breadth, 2.73 [m] in depth, 1.50 [m] in draft and 9 [knots] in design speed is proposed. Within its shape and accommodation, it is for 260 passengers and 19 cars, being the double ended form where both bow and stern are the same. It has 3 [tons] for freshwater tanks, 3 [tons] for gray / black water tanks and 114 [tons] for ballast tanks. In addition, its total electrical consumption is 1241.50 [kWh], with 191 lithium-ion batteries intended for different consumer groups such as machinery, propulsion system, communication and navigation equipment. On the other hand, for the lighting system, solar energy is available, having 40 panels located on the bridge deck, 96.28 [m^2] of which is its occupied area.

Within the complements, the approach was arranged in two groups. The first is for the mooring and anchoring system, for which calculating its equipment number equal to 135, equipment such as anchor and chain, winch, bollards and Panama chocks were selected. The second is for the analysis of seakeeping, despite the fact that the ship does not sail in turbulent waters, its study was required in case this experienced a sea state 4, being their analysis points at the bow end and on the bridge, resulting in passengers experiencing dizziness after 2 hours of sailing at the bow end of the main deck; this means that the ship is suitable since our maximum navigation period will be 15 [minutes].

Putting all this together, one can speak of an investment, for which four analysis scenarios were proposed, these are, stage 1 is when the ship operates only with electrical energy, stage 2 is when the vessel operates with electrical energy and solar energy , stage 3 is when the ship operates with fossil fuels and stage 4 is when the ship operates with fossil fuels and electric power. For the initial investment, the design and construction cost of the fixed assets, indirect costs of the shipyard and working capital were considered, with the result that for the different stages the investment is for; stage 1 is $ 4.5 millions, stage 2

is $ 5.3 millions, stage 3 is $ 4.4 millions and stage 4 is $ 4 millions. At first glance, stage 2 is more expensive than the other two scenarios, however this cost analysis is also reflected by preventive maintenance and operation costs, for which stage 2 has costs of $ 83 thousand and $ 2.1 millions respectively, while stage 3 has costs of $ 95 thousand and $ 2.2 millions respectively, it means that the costs of stage 2 are reduced compared to the others presented. On the other hand, for the feasibility analysis, four project selection criteria were considered, being the net present value (NPV), the internal rate of return (IRR), the period of capital recovery (PRC) and the profitability index (GO); where stages 3 and 4 were rejected for presenting a negative VPN, and stage 2 was chosen over 1 since this, in addition to meeting the criteria, also the sustainability pillars influence their selection.

Finally, for the sensitivity analysis, in different circumstances where the ship could be affected by a malfunction or enter the dock, three cases were analyzed where the results are that case 1 will have 20 optimal daily trips for the project to be profitable, case 2 will have 67% of optimal minimum passengers per year for which the project is accepted and case 3 where the ship would be affected if it were to have competition from a private company and its number of trips is reduced by half then, also the project would be profitable.

	Stage 1: Batteries	Stage 2: Batteries + Solar panels	Stage 3: Fossil fuels	Stage 4: Fossil fuels + Batteries
NPV	$ 3.147.609,46	$ 1.430.938,63	$ (3.468.610,36)	$ (3.585.966,70)
IRR	25,39%	20,95%	-	-
PRC	5,5 years	7,5 years	More than 10 years	More than 10 years
IR	1,7	1,27	0,22	0,12

In conclusion, the design of an electric ferry has been developed in compliance with the requirements of the shipowner, rules of the Classification Society and other regulations for sailing in the Puerto Aveiro area in Portugal, obtaining calculation notebooks and plans necessary to demonstrate validity in the design; the use of solar energy by means of panels destined for the ship's lighting system was also implemented, achieving compliance with the three pillars of sustainability, and finally, the feasibility analysis of the project was carried out by proposing four scenarios, the scenario being the use of electricity and solar energy the most profitable, since it has a high initial investment but its preventive maintenance and operation costs are cheaper than a conventional ship.

Key Words: Design spiral, ferry, lithium ion batteries, sustainability.