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Break-even analysis in engineering projects: the case of a new technology application

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Abstract

When it comes to making an investment to improve an existing technology, the breakeven point as well as the project lifecycle must be verified. The case of Colombian Navy riverine vessels allowed evaluating whether it was worthwhile to reduce the weight of the armor, in order to reduce the high costs of fuel consumption. The uniqueness of the research lies in the use of an engineering computational tool combined with a statistical analysis of the vessels navigation, in order to quantify the variable costs. With this objective criterion was done a breakeven analysis and evaluated the investment decision.

Keywords
Break-even analysis, fixed costs, variable costs, break-even point.

1. Introduction
There has been a discussion about the feasibility of improving the armor system of Colombian Navy riverine vessels. The current armor is considered too heavy and could be reduced to save fuel. This armor is a design of James Osorio Shipyard, which is a kind of sandwich made of two common naval steel A131 sheets, ¼" and 3/16" thick, with two inches of polyurethane between them (combined armor). The suggested armor is provided by Cotecmar shipyard, which consists in a single ballistic steel sheet, 3/16" thick and 50 Rockwell C of hardness (certified armor).

The current armor is twice the weight of the certified armor. It is supposed that the weight reduction will diminish the fuel consumption significantly, but the problem is to find a proper way to calculate how much this reduction is going to be. Furthermore, it is required to calculate how much the armor changing will cost. Having this information is possible to determine when the investment will begin to yield profit, and compare this time against the vessel's life cycle. The model applied is useful in any investment decision making process, especially in an engineering project.

Each shipyard is focused on a different competitive advantage. Cotecmar focuses on product differentiation. It has a world-class infrastructure that allows them to install a high quality ballistic steel [1]. James Osorio Shipyard is focused on low cost. It has developed a supply chain that enables to offer a reliable and low cost product. However the combined armor means more fuel consumption, less space and a rise of the center of gravity of the vessel [2].

There have been different ballistic tests utilizing both products [3], which have demonstrated the reliability of the systems. The results of these tests would suggest the use of the combined armor, supported on low costs. However, the operational costs need to be taken into account. The escalation of fuel prices and the tendency to reduce carbon dioxide emissions accentuates the importance of similar studies, finding a balance between environmental and economic aspects [4-7]. This paper presents a new model of variable costs calculation, combining a well-proven naval computational tool, used by the US Navy [8], with a statistical analysis of these vessels fuel consumption.

2. Literature review
The break-even analysis is a very useful tool for a good estimation for return on investment. Its goal is to find the point, in this case in terms of dollars and units, where investment costs equates profits. Above this point the business begins to obtain profitability [9]. Managerial decisions require a careful analysis of the behavior of costs and profits.

In these cases the break-even linear model is widely used. Both revenue and total costs are assumed to be linear in this model, i.e. the price and the variable cost per unit are constants. The uncertainty is considered implicit [10].

Jaedicke and Robichek (1964) introduced uncertainty explicitly into the linear model. This extension of the basic model makes it possible to draw more precise conclusions when the probability distributions are known. Several authors have later extended the theory. However, the extension of the uncertainty inclusion has not reduced the usefulness of the basic linear model itself [10].

The break-even analysis is an economic concept currently used in many fields. As an example, it has been used in health business to optimize the service in orthodontic practice in North Carolina, to predict the future financial potential of pharmacy business in Nebraska, to calculate variable costs of telemedicine consultation in Canada and to evaluate the feasibility and managing daily operations of an ambulatory center in Texas [11-14].

In an engineering project, the break-even analysis was used to decide the optimal distance when the hybrid energy system is more economical than the extension of electric power transmission lines in the north of Turkey. This study pioneered the use of break-even analysis applied to hybrid energy use, furthermore introduced an optimization for defining costs and deciding on the better project option between installing the hybrid energy system or the expansion of the transmission line [15].

Nowadays the break-even analysis is considered one of the most useful analytical tools utilized in real-world business decision making. In some academic fields scientists are trying to add a stochastic linear demand function, which predicts more accurately, but is less suitable for real applications, like the described in the previous references [16].

These studies have shown the usefulness of break-even analysis in engineering projects. For that reason, this tool was selected to determine the best proposal between combined and certified armor, which require the proper estimation of fixed and variable costs discussed below.

3. Methodology of break-even analysis

3.1. Method to decide the best option
The method to decide which armor type is the best option encompasses three steps:

1. Establish the difference of installation costs in monetary terms. The vessel studied was a "light riverine patrol vessel" that has previous studies and a deep knowledge of its characteristics, as well as the necessary calculations of weight and fuel consumption [2].
2. Establish, in terms of time, the break-even point for the installation costs. There are three options:
   a. Never.
   b. Short term, armor changing worthwhile.
   c. Long term, armor changing not worthwhile.

Note: This type of vessels has a fifty years life cycle. Nowadays the vessels have twenty years of use. Therefore, from the thirty remaining years, this study established a period of ten years remaining as the criterion for the minimum period acceptable prior to armor changing.

3. Determine the best option based on the results.

3.2. Fixed costs.
Fixed costs are defined as those costs that remain constant independent of production [9]. In the study these costs are referred as installation costs of the certified armor instead of the current combined armor. Within these costs underlies an important difference between combined and certified armor, which defines the initial point. A square meter of certified armor installed by Cotecmar weights 37,5 kilograms and costs USD$20 per kilogram installed [2], for a fixed cost of USD$750 per square meter. The same area with combined armor costs USD$350 installed. Considering the complete shielded area in a riverine patrol vessel is 203 square meters [2], the fixed costs result in USD$71.050 for the combined armor and USD$152.250 for the certified armor, a difference of USD$81.200.

The weight of the combined armor was calculated as follows: The polyurethane, once mixed and added, has a density of 1.200 kg/m^3. Considering the thickness of this layer is 2 inches (51 x 10^{-3} m), the weight is 61,2 kilograms per square meter. A naval steel sheet A131, thickness ¼”, 79 Rockwell B hardness [17], has a weight of 50,5 kg/m^2. The same sheet, but with a 3/16” thickness has a weight of 37,5 kg/m^2. These weights are listed in the table below.

Table 1. Specific weights for combined armor

Weight of steel ¼” (1 sheet)	50,5 kg/m^2
Weight of steel 3/16” (1 sheet)	37,5 kg/m^2
Weight of polyurethane (2 inches)	61,2 kg/m^2
Overall armor weight	149,2 kg/m^2

In the other hand, the certified steel used by Cotecmar, 3/16” ballistic steel, 50 Rockwell C hardness, has a specific weight of 37,5 Kg/m^2, i.e., four times less than the combined armor assembly. In a riverine patrol vessel this means that the shielded part using combined armor currently weighing 12 tons, would weigh only 3 tons using certified armor. If the weight of a soldier with his complete equipment is about 130 kilograms, the 9 tons of difference equals to the weight of 70 troops [2]. Likewise, the exchange of the armor type would provide five square meters of additional space for cargo, which in a small vessel could be important space.

This could mean that although the installation costs of certified armor are more than twice the combined armor, these costs are offset by the certified security and the remarkable improvement in vessel stability. Likewise, it is noticeable that the use of combined armor causes lower capacity and higher fuel consumption. This fuel consumption is the determining factor for variable costs for break-even analysis.

3.3. Variable costs

The variable costs are those that vary according the volume of units produced [9]. In this study, these costs correspond to the hours the ship sails in terms of fuel consumption, which are also known as operational costs. The objective data comes from the analysis of the monthly statistical reports produced by the riverine patrol vessels, allowing the determination of the average fuel consumption. To determine the necessary data required for the projection of 20 years of fuel consumption of a riverine patrol vessel, a three step procedure was established.

1. The statistical information of fuel consumption over the last two years was obtained and used for the projection.
2. Second, a computational tool of naval engineering was used to do the necessary calculation of the fuel consumption for the riverine patrol vessel in terms of gallons per hour.
3. A second run was done using the same software but reducing the nine tons of extra weight, in order to establish the reduction of fuel consumption.

3.3.1. Statistical data

The statistical information was obtained for a riverine patrol vessel for two years and is presented in the table.

Table 2. Monthly consumption and semiannual average fuel consumption in liters per month

Jul-07	6.810	Jan-08	8.857	Jul-08	5.935	Jan-09	967
Aug-07	9.705	Feb-08	3.331	Aug-08	7.304	Feb-09	7.096
Sep-07	4.578	Mar-08	9.265	Sep-08	345	Mar-09	6.677
Oct-07	5.804	Apr-08	8.100	Oct-08	4.335	Apr-09	8.023
Nov-07	3.489	May-08	10.502	Nov-08	5.765	May-09	8.010
Dec-07	809	Jun-08	6.800	Dec-08	3.951	Jun-09	12.605
Average 1	5.183,33	Average 2	7.808,83	Average 3	4.605,83	Average 4	7.231,83

Averaging the information in the table was found that the monthly fuel consumption for a riverine patrol vessel is 6.207,46 liters per month, which is equal to 1.640 gallons per month.
Note: The big variations in fuel consumptions between different months are related with the minimum required depth of the river for navigation.

3.3.2. Specialized Software

The software NAVCAD is a well-proven computational tool, widely used by universities and institutions related with naval engineering, especially for resistance prediction and power plant design and evaluation [8]. In this paper, the software was used to calculate the vessel's fuel consumption, once the vessel's main characteristics are entered into the program. Since the same software had been used for a previous study of the riverine patrols vessels, this information was available for use [2]. Considering the total weight of the ship is 159,65 tons (full load displacement), using combined armor, the fuel consumption was estimated at 6,25 gallons per hour.

3.3.3. Second Run

Nine tons were reduced from full load displacement, obtaining a new total weight of 150,65 tons. Then, the fuel consumption was recalculated, obtaining 5,8 gallons per hour when modeling the vessel using certified armor. It must be noticed that a variation of nine tons equates to six percent of the full load displacement of a 150 ton vessel.

4. Results

Utilizing the already known monthly average fuel consumption of a riverine patrol vessel with the current combined armor, it was possible to obtain a reduction factor from the calculation done for fuel consumption in gallons per hour, when comparing both combined and certified armor:

Fuel consumption (combined armor): 6,25 gph
Fuel consumption (certified armor): 5,8 gph
Reduction factor due to certified armor = 5,8 gph / 6,25 gph = 0,928

According to the reduction factor calculated, the monthly fuel consumption using certified armor would be: 1.640 gph x 0,928 = 1.522 gph. Expressing this in gallons per year would result in 19.680 gallons per year with combined armor and 18.624 with certified armor. With the information processed in terms of annual fuel consumption is possible to produce a graph in terms of years for the x-axis and thousands of gallons for the y-axis.

However, as the difference must be expressed in monetary terms, data regarding fuel cost must be inserted. The price of a gallon of fuel in the operational area of the riverine patrols is about USD$4 per gallon. According to the above and to graph the results in terms of the cost of the product, the difference in installation costs ($81.200) is divided by the price per gallon ($4), yielding a result of 20.300 gallons, which in turn accounts for the initial value of the y-axis in the certified armor line when x-axis is zero. With the complete information, the break-analysis graphics in terms of product costs and fuel consumption could be done.

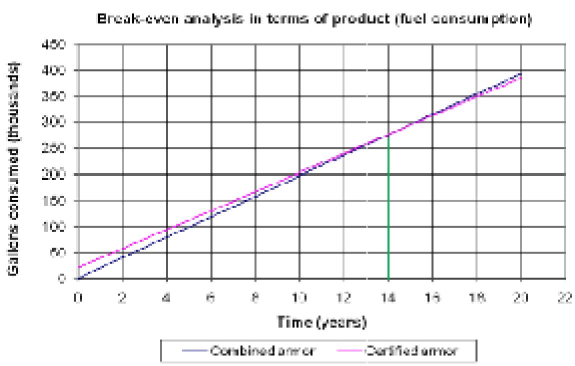

Fig. 3. Break even analysis based on fuel consumption

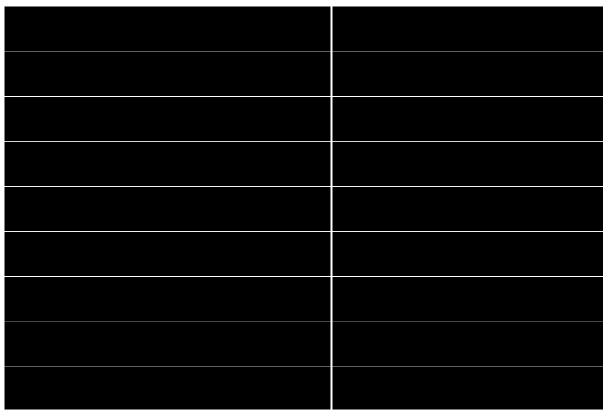

Fig. 4. Break even analysis based on money spent in fuel

5. Discussion

The two graphics presented, based on fuel consumption and based on costs spent on fuel, showed that the break-even point is in fourteen years. This period of time exceeds in four years the ten year minimum criteria adopted in the methodology as the cutoff point, indicating that investing in the change of the combined armor by certified armor is not worthwhile.

There are some additional costs encompassed in the change into new technology that would require other investments, not figured into the costs calculations, like the training required for welders to join commercial steel with armored steel and the losses due to the less cargo capacity of the ship using the combined armor.
These costs related above are minor decisions that would be worth if the break-even point would near the limit of ten years established as the decision criterion. In this case it would be necessary to add other minor costs in the equation to make a final decision.

5. Conclusions

The new model of variable costs calculation, combining the naval computational tool with the statistical analysis of vessel's fuel consumption was useful and reliable for break-even analysis.

A new technology application can seem favorable and can have advantages over a current one, but the break-even analysis is required to have an objective criterion for decision making investment.

The knowledge of the engineering project life-cycle is a critical factor, because it determines the criterion to be evaluated during the break-even analysis.

For future research, some questions remain unsolved: How does the end user perceive the differences between the combined and the certified armor? How can this perception be valued? How many man-hours cost does one option weigh against the other? Does using certified armor extend the lifecycle of the vessel and if so should a new time criteria be established?

Finally, these questions show that decision making may be increasingly complicated, but using a practical and reliable tool as the break-even analysis, helps decisions to be objectively made based on the most relevant factors.

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