ANALYSIS AND EVALUATION OF ALTERNATIVES FOR FLUVIAL SURVEILLANCE BY THE COLOMBIAN NAVY

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ABSTRACT

This work developed a general methodology and support models for the analysis and evaluation of alternatives for fluvial surveillance in Colombia by the Colombian Navy. In the application of the methodology two models were developed, an economic evaluation model, and an Analytic Hierarchy Process model, that interact to achieve the main objective. Based on the results of the analysis a specific recommendation was formulated to the Navy.

Keywords: analytic hierarchy process, economic project evaluation, fluvial surveillance

Introduction

Fluvial surveillance is a major issue for the Colombian national security. The Colombian National Navy has to guarantee the fluvial control of the country, which is influenced by environmental and economical factors, among others.

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This paper presents a synthesis of the consultancy given by Universidad de los Andes to the National Army in the structuring and analysis of the best option for Fluvial Strengthening using a structured Decision Analysis methodology. The interdisciplinary team conformed established the main aspects of the problem, and defined the relevant variables, the stakeholders, the evaluation criteria and the decision variables. This allowed the decision alternatives definition and their later evaluation. Figure 1 presents the decision analysis methodology proposed by Castillo (Castillo, 2008), which was used in the structuring and analysis of the problem.

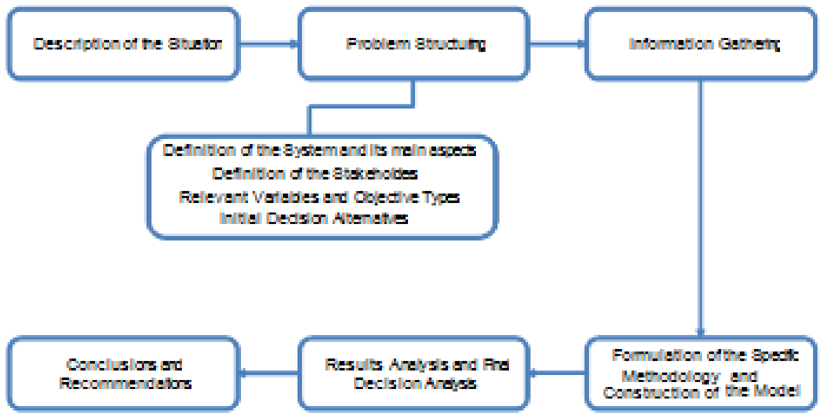

Figure 1. Decision Analysis Methodology

Problem Description

In the recent years, the National Navy had identified the need of strengthening the fluvial control through the improvement of the capacity of its current force, achieving an increase in the coverage, the availability and the frequency of the fluvial control, as well as an efficient logistic support to the rural population. Currently, a partial coverage of 18.000 km of navigable rivers is achieved. The Navy aims to contribute with the defense and security of the Nation through the effective use of the fluvial military power in the navigable zones. The Brigades currently have River Combat Elements (Spanish acronym E.C.F.) that although are characterized by their speed, maneuverability and firepower, are negatively affected by hydrographic factors that limit its navigation capability in the summer seasons, causing a reduction in the fluvial control. Additionally these elements generate high operational and maintenance costs, and, because of its structure, are vulnerable to attacks. Because of this it was deemed relevant to perform a formal evaluation of the alternatives for replacing the fleet, taking into account several criteria.

Problem Structuring

3.1 Main Aspects

The following aspects were taken into account for the analysis of the problem, the construction of the model and the evaluation of the alternatives. **Technical:** operational characteristics of the means to be used for the fluvial control; **Tactical:** need to adapt the fluvial operations doctrine regarding the use of the means for undertaking offensive operations; **Economical:** Issues related with the capital investment, the operational and maintenance costs, as well as the economical performance measures; **Mission:** capability to increase the fluvial coverage and availability aiming to fulfill the Institutional Mission; **Logistic:** infrastructure, capacity and necessary technical support for the proper use of the resources; **Social:**

capability of the resources to be used to guarantee the continuous logistic support to the riverside populations and it access to the river; **Environmental:** potential environmental impact generated by the different resources; **Geographical Conditions:** geographical characteristics of each one of the river basins where operations are conducted.

3.2 Relevant Variables

The main variables identified were: Load capacity of the resources, Firepower, Speed, Maneuverability, Adaptability, Availability facing changing conditions due to the navigability conditions of the rivers, Investments, Operational and maintenance costs, and other costs of implementation, Coverage level, Autonomy level, Security and armor level, and Adaptability and flexibility regarding the accomplishment of different types of missions.

3.3 Decision Variables

The decision variables identified for the alternatives definition were: **Type of Fluvial Resource**, regarding the fluvial resource to be used, considering: element type 1, type 2, type 3 and type 4. The **Amount of Fluvial Resources** and the **Entrance Time**, regarding the amount of resources to be acquired and the moment of their acquisition.

3.4 Decision alternatives definition

Based on the decision variables, and after establishing the composition of the elements, the initial alternatives were built. It is important to highlight that the alternatives did not consider a total replacement of the current elements; the work team of the Navy decided to consider a replacement of 50% of the elements in the horizon of the study. Because of this, the alternatives were constituted by a mix of elements and this was taken into account in their evaluation. The Navy team defined the alternatives A1, B1, C1, D1, A2, B2 and D2 (A and D-Hovercrafts Combinations, B-Waterjets, C-Current Boats). The alternatives A1, B1 and D1 correspond to the inclusion of type 1, type 2 and type 4 elements, respectively, with a slow rate of acquisitions of the new elements. The alternatives A2, B2 and D2 correspond to inclusion of the same type of elements, but with an accelerated rate of acquisitions. Finally the, C1 alternative conserves the current elements, therefore its costs are only related to its operational costs. Table 1 presents the structure of a generic alternative.

Table 1. Alternative A1 – Element Type 1

Element Type 1 (A1)												
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Element Type 1	In		2	4	4	4	4	3	3	3	3	2
	Total	0	2	6	10	14	18	21	24	27	30	32
Element Type 2	In		0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0
Element Type 3	In		0	0	0	0	0	0	0	0	0	0
	Out		2	4	4	4	4	3	3	3	3	2
	Total	64	62	58	54	50	46	43	40	37	34	32
Element Type 4	In		0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0
Total of Elements		64	64	64	64	64	64	64	64	64	64	64

3.5 Decision Criteria

The decision criteria defined by the team for the evaluation of the different alternatives were:

Social: capacity of the different alternatives to guarantee the continuous logistic support to the riverside communities, including their access to the river.

Environmental: level of contribution to the protection of the environment of the different alternatives.

Technical: takes into account four sub criteria.

Autonomy: Considers the navigable time without replenishment for each alternative; **Security Level:** capacity of crew protection offered. Likewise, it refers to the accident levels implicit in the operation of the resources considered; **Maintainability:** factors like the post-sale service, the knowledge of the use of the technology, the infrastructure and the training needed; **Operational Experience:** degree of experience in the military use of each alternative.

Mission: takes into account two sub criteria.

Coverage and Navigability during the year: amount of navigable kilometers and proportion of time during the year that is possible to navigate; **Operational Flexibility:** capability to accomplish different missions, including offshore operations.

Economical (Costs): everything related with the capital investment, the operational and maintenance costs, and the measures of economical performance.

Methodology for the alternative analysis

The specific steps of the methodology for the analysis and selection of the best alternative are:

Step 1: Economic Evaluation of the Alternatives – Deterministic Model

A spreadsheet is built with the relevant economical information of each one of the alternatives.

Step 2: Economic Evaluation and Sensitivity Analysis – Probabilistic Model

Based on the deterministic model made, a probabilistic model should be incorporated into the analysis if necessary.

Step 3: Final Alternatives Selection to be Evaluated with the Multiattribute Model

Selection of the alternatives based on the results of the deterministic and the probabilistic model

Step 4: Global Evaluation of the Alternatives Using AHP – Workshop Multiattribute Model

Using the alternatives evaluation criteria, a multiattribute decision model is built and the final evaluation of the alternatives is made.

Economic Evaluation

5.1. Description of the model

The economic model is built on a parameterized spreadsheet that considers the variables and technical-operational parameters, among others. It contains an economical balance for each alternative that calculates the present value of the cost.

5.2 Results and Sensitivity Analysis of the Deterministic Model

The results of the economical evaluation of the seven alternatives are summarized in Table 2.

Table 2. Present Value of the Costs – Alternatives[1]

Alternative	Name	PV Cost (MU$)	Investment (MU$)
Element Type 1	**A1**	222.88	54.96
Element Type 2	**B1**	237.84	52.56
Element Type 3	**C1**	185.04	---
Element Type 4	**D1**	275.28	86.16
Element Type 1-2	**A2**	226.24	65.6
Element Type 2-2	**B2**	248.88	62.72
Element Type 4-2	**D2**	294.32	102.96

The alternative with the lower cost is C1 (Type 3) and the one with the higher cost is D2 (Type 4 – Accelerated Rate of Purchase). The difference among the costs of these two alternatives is approximately 137 MU$. Those alternatives that consider an accelerated rate of purchase present higher costs than those corresponding to the non accelerated purchase rate. Based in these results the sensitivity analysis was made.

[1] These are not the real calculated costs due to confidentiality reasons. Although the proportional relations are maintained

5.3 Probabilistic Model
According to the results of the sensitivity analysis, it became evident that there were not changes in the order (ranking) of the alternatives. Therefore no probabilistic model was built.

5.4 Selection of the final alternatives to be evaluated with the Multiattribute Model
After the economical analysis concluded, the team of the Navy decided to consider a final evaluation of the alternatives A1, B1 and C1 using the multiattribute model (AHP).

Multiattribute Model

6.1 Description of the Multiattribute Model
Based on the decision criteria defined by the team, a multiattribute model was built (AHP), which was used to perform a structured evaluation of the final alternatives (A1, B1 and C1). The model built has two hierarchies, one corresponding to Benefits, and the other corresponding to Costs, as shown in Figure 2.

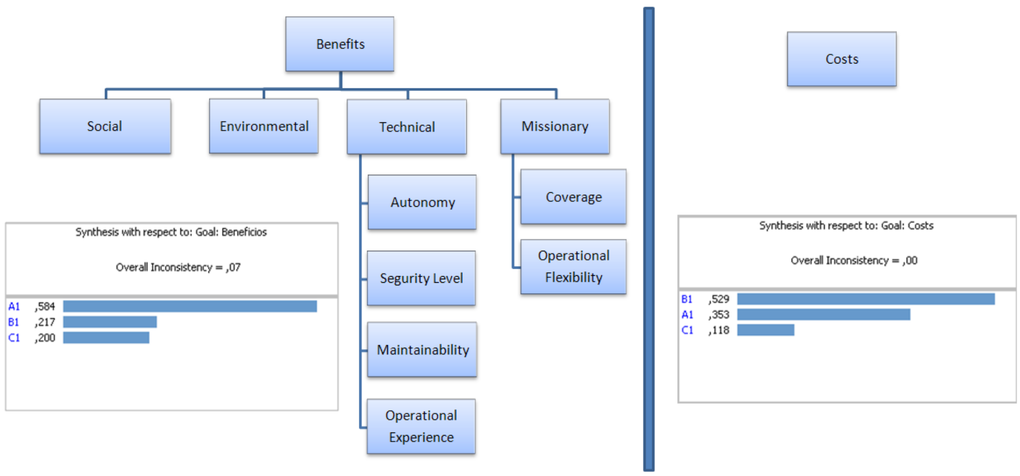

Figure 2. Hierarchies – Multiattribute Model and Results

In order to evaluate the alternatives using AHP, a five hour workshop was done with a group of 9 officers and experts from different areas. For the mathematical evaluation the team used Expert Choice 11.5. Figure 2 summaries the alternatives behavior regarding each hierarchy, where the alternative with more benefits is A1 with a weight of 0.584, while the most expensive B1 with a weight of 0.529. The final evaluation of the alternatives was calculated taking into account its behavior regarding the **Benefits** and the **Costs**. The global performance was calculated using the negative additive formula proposed by Saaty (Saaty, 2005). Figure 3 presents the global performance index for different values assigned to the benefits and the costs.

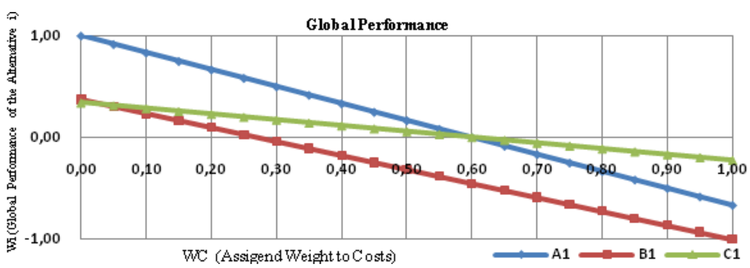

Figure 3. Sensitivity Analysis of the Global Performance of the Alternatives

Given the nature of the project and aiming to fulfill the institutional mission of the National Navy, the weights for the **Benefits** and the **Costs** should be assigned by the relevant decision makers inside the Navy. Once these weights are defined, is possible to calculate the global performance of each of the alternatives. As an example, if a weight of 0.3 is assigned to the costs, the selected alternative would be A1, followed by C1 and B1.

Conclusions

Regarding the Multiattribute Model

1. The alternative that presented the best behavior in Benefits was A1, due to its excellent performance in three of the four criterions, while C1 presented the best behavior in the Costs hierarchy. The global performance of B1 is dominated by the two other alternatives, independently of the weights assigned to the hierarchies.
2. As a final balance of the result of the analysis of the AHP model, A1 presented strengths regarding coverage, operational flexibility, security level and social aspect (humanitarian aid). Whereas C1 presented strengths regarding the maintenance and the costs. If a broader study horizon was considered, the differences in costs between these alternatives would tend to be lower.

General Conclusions and Final Recommendations

3. This study represents a significant contribution in the decision process faced by the Navy, considering that five out of the seven alternatives initially contemplated were discarded based on the analysis performed using the methodology. The selection between the two final alternatives will depend on the weights of the Costs and Benefits hierarchies.
4. The model built for the economical evaluation allowed a robust and detailed evaluation of the alternatives, due to the consideration of all the items in a flexible and parameterized way. The analysis has a significantly better level of detail, rigorousness and scope than the economical analysis available at the beginning of the project.
5. The study performed allowed to evaluate the alternatives built in a structured way, making explicit the decision criteria of the Navy. This allowed us to consider those criteria in a clear and ordered way during the alternatives evaluation process.
6. It is important to highlight that all the alternatives built, with the exception of Alternative C1, consider the gradual acquisition of elements, which allows evaluating the real performance in operations of the different equipments, facilitating thus the possibility of making adjustments in time.
7. It is relevant to highlight that the project was considered as a success case by the Navy. This has motivated the use of the methodology for the analysis of similar decision situations.

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