ANALYSIS AND EVALUATION OF ALTERNATIVE SITES FOR A NEW HEAVY CRUDE UPGRADING PLANT IN COLOMBIA

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ABSTRACT

The work presents a general methodology and supporting models to analyze and select alternative sites for a heavy crude upgrading plant in Colombia. As a central part of the application of the methodology an Analytic Hierarchy Process (AHP) model was constructed, with two hierarchies (Risks and Benefits). The results of the analysis were used to formulate a specific recommendation to the Colombian Petroleum Company (Ecopetrol) concerning the best alternative.

Keywords: Analytic Hierarchy Process, heavy crude upgrading plants, Multicriteria Decision Making.

1. Introduction

Commercialization of the heavy crudes produced by the Colombian Petroleum Company (Ecopetrol) requires them to be mixed with diluents before they can be transported along the oil pipelines of the company. The demand for diluents has increased at the same rate as the production of heavy crudes. The company has evaluated strategies to reduce the

risks associated with the dilution strategy currently used to transport heavy crudes, and has concluded that a viable option is to construct a crude upgrading plant. Following an initial feasibility study carried out by the company, a total of 12 possible sites (alternatives) were identified where the plant could be built.
The findings of the initial feasibility study is the initial point for the current analysis, which was carried out by the same work team in two phases. The first phase consisted of selecting the best five alternatives from an initial 12, pre-selected by Ecopetrol. The analyses presented in this paper are applied to the five alternatives selected during Phase 1 of the project. The paper concludes by making a recommendation concerning the best location. Currently, Ecopetrol is evaluating potential partners to build the plant in the location that was recommended in this analysis.
In addition to its strategic significance for the company, and the elevated investment costs (construction of the plant will take about five years and the investment required is in the order of thousands millions of dollars), other important dimensions had to be taken into account when analyzing the decision, requiring a Multi-Criteria Decision Analysis model to be constructed in order to evaluate the alternatives.

2. Literature Review

Decision Analysis approach offers a structured methodology that can be used to conceptualize and provide support for decisions involving risk and uncertainty (Castillo, 2006), and it may impact on decision quality (Salinas, 2009). It was decided to use an AHP approach (Saaty, 2000). For this specific decision problem, it was considered appropriate to use two merits – Risks and Benefits – in order to construct an AHP model with two hierarchies to evaluate the alternatives. The results were consolidated using an index of overall performance, which was defined using Saaty´s (2005) guidelines.

3. Objectives

1. Design a methodology that incorporated qualitative and quantitative criteria and variables in order to enable Ecopetrol to analyze and select from among a set of alternative sites for a heavy crude upgrading plant in Colombia. 2. Construct the models required by this methodology to evaluate the proposed sites in a structured and rational manner. In particular, to evaluate the risks, strengths and weaknesses of the different alternatives that were in the end considered. 3. Carry out an analysis of the results obtained, and to produce recommendations and conclusions.

4. Research Design/Methodology

The project was carried out using the General Methodology for Decision-Making Analysis designed by Castillo (2008), presented in Figure 1.

In addition, a Specific Methodology was designed to resolve the particular problem with which we were concerned. This methodology involved the following five stages: Stage 1: Characterization of the alternative sites. Stage 2: Final definition of evaluation criteria. Stage 3: Construction of the multi-criteria model for the evaluation of alternative sites.

Stage 4: Evaluation of the alternative sites. Stage 5: Analysis of the results of the multi-criteria model and selection of the best alternative site.

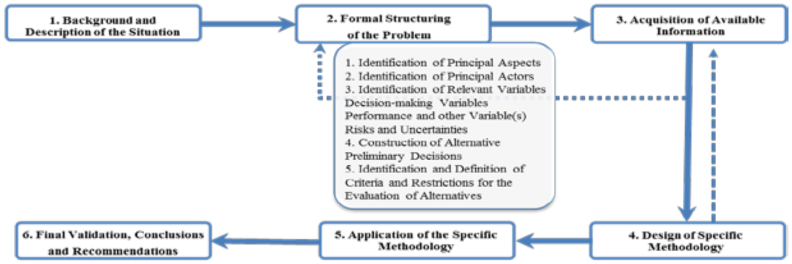

Figure 1. General Methodology for Analysis and Decision-Making

In order to include all relevant aspects of the problem, such as logistical issues associated with the construction and operation of the plant and its environmental implications, a multi-disciplinary working group was established, tasked with providing and analyzing all relevant information and assessing the different alternatives. Experts were drawn from Ecopetrol's teams responsible for Process Engineering, Geomatics, Environmental Management, Property Management, Physical Security, Cost Engineering, Project Maturation and Financial Analysis. Additional experts were drawn from consulting firms in the following areas: i) Engineering Design[1], ii) Roads, Transport, Ports and Access to Natural Resources, iii) Environment in the Energy Sector and, iv) Transport of Extra Heavy and Oversize Cargo. A total of over 40 interdisciplinary meetings involving more than 30 experts were held to agree the Design and Application of the Specific Methodology, including five workshops to evaluate the criteria and the alternative sites.
The principal analyses and results of the different stages of the analysis were discussed, adjusted and validated by various work teams and managers in different levels of Ecopetrol.

5. Data/Model Analysis

5.1 Characterization of the Decisions on the Alternatives

The five alternatives are located in different locations in the country. These locations present remarkable differences in many aspects as geographical, cultural and accessibility, among others. Additionally, a set of dimensions was identified in order to produce a general characterization of the alternatives, allowing their initial evaluation to be carried out. This characterization resulted from a series of information-gathering in site visits, which enabled the different specialist teams to gain a clearer and more precise understanding of the information associated with each site. These dimensions were as follows: i) Location, ii) Environment, iii) Accessibility and Transport Systems, iv) Physical Security, v) Complexity in the Acquisition of Land Rights, and vi) Social.

5.2 Definition of the Evaluation Criteria

As a result of the discussions in some of the multidisciplinary working groups the decision-making criteria used to evaluate the alternatives were defined with precision. The criteria were grouped in two hierarchies, the first corresponding to Risks, and consisting of 22 criteria and the second, corresponding to Benefits, consisting of two

[1] The engineering firm Tipiel S.A. led the part of the process involving design engineering and was responsible for the overall coordination of the project.

criteria associated with the economic performance of the alternatives. All the criteria are presented in Figure 3.

The risks considered in the hierarchy of Risk correspond to residual risks, that is, it was considered that they could not be mitigated through investment. As a consequence, their eventual impact was not included in the Economic Model.

5.3 Construction of the Multi-Criteria Model for Evaluating the Alternative Sites.

A Multi-Criteria AHP Model with two hierarchies (Risks and Benefits) was constructed, which was used to evaluate the alternative sites. Expert Choice 11.5 software was used to evaluate the alternatives. The hierarchies constructed are presented in Figure 3.

5.4 Evaluation of the Alternative Sites.

The evaluation of the alternatives was carried out in two stages: i) Preliminary Evaluation and ii) Final Evaluation. Alternative 4 was excluded during the first phase. For the second phase, four workshops were organized, which focused on discussing the evaluations carried out previously by each specialist group.

Figure 2 provides an example of the methodology, presenting the pairwise comparison matrices of first level criteria and for each of the hierarchies (for confidentiality reasons, the values presented here do not correspond to real values obtained in the project).

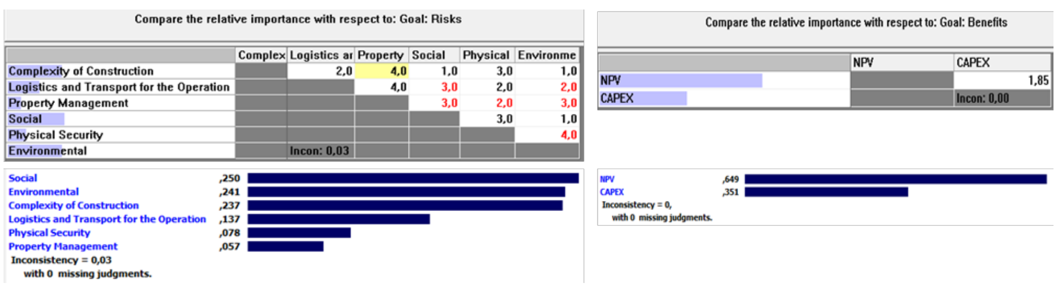

Figure 2. Comparison Matrices for Pairs of First Level Criteria

5.5 Analysis of the Results of the Multi-Criteria Model and the Selection of the Best Site Alternative

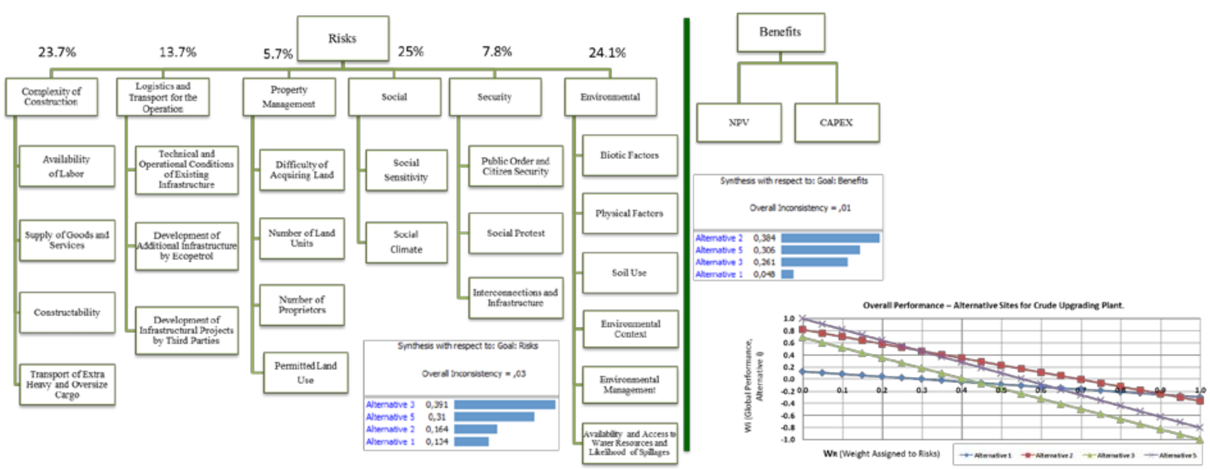

Figure 3. Criteria and Performance Scores of the Alternatives for the Risk and Benefit Hierarchies, and Analysis of the Overall Global Development Sensitivity of the Alternatives

Figure 3 presents the principal results of the evaluation of the alternatives, showing the importance (weight) of each of the first level criteria, computed with the pairwise matrices presented in Figure 2. In addition, it presents the performance of each alternative included in the analysis. For both hierarchies, the Overall Index of Inconsistency of the real comparisons does not exceed 0.04. Additionally, for the hierarchy of Risks different sensitivity analyses of the weights of the criteria were carried out, without achieving significant changes in the performance or in the ranking of the alternative sites analyzed.

The final evaluation of the alternatives was carried out on the basis of the hierarchies of Risks and Benefit. Global performance was calculated using the additive negative formula proposed by Saaty (2005). Figure 3 presents the overall performance index for different weighs assigned to the Risks and Benefits.

6. Limitations

Given the time restrictions and limited availability of information it was not possible to carry out a formal probabilistic analysis of the likelihood that risks considered in the hierarchy of Risk would occur or materialize.

7. Conclusions

1. The methodology employed showed to be robust, and the results have the appropriate precision level to enable Ecopetrol to make a decision, given that it permits the performance of each alternative under consideration to be estimated and the alternative sites to be placed in order of suitability. 2. The best alternative in each hierarchy was identified, and their performance in each criterion was analyzed. 3. In terms of overall performance index, the model allowed to obtain a ranking of the alternative sites for the Heavy Crude Upgrading Plant in Colombia, and consequently to identify the best alternative.

8. Key References

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