ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT,

PUERTO BOLÍVAR PROJECT – PHASE 1

– ANALYSIS OF ALTERNATIVES –

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EXECUTIVE SUMMARY

This document provides an assessment of the proposed alternatives for the existing docks and access channel dredging projects at the Port Terminal, and for expansion through construction of dock 6.

The Integrated Value Model for Sustainability Assessment (MIVES, in Spanish) with significant characteristics such as consistency, facility, use, efficiency, multi-criteria and assessment of heterogeneous alternatives is outlined to that purpose.

On developing the method, it arises the decision tree with economic, environmental and social requirements, each one of which is broken down into indicators enabling to assess the performance of the alternatives in these aspects. To that effect, weights are established for all decision tree levels, and value functions allowing to transform, ratings by attributes, to value functions between 0 and 1. By bringing together the value results of each indicator, a Sustainability Index (SI) is obtained. The greater the SI, higher is the sustainability of the analyzed alternative.

The results show that the sediment deposit dredging alternative in the open sea is the one that has obtained the greatest sustainability index due to lower maintenance costs of this alternative. Therefore, the dock construction and operation alternative with steel piles is the one that has obtained the greatest sustainability index due to lower investment costs of this alternative.

ANALYSIS OF ALTERNATIVES

The analysis of alternatives is carried out for future projects planned to be implemented in the Port Terminal, both in the access channel maintenance dredging, maneuvering zone and docks, and in the construction of the sixth dock of the Terminal.

To select one alternative from the several ones raised when conceptualizing a project, it is necessary to identify the mechanisms leading to a rational decision-making, through criteria being important for the decision maker and/or its stakeholders.

There are multiple mechanisms to perform this type of analysis. The role of the analysis techniques available for the decision making is to overcome the difficulties encountered by the decision-makers in handling great amounts of complex information, consistently. These techniques must be associated with a rational, sequential and repeatable procedure, and must be defensible; in other words, the data, criteria and the performance measures enabling external entities to assess and validate the process, must be clear (Trigueros 2008). The most common are techniques of monetary analysis, methods of multi-criteria analysis, and methods of variable weighting or weight assignment.

A multi-criteria methodology, MIVES: Integrated Value Model for Sustainability Assessment (Viñolas Prat et al, 2009), can be used as a result of its characteristics of consistency, ease of use, efficiency, multi-criteria, heterogeneous alternatives

1. Methodology

The Integrated Value Model for Sustainability Assessment (MIVES) is a combination of techniques whose main characteristic is to allow the decision-makers to prioritize and select among heterogeneous alternatives.

The processes that make it up are the following:

- Decision boundary: definition of the person taking the decision, the system limits and the boundary conditions.
- Definition of the decision-making tree: The aspects to be taken into account in the decision are arranged by branches.
- Creation of value functions: they consist of mathematical functions to obtain valuations from 0 to 1 of all aspects belonging to the last division of the decision-making tree.
- Weight assignment: Definition of the relative importance of each one of the aspects concerning the remaining ones belonging to a same division of the decision-making tree.
- Definition of the alternatives: Election of the alternatives to be analyzed for the decision-making problem raised.
- Assessment of the alternatives: Achievement of value index for each alternative raised.

Performance of the sensitivity analysis: Analysis of the possible change of value index of each one of the alternatives in the event that weights or value functions defined in the first phases change. This phase is optional within the MIVES methodology.

Cross-check of results: Long-term verification that the assessment model continues adjusting to what was intended to originally assess and if the calculations made in each one of the alternatives is as expected. This phase can be considered as a control phase of the model and alternatives, and is also optional within the MIVES methodology. (Polytechnic University of Catalonia 2009).

1.1. Construction of the decision tree

It consists of breaking down the decision problem into more simple components, and its organization by branches and by levels, in accordance with the decision maker's preferences. In the first level, the most qualitative and general aspects of the decision making are located, then, the criteria and sub-criteria, and in the last level, the most unique aspects: the indicators.

Requirements: are the most qualitative aspects and represent a broader vision of the criteria under which the decision is made, in case of an analysis from the sustainability point of view, requirements agree with the three basic sustainability pillars: economic, social and environmental.

The indicators are qualitative or quantitative variables from which the alternative value is quantified through the value functions. For its definition, it is advisable to use teamwork techniques such as "delphi technique,", "decision conferencing", or "brain storming".

1.2. Weight assignment by analytic hierarchy process.

This stage consists of establishing preferences among the elements of a same division, the weights of the indicators are calculated in relation to others belonging to a same criterion, the weights of the criteria are calculated in relation to the remaining belonging to a same requirement, and all requirements are compared to each other (Viñolas Prat et al. 2009). The sum of the weights of elements belonging to a same division is equal to the unit.

Decision matrix: For each comparison block, the construction of a n-by-n square matrix is required, being n the number of elements to be compared (requirements, criteria or indicators of the same division). The value matrix shall have value 1 diagonally, resulting from the comparison between an element with itself (which shall have equal importance). The inverse element of the matrix is the inverse number. For example, if the indicator i with respect to indicator j has an importance of 4, when comparing the indicator j with the indicator i it shall be the inverse value, that is ¼.

1.3. Construction of value functions.

The value function enables to pass from a quantification of a variable or attribute to a dimensionless variable comprised between 0 and 1, where 0 reflects the minimum satisfaction (Smin) and 1 reflects the maximum satisfaction (Smax). Together with the weights calculated for each variable, it enables to obtain the value, firstly for the indicators, then for the criteria, after requirements and finally for each alternative, so that one or several optimal alternatives can be defined.

Definition of the value function trend:

- Increasing, the decision maker's satisfaction increases with an increased indicator value
- Decreasing, the decision maker's satisfaction decreases as long as the indicator value increases
- Mixed, the maximum decision maker's satisfaction takes place in midpoints of the indicator value and the maximum dissatisfaction takes place in extreme points, Gauss curve type

Definition of the points corresponding to the maximum and minimum satisfaction.

These points define the limits of the value function on the x axis and are provided by the quantification or measure of the variables being analyzed Smin (point of minimum satisfaction) and Smax (point of maximum satisfaction). These two points have a satisfaction value or response on the axis and of the function of 0 (Smin) and 1 (Smax), respectively.

These points are established in accordance with three criteria:

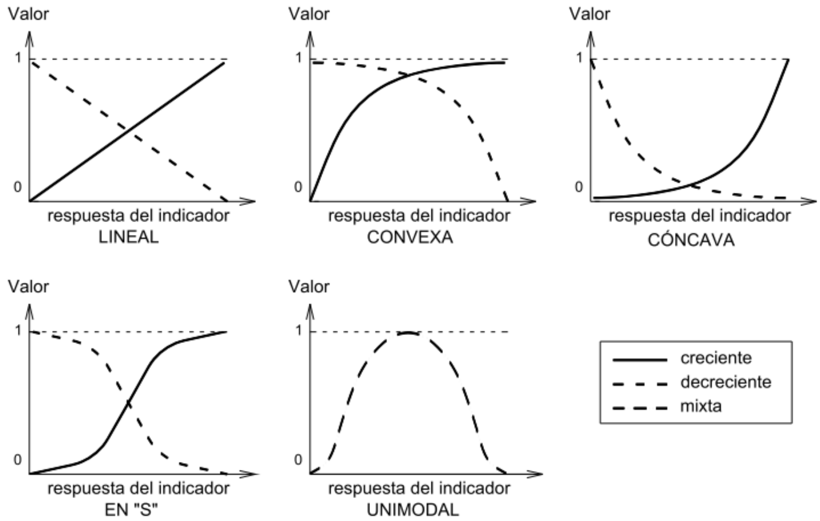
- Rules and regulations: when the variables are regulated by existing rules and therefore, are limited to given values, or the minimum and maximum values included within the interval defined by them.
- Experience with previous projects: values can be determined by the experience, from historical data, from data found in the literature or from data obtained from previous projects. The range of values is slightly more flexible than when rules and regulations are met.
- Value produced by the different alternatives regarding an indicator. In this case, the limits of the value function are provided by the minimum and maximum values of the different alternatives regarding an indicator. Therefore, if a new alternative appears, the limits of the function and the respective value of the indicators can change data:

Definition of the function shape:

- Linear: the increase or the decrease is of constant value along the alternative response range.
- Convex: it presents a great value increase for responses close to the one generating the minimum value if the function is increasing or a great value decrease for responses close to the minimum value if the function is decreasing.
- Concave: it shows a great value increase for responses close to the one generating the maximum value if the function is increasing or a great value decrease for responses close to the minimum value if the function is decreasing

- In S: the maximum value increase or decrease occurs in the central part of the range of responses while it is lower in the points close to the minimum and maximum

Figure 1. Types of value functions



Fuente: Alarcon et al. (2011)

Valor: Value, Respuesta del indicador: Response of the indicator. LINEAL: LINEAR
Value, Response of the indicator, CONVEX
Value, Response of the indicator, CONCAVE
Value, Response of the indicator. IN “S”
Value, Response of the indicator, UNIMODAL
Creciente: Increasing, Decreciente: Decreasing, Mixta: Mixed

Definition of the mathematical function of the value function: The mathematical equation proposed by Alarcon et al. (2011) is the following:

Table 1. Mathematical value function

Increasing function			
Function	**C**	**K**	**P**
Linear	C ≈ Xmin	≈0	≈ 1
Convex	$Xmin + \frac{Xmax - Xmin}{2} < C < Xmin$	<0.5	>1
Concave	$Xmin < C < Xmin + \frac{Xmax - Xmin}{2}$	>0.5	<1
S shape	$Xmin + \frac{Xmax - Xmin}{5} < C < Xmin + \frac{4(Xmax - Xmin)}{5}$	0.2/0.5	>1
Decreasing function			
Function	**C**	**K**	**P**
Linear	C ≈ Xmin	≈0	≈ 1
Convex	$Xmax < C < Xmax + \frac{Xmin - Xmax}{2}$	<0.5	>1
Concave	$Xmin - \frac{Xmin - Xmax}{2} < C < Xmin$	>0.5	<1
S shape	$Xmax - \frac{4(Xmax - Xmin)}{5} < C < Xmax + \frac{(Xmax - Xmin)}{5}$	0.2/0.5	>1

Source: Alarcon et al. (2011)

2. DEFINITION OF ALTERNATIVES

The alternatives raised for the dredging and construction projects of dock 6 are described below. The aforementioned alternatives are those raised in the respective Environmental Impact Studies and the Complementary Environmental Study.

2.1. Dredging

According to the studies performed, the amount of 575.384,84 cubic meters shall be extracted from the Docks Area (Dock 1, 2, 3, 4, 5 and 6), as follows:

Dock #1 = 58.598,56 m^3

Dock #2 = 22.526,22 m^3

Dock #3 = 73.075,41 m^3

Dock #4 = 45.628,87 m^3

Dock #5 = 124.308,33 m^3

Dock #6 = 251.247,45 m^3.

Meanwhile, 7'000.000 m^3 of sediments shall be extracted from the Maneuvering Zone and Access Channel.

ALTERNATIVE 1: Dispose of the sediments from the dredging of docks on land, and the sediments from the dredging of the maneuvering zone and access channel in the open sea.

The sediments extracted from the docks area, would be deposited in the old premises of ISSFA, an area close to the docks of the Puerto Bolívar Terminal, the same in which the dredging material was disposed of in the years 2012 and 2013.

It involves three pools of 12,9 hectares approximately, in which walls and a fourth pool shall be built. The capacity of the pools is 375.000 m3. When this capacity becomes saturated, the material would be removed and delivered for earth filling works.

As this area is close to the dredging area, a land pipe could be installed by following the right side of the road leading to the beginning of Dock 5, and after, it will be installed on the docksides until reaching the beginning of Dock 3, being able from that point to dredge Docks 3, 2 and 1 more easily. Subsequently, the pipe will be cut and the drainpipe will be installed between Dock 4 and 5, the pipe cutting job will be performed in 5 days, and dredging of Dock 4 will continue, which will be finished in about 30 days; finally, Dock 5, which would take 50 days; having a total working time of 162 days.

It is important to highlight that the pipe would not block any area nor cause any type of affectation; in addition, it shall not affect the Dredger maneuvers as it is close to the Project area, the time of dredging will be reduced, reducing the dredge operating costs, as well as the personnel involved in the project.

While the dredging material of the Maneuvering Zone and Access Channel consisting of 7'000.000 m3 approximately, they will be located in an area in the open sea, which, according to the Bathymetric Study performed by the company CONSULSUA Cia. Ltda. is the recommended area. This area has a surface of 4 km^2, is 13,75 miles from the sea buoy (25 km), this area has depths exceeding -30 m MLWS, being able to reach -40m MLWS, the predominant currents at this site are directed towards the Northeast, making that the sediments move in this direction. It is 18 km far from Santa Clara Island and 13 km far from Puna Island.

ALTERNATIVE 2: Dispose of the total dredging in the open sea.

A single deposit area will be considered in the Jambelí channel with an area of 4 km2, this deposit basin corresponds to an area with good depths, for the deposit of material, a grid will be defined in the area divided every 200 meters in order to determine an unloading plan for each equipment and the process shall consist of depositing the sediment in each grid defined with coordinates (number, letter), thus ensuring the distribution of the material uniformly and equitably on the entire area and avoiding its accumulation in a single site. This will be controlled through regular bathymetries and the unloading plan will be adjusted in accordance with the results if necessary, this area is 13,6 nautical miles from the sea buoy (25 km).

2.2. Construction of Dock 6

ALTERNATIVE 1. Driven, steel piles.

For this alternative, the first iteration for the pile diameter is 914 mm with 25 mmm wall thickness (the reduced thickness is 21 mm if the corrosion allowance is considered). The advantage of steel piles is that they can be perfectly driven for soil conditions of the location. The construction process is quick.

ALTERNATIVE 2. Driven, concrete piles

Driven concrete piles work well and the capacity of piles is slightly lower than the steel piles (considering the same diameter of 914 mm). However, considering the embedded depth foreseen for these piles, their weight becomes quite significant and will require heavy equipment for hoisting them.

ALTERNATIVE 3 Drilled, concrete piles

For this alternative, a steel liner can be used and, considering the diameter of the piles, a minimum of 12 mmm pile thickness will be required. Even more, considering the geotechnical conditions: soft and unstable soil layer and they should be buried up to the base of piles, thus avoiding a failure thereof.

3. DEVELOPMENT

This chapter will develop the procedure to obtain the Sustainability Index (SI), structured through a requirements tree based on the MIVES model.

The SI is obtained by adding the value summation obtained for each indicator or criterion assessed IVj (Aj, x), weighted in three levels, composing the relative weight of each indicator, criterion and requirement. The weights of the requirements are obtained from adjusting the values obtained through the AHP process, while the weights of criteria and indicators are the result of the direct assignment.

$$IS = \sum k_{Rt} \cdot k_{Cy} \cdot k_{Ij} \cdot IV_j(A_x)$$

Wherein:

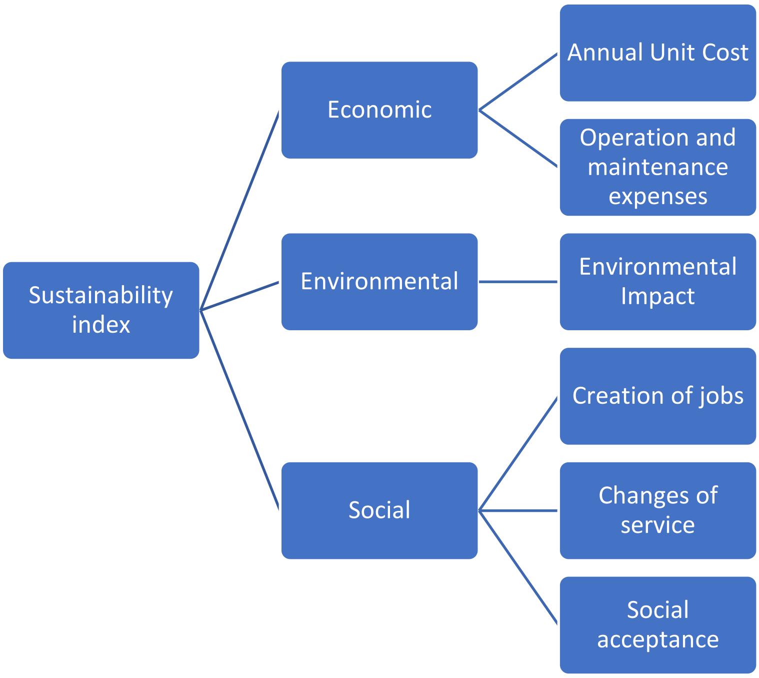
IS is the index of the analysis result index.

Ivj(Ax) is the ith value of x alternative.

k_{Rt}, k_{Cy} and k_{Ij} are the weights of each requirement, criterion and indicator, respectively.

The decision tree will be built on the basis of requirements, criteria and sustainability indicators.

Figure 2. Decision tree



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Weights of criteria and indicators are the result of the direct assignment.

Table 2. Weight assignment for criteria and indicators

CRITERIA	**WEIGHTS** K_{RT} **(%)**	INDICATORS	**WEIGHTS** K_{CY} **(%)**
ECONOMIC	30	Annual Unit Cost	50
		Operation and maintenance expenses	50
ENVIRONMENTAL	30	Environmental Impact	100
SOCIAL	40	Change of service capacity	30
		Creation of jobs	50
		Social acceptance	20

Prepared by: Ecosambito, 2020

3.1. Economic Aspect

This requirement assesses the use given to the economic resources being at the disposal of the institution.

__Annual Unit Cost__. It assesses if the investment analyzed is balanced in time and according to the service that shall be provided. It is in accordance with the useful life of the alternative proposed.

$$CUA = \frac{Initial\ investment}{VU_{total}}$$

Wherein:

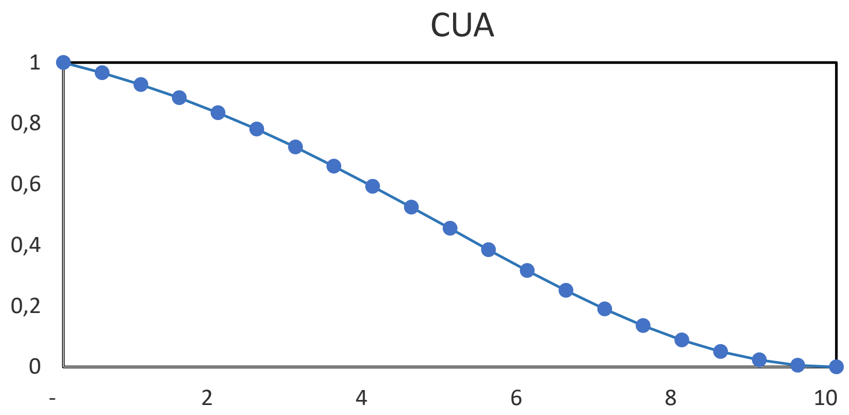
Initial Investment is the total amount budgeted to perform the work.

VU_{total} are the years foreseen to exploit the investment.

Because there is not always real data of the investment to be made, an estimated valuation can be used that enables to differentiate the alternatives that require a greater economic effort from those requiring lower investments, thus, we will establish attributes for this valuation. To that purpose, a valuation from 1 to 10 is proposed, being 10 the most expensive alternative, and 1 the cheapest alternative.

The value function to obtain this indicator is decreasing.

Figure 3. Value function for CUA



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__Operation and maintenance expenses__. This indicator represents the long-term economic investment that the Project must ensure so that the investment is still capable of providing the service for which it was created. This change can be positive (increasing maintenance expenses) or negative (if there is a reduction of these expenses). It takes into account the maintenance costs (costs of spare parts and repairs), and operating costs (personnel, inputs, etc.).

Table 3. Rating by attributes for GOyM

Operation and maintenance expenses (GOyM)		
Attribute	**Description**	**Score**
Large increase	It generates a very large increase of the maintenance expenses	1
Small increase	It generates a small increase of the maintenance expenses	2
Void/marginal	Marginal change of the maintenance expenses	3
Savings	It generates a small savings of the maintenance expenses	4
Large savings	It generates a large savings of the maintenance expenses	5

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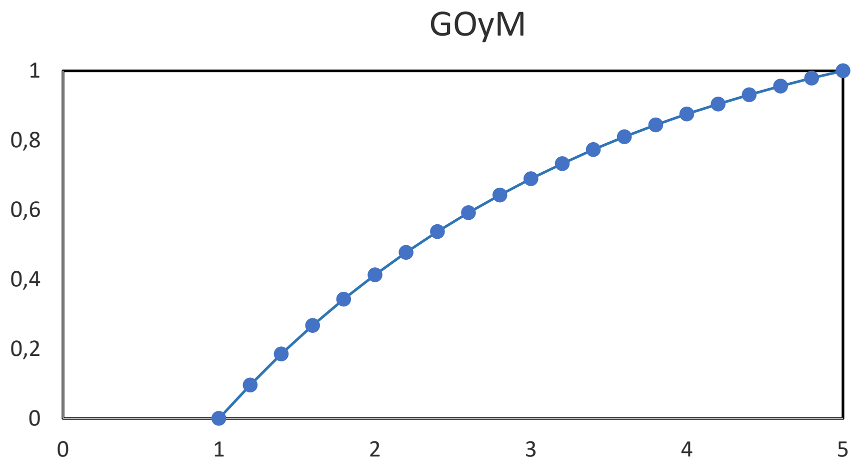
The value, increasing and concave function is shown below:

Figure 4. Value function for OME



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3.2. Environmental Aspect

Environmental Impact. It is defined as the direct or indirect effects that an investment can cause on the different elements of the environment, and the possible affectation to the interrelations existing among these elements.

For a project to be implemented, there are regulations that require environmental impact studies resulting in a series of measures to prevent, control and minimize the possible negative environmental impacts of the investments. Thus, only the projects meeting these previous requirements can be considered for implementation thereof.

Table 4. Rating by attributes for IAmb

Environmental Impact					
Indicator	**Negative impact**	**With no change**	**Low**	**Medium**	**High**
It considers adaptation aspects to the climatic change	1	2	3	4	5
It considers the use of materials and inputs of proximities	1	2	3	4	5
It keeps the quality of the physical aspects: air, water, soil	1	2	3	4	5
It improves the sound quality	1	2	3	4	5
It preserves the biodiversity	1	2	3	4	5
It preserves the landscape	1	2	3	4	5

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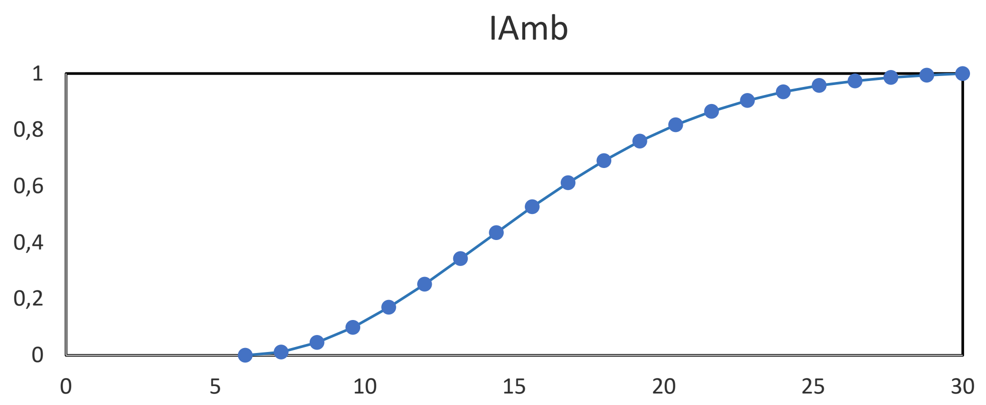
The value function created has an S shape, and does not return value for entries lower than 6 (negative impacts). The maximum value is equal to 30, which is the maximum possible sum of attributes of this indicator.

Figure 5. Value function for IAmb



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3.3. Social Aspect

It assesses the project's consequences on the community, and the conceptualization of sustainability is complete for the projects assessed.

<u>Creation of jobs</u>. It measures jobs in the construction and exploitation/operation stages of the investment. It intends to prioritize those investments that can create more jobs over time. With this purpose, this indicator takes into account the following:

Table 5. Rating by attributes for CPT

Creation of jobs (CPT)		
Jobs in Construction Stage (EFC)	Jobs in Operation and Maintenance Stage (EFO)	Score
0 ≤ EFC ≤ 5	0 ≤ EFE ≤ 5	1
5 ≤ EFC ≤ 25	5 ≤ EFE ≤ 25	2
25 ≤ EFC ≤ 50	25 ≤ EFE ≤ 50	3
50 ≤ EFC ≤ 100	50 ≤ EFO ≤ 100	4
EFC > 100	EFO > 100	5

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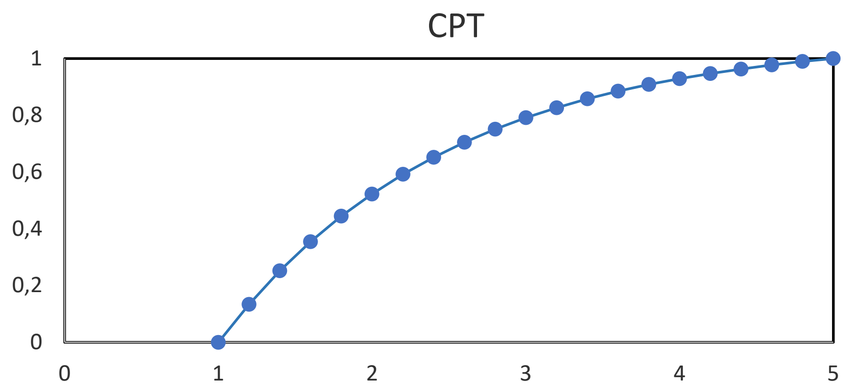
Figure 6. Value function for



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Change of capacity. It assesses the capacity increase, in maximum flow or number of users, which can use a certain infrastructure or service per unit of time, after implementing the project.

Table 6. Rating by attributes for Acs

Social Acceptance (AcS)		
Attribute	**Description**	**Score**
Very low	Demonstrations of opposition by the community or stakeholders.	1
Low	Punctual claim or complaint	2
Normal	There is no position defined by the community.	3
High	Good response and acceptance by the host population.	4
Very high	Excellent response and acceptance in the community	5

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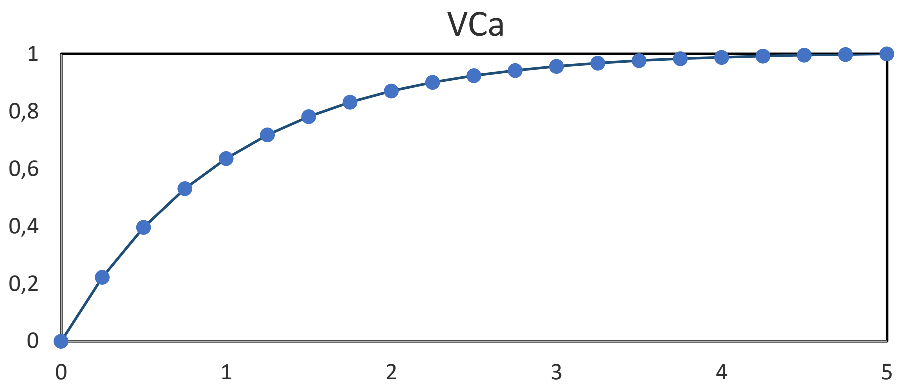
Figure 7. Value function for VCa



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Social Acceptance: Analysis of the degree of acceptance of the social actors, stakeholders and community in general, regarding the proposed alternative.

Table 7. Rating by attributes for VCa

Change of capacity (VCa)		
Attribute	**Description**	**Score**
Very low	The capacity increase if very reduced (Δ Capacity ≤ 10%)	1
Low	The capacity increase is reduced (10% <Δ Capacity ≤ 40%)	2
Normal	The capacity increase is average (40% <Δ Capacity ≤ 60%)	3
High	The capacity increase if significant (60% <Δ Capacity ≤ 80%)	4
Very high	The capacity increase is very significant (Δ Capacity> 80%)	5

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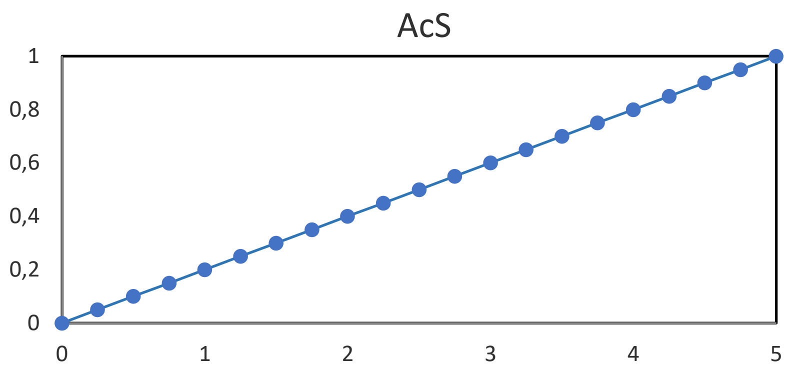
Figure 8. Value function for AcS



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4. Results

After assessing the alternatives proposed by using the described methodology, the following results are obtained:

4.1. Dredging

The numerical results of the assessment are shown in the following Table:

Table 8. Analysis result of dredging alternatives

	DREDGING	
INDICATOR	**Alternative 1**	**Alternative 2**
CUA	0,00	0,03
GOYM	0,00	0,13
IAMB	0,08	0,08
CPT	0,10	0,03
CSR	0,10	0,09
ACS	0,05	0,04
	0,34	0,40
SI (%)	33,63	39,69

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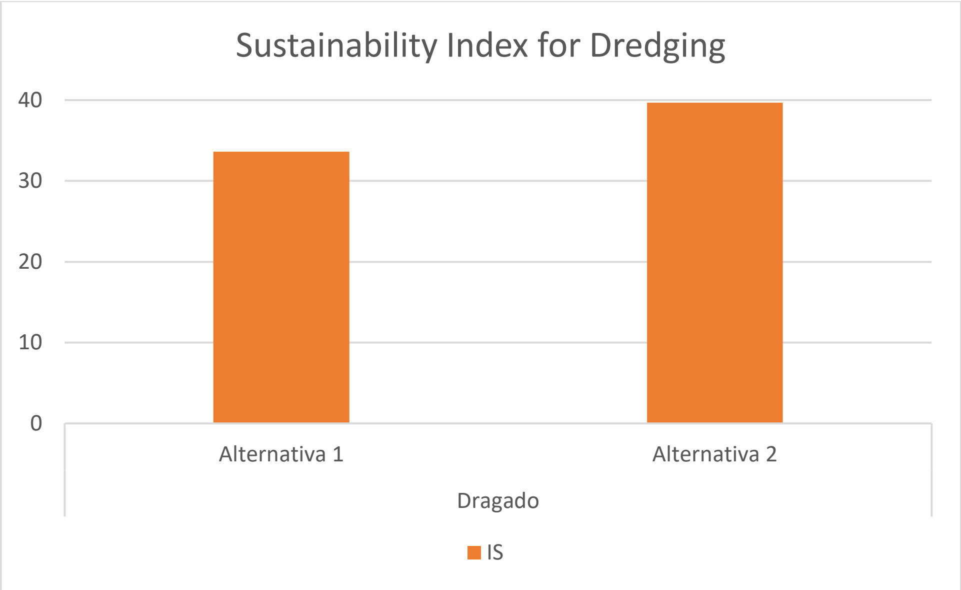
The results obtained show that Alternative 2 "Dispose of the total dredging in the open sea", obtains a sustainability index greater than alternative 1 "Dispose of the sediments from the dredging of docks on land, and the sediments from the dredging of the maneuvering zone and access channel, in the open sea."

The contribution of each sustainability criterion is also shown to the total valuation.

Figure 9. Sustainability Index for Dredging Alternatives



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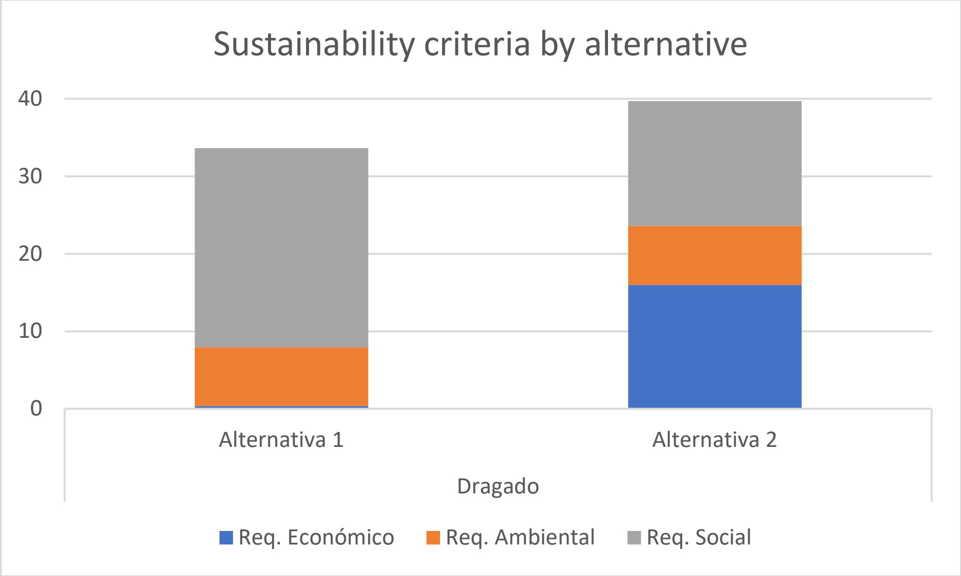
Alternativa 1: Alternative 1, Alternativa 2: Alternative 2. Dragado: Dredging, IS: SI

Figure 10. Sustainability index by criterion for dredging alternatives.



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Alternative 1, Alternative 2, Dredging, Req. Económico: Economic requirement. Req. Ambiental: Environmental requirement, Req. Social: Social requirement

The graph shows that alternative number two has a significant advantage from the economic point of view; this is due to the maintenance costs, which negatively affected the result.

4.2. Dock 6

From the 3 alternatives submitted to the assessment, Alternative 1 (steel piles) obtained a greater sustainability than the other two alternatives.

Table 9. Analysis result of alternative of dock 6.

	DOCK 6		
INDICATOR	**Alternative 1**	**Alternative 2**	**Alternative 3**
AUC	0,05	0,03	0,01
GOYM	0,13	0,09	0,10
IAMB	0,12	0,12	0,14
CPT	0,03	0,03	0,03
CSR	0,09	0,09	0,09
ACS	0,03	0,02	0,00
	0,45	0,39	0,38
SI (%)	45,18	38,51	37,52

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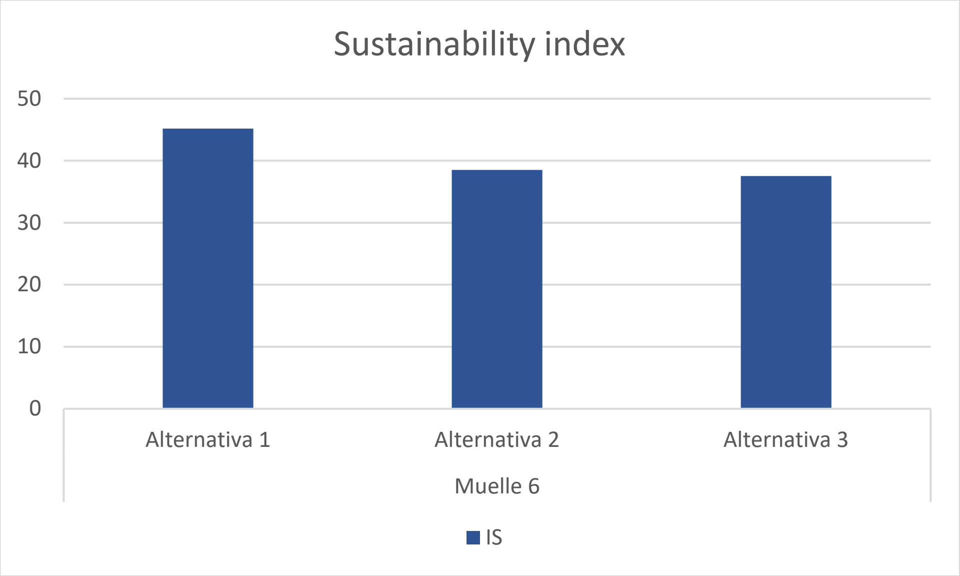
The results are shown below.

Figure 11. Sustainability index for construction alternatives of dock 6.



Alternative 1, Alternative 2, Alternative 3, Muelle 6: Dock 6, SI

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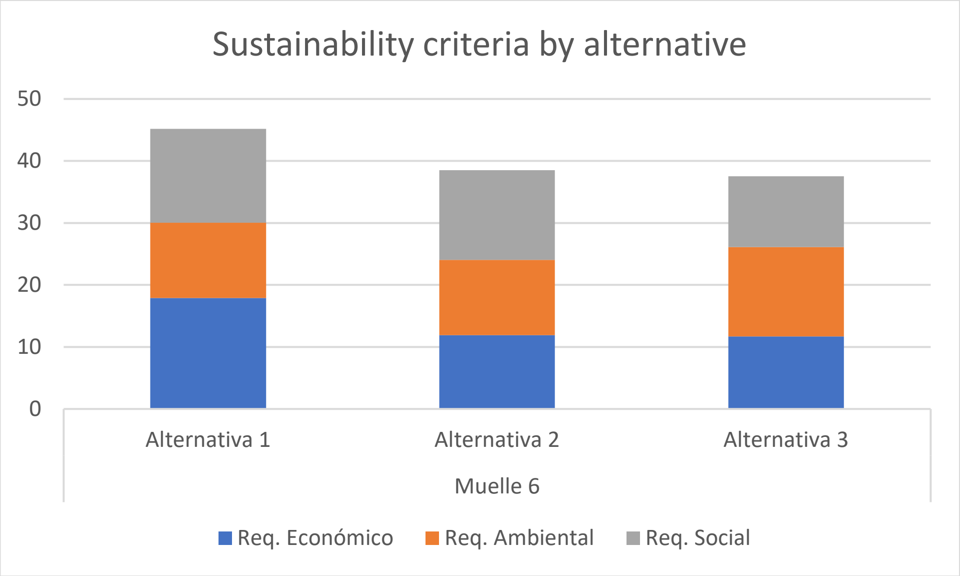
Figure 12. Sustainability index by criterion, for alternative of dock 6



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Alternative 1, Alternative 2, Alternative 3, Dock 6, Economic requirement, Environmental requirement, Social requirement

In case of the construction alternative of dock 6, the factor that provides more sustainability to Alternative 1 is the economic requirement; however, there is also a significant and balanced contribution from the economic and social requirements.

5. Conclusions

A methodology combining several techniques to facilitate the decision making has been used, including several criteria, required for an analysis covering different points of view.

The prepared decision tree includes the sustainability requirements, and in each requirement, indicators enabling to qualify the performance of the alternatives in these aspects were identified.

The analyzed alternatives have very similar characteristics; therefore, the model delivers adjusted results; however, indicators that can be differentiating factors are included, and help to identify the most sustainable alternative.

The Dredging alternative with deposit of all sediments in the open sea is the one that has obtained a greater sustainability index because the maintenance costs of this alternative were lower.

The construction and operation alternative of the Dock, with steel piles, is the one that has obtained a greater sustainability index because of the lower investment costs of this alternative.

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