



Bases para la planificación sostenible de
áreas marinas en la Macaronesia

Identification of
areas for Blue
Growth

DETAILED MCDA DRAFT METHODOLOGY
UNIVERSIDADE DOS AÇORES – FUNDAÇÃO GASPAR
FRUTUOSO

To cite this report:

Shinoda, Deborah; Calado, Helena; Vergílio, Marta; Kramel, Diogo; Caña Varona, Mario.
2018. Identification of Areas for Blue Growth: Detailed MCDA Draft Methodology.
University of Azores. Report prepared as part of PLASMAR Project (co-financed by
ERDF as part of POMAC 2014-2020). 30 pp.

Reproduction is authorised provided the source is acknowledged.

LEGAL NOTICE

This document has been prepared as part of PLASMAR Project (co-financed by ERDF as part of POMAC 2014-2020), however it reflects the views only of the authors, and the Project partners or POMAC 2014-2010 programme cannot be held responsible for any use which may be made of the information contained therein.

TABLE OF CONTENTS

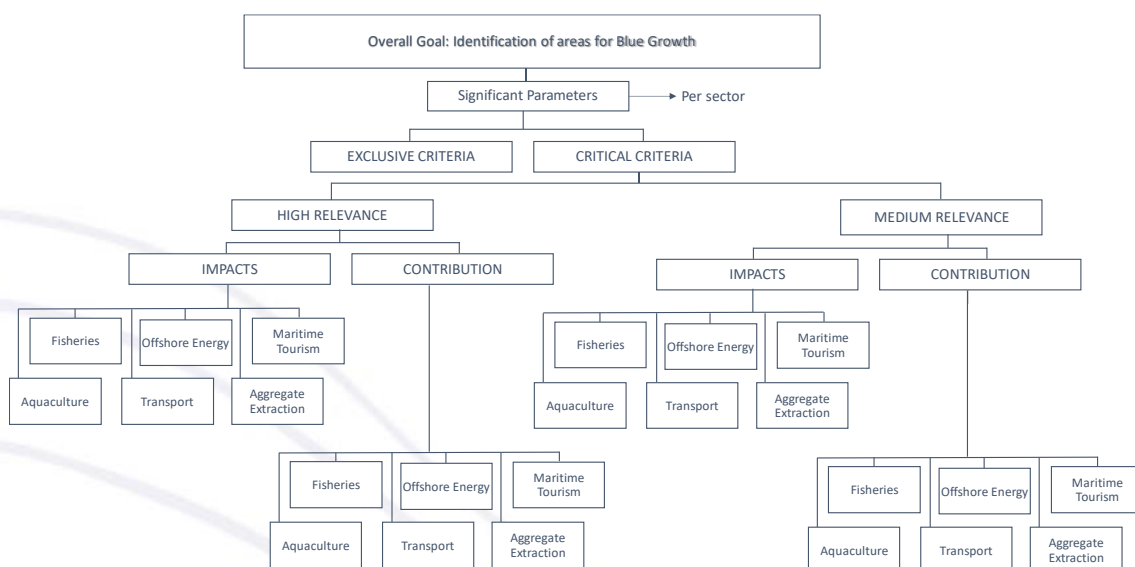
EXECUTIVE SUMMARY	6
I. INTRODUCTION	7
1 INTRODUCTION	8
II. SUBSIDIZING THE IDENTIFICATION OF AREAS FOR BLUE GROWTH	9
2 MULTICRITERIA DECISION ANALYSIS	10
2.1 ANALYTICAL HIERARCHY PROCESS (AHP)	12
3 IDENTIFYING AREAS FOR BLUE GROWTH: DEFINING WEIGHTS TO PARAMETERS	13
3.1 ESTABLISHING THE CONTEXT: DEFINING THE GOAL AND THE OBJECTIVES	13
3.1.1 ESTABLISHING THE CONTEXT: DEFINING THE CRITERIA	14
3.1.2 PLASMAR PARAMETERS DEFINITION	18
3.2 ESTABLISHING THE CONTEXT: DEFINING THE STAKEHOLDERS	20
3.3 SPECIFYING PREFERENCES	22
3.3.1 STEP 1: DETERMINATION OF THE WEIGHT COEFFICIENTS FOR THE CRITERIA	22
3.3.2 STEP 2: CALCULATING THE WEIGHTS PER SECTOR	24
3.3.3 STEP 3: CALCULATING THE CONSISTENCY RATIO (CR)	24
3.3.4 STEP 4: CALCULATING THE FINAL WEIGHT	25
4 METHODOLOGY REMARKS	28
REFERENCES	29

Executive Summary

This report will describe a proposal of a decision-making support tool that aims to achieve a hierarchy definition for contribution and impact of parameters for different maritime sectors in Macaronesia. The methodology is proposed under the PLASMAR activity 2.1.2 “Pilot Zoning – identification of areas for Blue Growth development within ecosystem approach” and will contribute to the spatial identification of areas for blue growth through the parameters’ grading system.

The proposal consists on the adaptation of a Multicriteria Decision Analysis methodology, the Analytical Hierarchy Process (AHP). The AHP is one of the most widely used multicriteria decision-making technique and its use is based on relatively easy procedures as well as on the possibility to evaluate the inconsistency (Aguarón, Escobar and Moreno-Jiménez, 2016). Moreover, the AHP analysis is mainly based on: the hierarchy of interrelated decision elements describing the problem, composing a decision-tree; the pairwise comparison of the decision elements; and the consistency ratio.

In this methodological proposal, the criteria analysed were defined as the PLASMAR Parameters, and the pairwise comparison aims to be based on experts’ consultation. The structure of the proposed analysis can be observed in the Figure below.



Final proposition of hierarchical structure for the PLASMAR analysis.

As observed in the Figure above, the analysis will consist on the selection of PLASMAR significant parameters, the significance will be based on the attributed high and medium relevance defined within the project. Following this first selection, the parameters contribution and sectorial impacts over the parameters will be analysed to each maritime sector through the multicriteria methodology. The final output of the analysis will be a score to each parameter per sector. For further details, a step-by-step approach to guide the methodological proposal application was developed in the report.

I. Introduction

1 Introduction

Aiming the development of methodologies to support Maritime Spatial Planning (MSP) and Blue Growth, the project PLASMAR “Setting the basis for sustainable maritime spatial planning in Macaronesia” has the goal to potentialize the development of marine activities in balance with the biogeographical specific characteristics of Macaronesia region (including in Portugal the Azores and Madeira archipelagos, and in Spain the Canary Islands). It also aims to support the achievement of the Good Environmental Status (GES) launched at the Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC).

The PLASMAR activity 2.1.2 “Pilot Zoning – identification of areas for Blue Growth development within ecosystem approach” intends to identify potential areas for the “blue growth” in Macaronesia. This task consists on developing a general methodology of zoning activities/sectors over the maritime space and implementing a pilot zoning for Macaronesia, which will be developed on INDIMAR platform.

The elaboration of a zoning proposal demands basis information. Hence, this data will be gathered, organized and produced in the following activities:

- i. Activity 2.1.1 “Finding the balance of Blue Growth Sustainable Development within Ecosystem Approach”;
- ii. Activity 2.2.1 “Analyses of data & information availability, current and potential data holders/providers, in the scope of Maritime Spatial Planning”;
- iii. Activity 2.3.1. “Marine monitoring methods needed to apply MSP ecosystem approach”.

From the results obtained in the project, a zoning methodology will be established considering the following marine sectors:

- i. Aquaculture;
- ii. Fisheries;
- iii. Marine transportation;
- iv. Offshore renewable energy;
- v. Aggregate extraction;
- vi. Marine tourism.

The pilot zoning will identify the best suitable areas for specific maritime activities, in line with the maintenance of the GES, according to the information available in the Marine Distributed Data Infrastructure. This is a result of the Activity 2.2.1 of PLASMAR “Analyses of data & information availability, current and potential data holders/providers, in the scope of Maritime Spatial Planning”.

In this sense, the different methodologies currently applied for Multi-Criteria Decision Making (MCDM) will be further developed in order to subsidize the methodology currently being developed in this project.

II. Subsidizing the identification of Areas for Blue Growth

2 Multicriteria Decision Analysis

The concept of Multicriteria Decision Making (MCDM), or Multicriteria Decision Analysis (MCDA), concerns structuring and solving decision and planning problems involving multiple criteria (Majumder, 2015). Steps to develop a MCDA, in a participatory way, are represented in Figure 1 (Durham *et al.*, 2014).

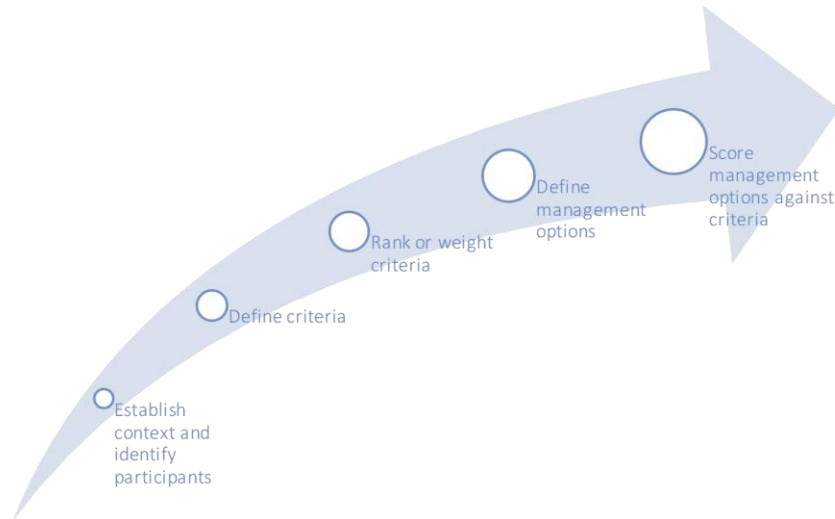


Figure 1: Steps of MCDA. Source: Adapted from (Durham *et al.*, 2014).

The concept of MCDM concerns problems that demand one decision between several possible alternatives influenced by different criteria. The main methodologies are listed by (Velasquez and Hester, 2013):

1. ANP – Analytic Network Process
2. AHP – Analytic Hierarchy Process
3. MAUT – Multi-Attribute Utility Theory
4. TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution
5. PROMETHEE – Preference Ranking Organization Method for Enrichment of Evaluations
6. ELECTRE - Elimination and Choice Expressing Reality
7. SAW – Simple Additive Weighting
8. MACBETH – Measuring Attractiveness by a Categorical Based Evaluation Technique

The application of these methods will vary depending on the application area, due their specific characteristics. Huang, Keisler and Linkov, 2011 explore the use of each method in the field of environmental sciences based on the analysis of 300 study cases between 2001 and 2009. Similar study was taken by (Marttunen, Lienert and Belton, 2017), the authors analysed 68 papers published between 2000 and 2015. In Figure 2 the representation of the results of both articles is represented through the most common uses in different areas and the percentage of application of each method.

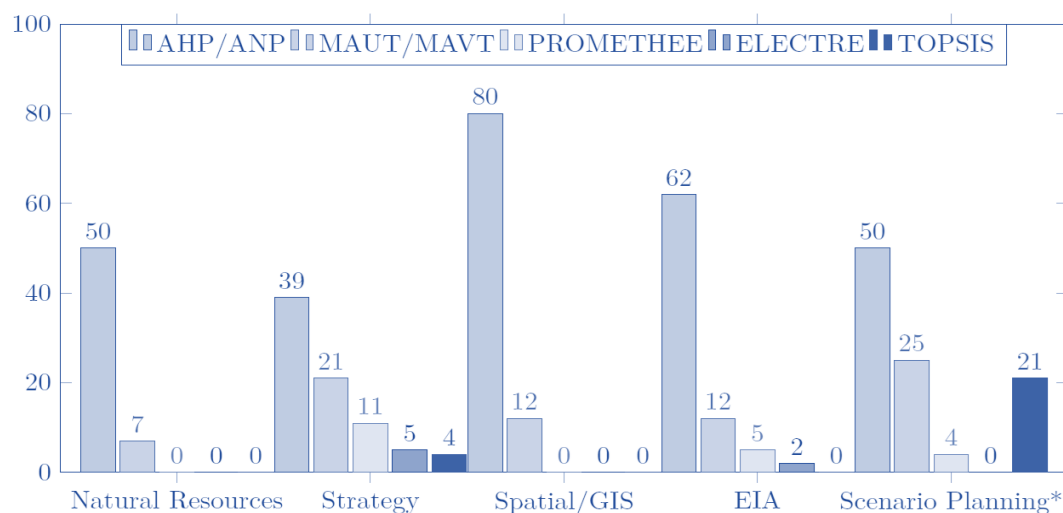


Figure 2: Use of MCDM methods in different fields of science (based on Huang et al. 2011).

From Figure 2, the AHP/ANP method has been largely used in literature and across several scientific fields. Furthermore, it is important to observe that other methods express moderate relevance in application.

In a methods comparison (Table 1), it is possible to observe that AHP presents good precision with low amount of data, time and technical knowledge. Moreover, even though the results are not as precise for the AHP methodology as for the other methods, the consistency checking guarantees the reliability of the analysis and builds a good problem modelling possibility with limited data. In MSP, as well as small islands context as the ones addressed by the PLASMAR project, data acquisition can be costly or even impracticable. As a result, AHP can be a powerful resource for these realities, based on the knowledge of experts, technicians and professionals in the area.

Table 1: Models comparison.

Criteria	AHP	MAUT	TOPSIS
Precision	Good	High	Good
Versatility	High	Very high	High
Amount of data	Low	High	High
Time	Low	High	Low
Technical knowledge	Low	High	Medium
Specific software	No	Yes	Programmable
Method	Pairwise comparison	Utility function	Ideal and anti-ideal options
Output	Punctuation ranking	Punctuation ranking	Partial ranking with efficacy score

2.1 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a general theory of measurement (Saaty, 1987) and a useful decision-making support technique (Soma, 2003). The AHP is one of the most widely used multicriteria decision-making technique for dealing with multi/stakeholders problems (Aguarón, Escobar and Moreno-Jiménez, 2016). Its use is based on relatively easy procedures and on the possibility to evaluate the inconsistency of the preferences (Aguarón, Escobar and Moreno-Jiménez, 2016).

The AHP methodology involves four main steps (Saaty, 1990). The steps based on Soma (2003) description, and the actions taken in this study to cover them will be further explained:

1. Developing a hierarchy of interrelated decision-elements describing the problem (Figure 3). To address this step, the current study dedicated the sections “*Establishing the context*” (Sections 3.1, 3.2, 3.3).

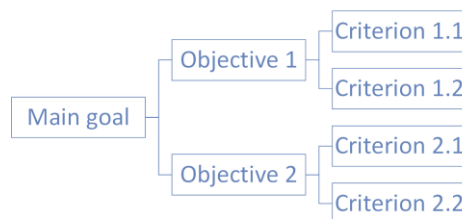


Figure 3: Example of decision-tree. Source: Soma, 2003.

2. Performing a pairwise comparisons of the decision elements through a weighting scale to generate input data, with all the decision elements agreed upon by all the stakeholder groups. This step is comprehended in the section 3.3 “*Specifying preferences*”, specifically in section 3.3.1 “*Step 1: Determination of the weight coefficients for the criteria*”.
3. Computing the relative weights of the decision-elements. This step is comprehended in the section 3.3 “*Specifying preferences*”, specifically in section 3.3.2. “*Step 2: Calculating the weights per sector*”.
4. Determining the prioritisation of objectives, criteria and management options in order to identify the alternative decision possibilities. This step is partially comprehended in the section 3.3 “*Specifying preferences*”, specifically in section 3.3.4. “*Step 4: Calculating the final weight*”. This study aims to compare the different criteria, however, not the alternatives. Further details are given in the next sections.

3 Identifying areas for Blue Growth: Defining weights to parameters

Aiming the achievement of the Action 2.1.2. of PLASMAR, “Pilot Zoning – Identification of areas for Blue Growth development within ecosystem approach”, a detailed methodology of weight calculation for the parameters identified under the project will be further proposed in order to subsidize the goal of the action.

3.1 Establishing the context: Defining the goal and the objectives

Initially, in order to guide the research and the pairwise comparison analysis, the overall goal of the research must be defined (Saaty, 1990). Considering the PLASMAR action 2.2.1, on which this work is based, the overall goal considered on this analysis was the “Identification of areas for Blue Growth”, as observed in Figure 4. Moreover, this goal was subdivided in order to comprehend the relation of the different parameters already developed by the project. The subdivision consisted on “Contribution”, referring to the parameters contribution to the sector, and the “Impacts”, referring to the parameters impacted by the sector.

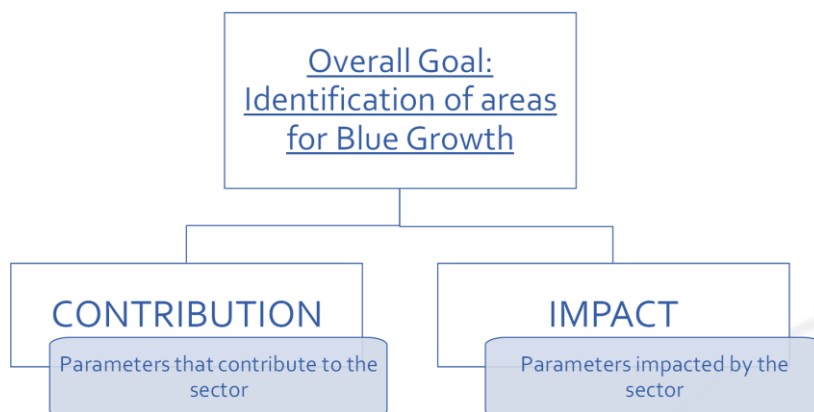


Figure 4: Goal definition in the analysis.

Secondly, in order to comprehend the different maritime sectors addressed during the project as the blue growth sectors, the overall goal, and consequently, each goal's subdivision, was further subdivided into objectives. This subdivision aimed the identification of specific criteria and weights for each sector (Figure 5).

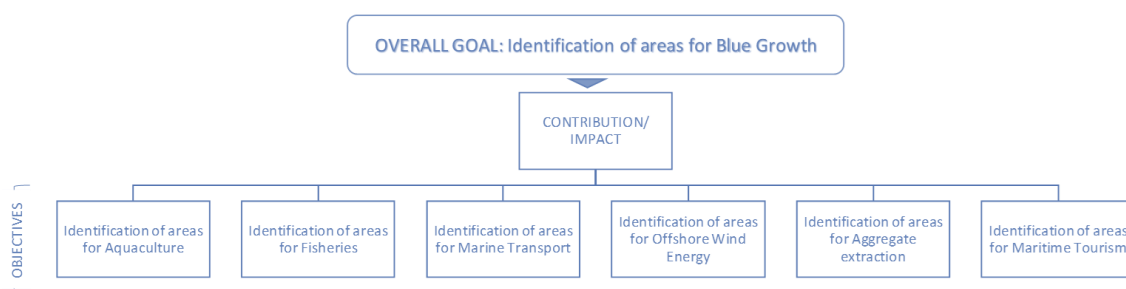


Figure 5: Objectives definition

3.1.1 Establishing the context: Defining the criteria

The criteria adopted for the multicriteria analysis in this study were the PLASMAR data framework, in order to associate the aforementioned analysis with the spatial data developed in the scope of the project. The structured list of clusters of criteria (group of parameters or cluster), criteria (parameters) and sub-criteria (sub-parameters) is presented in Table 2. Details on the selection of the parameters will be available soon at plasmar.eu. Moreover, the criteria still under partners' evaluation and, as a result, is not yet fully developed. This list might need to be updated on the analysis.

Table 2: PLASMAR data framework adopted for the identification of areas for Blue Growth.

Group of parameters	Parameter	Sub-parameter
MSFD Good Environmental Status criteria elements	Descriptor 1: Biodiversity – Habitats and Species	Marine Habitats
		Coastal habitats
		Sensitive species distribution/migrations
		Mammals
		Birds
		Turtles
		Cephalopod
	Descriptor 2	Non-indigenous species
	Descriptor 3	The population of commercial fish species
	Descriptor 4	Elements of food webs
	Descriptor 5: Human-induced eutrophication	Chlorophyll a
		Dissolved oxygen
		Nutrients
		Water transparency
	Descriptor 6	The sea floor integrity (physical loss & disturbance)

	Descriptor 7	Permanent alteration of hydrographical conditions
	Descriptor 8	Concentrations of contaminants – heavy metals and other contaminates
	Descriptor 9	Contaminants in seafood - assessed data, not time series
	Descriptor 10	Marine litter
	Descriptor 11	Energy, including underwater noise data
MPA	Nationally designated areas (CDDA by EEA)	
	Natura 2000	
	Local data	
Land use/cover	CORINE (land cover)	
	Land use	
	No take zone	
	Distance to the coast	
	Point and lineal coastal pressures	
Oceanography	Temperature	
	Sea surface/sea bottom temperature	
	Sea salinity	
	Mixed layer thickness	
	Currents	
	Waves	
	Depth/bathymetry	
Maritime activities/pressures	Aquaculture pressures	Aquaculture facilities
		Seaweed cultivation
	Maritime Transportation pressures	Maritime traffic lanes/intensity maps
		Offshore supply/bunkering
		Harbours/ports
	Fisheries pressures	Fish landings
		Fishery areas/efforts
	Mineral Resources pressures	Aggregate extraction
		Dredging / Sand extraction
		Fossil fuel extraction
		Deep sea mining
	Tourism pressures	Artificial reefs
		Coastal Tourism
		Cruise Tourism
		Maritime tourism

Others	Diving
	Windsurfing
	Wreck
	Dumping
	Desalination
	Cables
	Military area
	Ship building
	Blue biotech
	Coastal point pressures (submarine outfalls, gullies...)
	Research area

In order to evaluate the relevant parameters for each maritime sector, the critical parameters might be identified by expert's consultation, which is currently being developed among the project partners. It is worth referring that the current parameter survey taking place among the partners aims to determine the significance/relevance of the parameters, as well as identify missing parameters. In this survey, the importance of each parameter will be classified as "low", "medium" and "high" for each activity. Thus, the critical parameters will be considered as the ones defined as "high" and "medium".

Later, based on this first selection, a second selection will classify the critical parameters in "exclusive criteria" and "critical criteria" (Figure 6). The "exclusive criteria", based on Botelho *et al.* (2015), are defined as the criteria that presents no trade-off for its development due to legal constrains, for instance, the jurisdictional area of the port, buffer areas for diving and recreational activities, marine protected areas (MPAs), etc. On the other hand, the "critical criteria" are the remaining critical parameters classified for each activity, these are the criteria that will be weighted on the multicriteria analysis taken in this study. This selection aimed to build a hierarchy of the interrelated decision-elements through the experts, resulting in criteria with comparable unities. Additionally, "medium" and "high" parameters were separately considered in order to preserve the homogeneity in the pairwise comparison, however, if necessary (e.g., the case of few parameters classifies for "medium" or "high"), they can be jointly considered. Moreover, if only one parameter remains in the cluster after the classification, it is advisable to consider all the parameters in the cluster for the pairwise comparison.

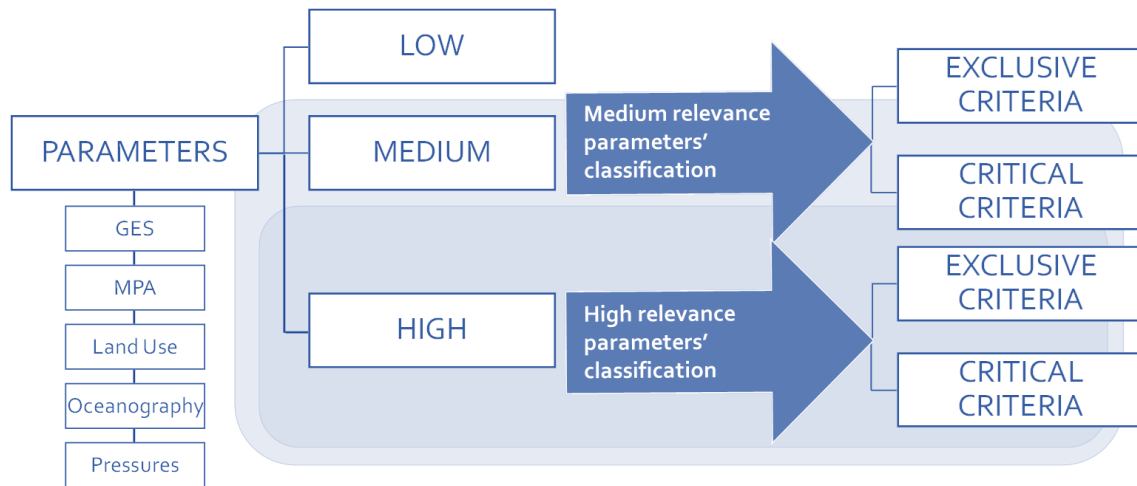


Figure 6: Parameters selection for the multicriteria analysis.

The final hierarchical structure proposed for this analysis can be observed in Figure 7.

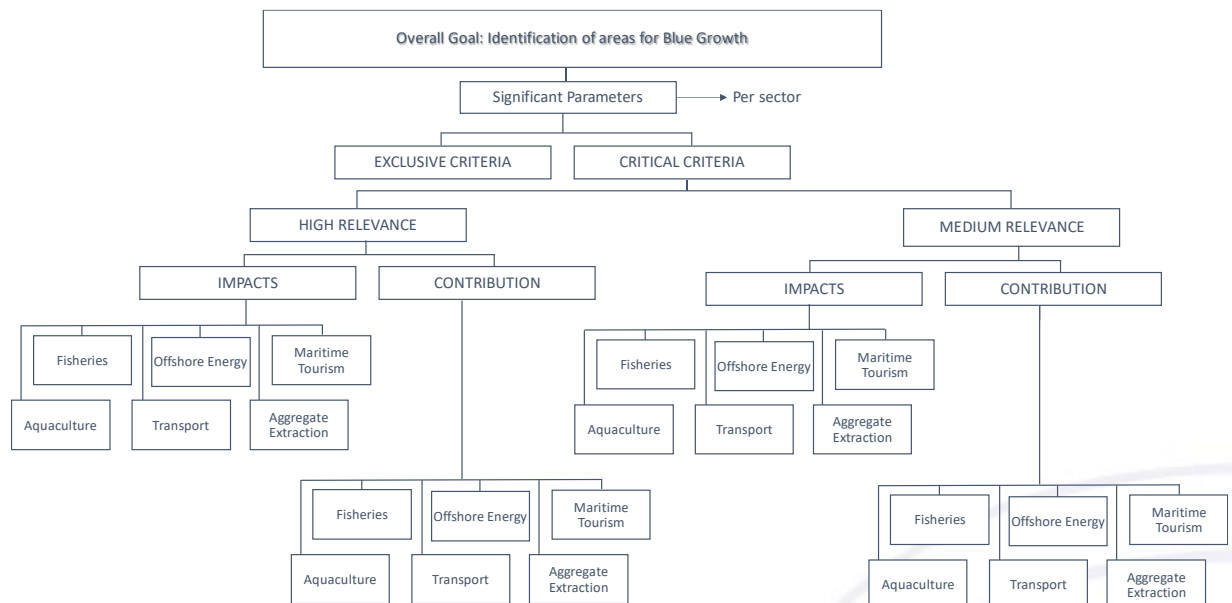


Figure 7: Final proposition of hierarchical structure for the PLASMAR analysis.

3.1.2 PLASMAR Parameters Definition

A brief description of some parameters is given below.

- **MSFD Good Environmental Status**

Biodiversity	Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions
Non-indigenous species	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems
Commercial fish species	Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock
Elements of food webs	All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity
Eutrophication	Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters
The sea floor integrity	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected
Permanent alteration of hydrographical conditions	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems
Concentrations of contaminants	Concentrations of contaminants are at levels not giving rise to pollution effects
Contaminants in Seafood	Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards
Marine litter	Properties and quantities of marine litter do not cause harm to the coastal and marine environment
Energy and noise	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

- **Maritime Protected Areas (*Several sources*)**

Natura 2000	Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive
No take zones	Protected areas closed to fishing
CDDA by EEA	The Nationally designated areas inventory (CDDA), formerly known as the Common Database on Designated Areas, is now an agreed annual Eionet core data flow maintained by the European Environment Agency (EEA) with support from the European Topic Centre on Biological Diversity (ETC/BD). The CDDA data is delivered by each country as spatial information (Type 1) and thematic information (Type 2) and the dataset is used by the EEA and e.g. the UNEP-WCMC for their main European and global assessments, products and services

- **Land Use/Land Cover**

- **Oceanography** (Source: <http://marine.copernicus.eu/training/education/ocean-parameters/>)

Sea Surface Temperature (SST)	Sea surface temperature is the temperature of the ocean near the surface
Sea Bottom Temperature (SBT)	Sea bottom temperature is the temperature of the ocean near the bottom
Currents	By transporting heat and energy, ocean currents play a major role in shaping the climate of Earth's many regions. Surface currents (restricted to the upper 400 m of the ocean) are generally wind-driven and develop their typical clockwise spirals in the northern hemisphere and counter-clockwise rotation in the southern hemisphere (for warm currents). Deep ocean circulation is the result of a number of factors including temperature and salinity variations in water masses, shorelines, subsurface topography, tides, etc.
Salinity	Sea Surface Salinity is a key parameter to estimate the influence of oceans on climate. Along with temperature, salinity is a key factor that determines the density of ocean water and thus determines the convection and re-emergence of water masses
Sea level	The sea surface is anything but flat. There are bumps and troughs , all due to different physical characteristics such as gravity, currents, temperature and salinity... Since we do not know much about the ocean's bottom, it is easier to refer to "sea height" instead of sea depth. Sea level is measured with reference to a fixed surface height. By analyzing variations from this reference point, scientists determine ocean circulation (currents and eddies at the edges of holes and bumps), seasonal or inter-annual variations, or even longer periods (long-term rise in sea level).
Wind	Surface winds, combined with other atmospheric forces (solar energy, precipitation rate, evaporation rate) are all responsible for the movement of water masses in the ocean, and are thus responsible for ocean currents. Marine winds shape the ocean, and can cause waves as high as a mountain to swell during a storm. They are the source of many legends and color the moods of seafarers around the world
Biogeochemistry	Phytoplankton (vegetable plankton) is the first link in the ocean's food chain, and is the main source of food for most fish. Phytoplankton contains chlorophyll, which instigates photosynthesis in the ocean, absorbs atmospheric CO2 and releases oxygen in sunlight. More than any land-based plant, phytoplankton is the biggest producer of oxygen on Earth

- Marine pressures/activities

3.2 Establishing the context: Defining the stakeholders

In view of the need for consultation in the definition of weights for the criteria, this study proposes the adoption of an approach based on the Best Expert Judgment (BEJ). The BEJ method aims the identification of optimal decisions by providing experts and decision-makers structured framework (Weisberg et al., 2008; Burgman et al., 2011 as cited in Elliott et al., 2018). Despite the uncertainties in complex marine areas, management conclusions can still be reached through integrative assessment (Elliott et al., 2018), experts can synthesize and communicate understanding for societally important questions (Mach et al., 2017). In BEJ, experts can integrate evidence across disciplines, however, they must consider uncertainties and appropriate generalizations across results (Mach et al., 2017).

Bearing in mind the actions developed under the PLASMAR project, the consultation will be applied on the project's partner researchers, once they are currently developing a dense research over the Macaronesia area and, as a result, they also hold the structured framework of PLASMAR project within their research. Within each partner's institution, specialists will be identified for each sector, as observed in Figure 8.

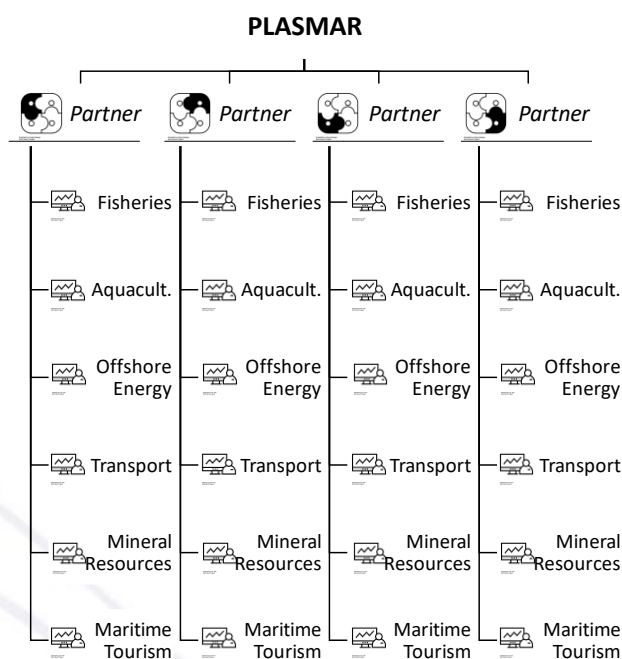


Figure 8: Internal consultation scheme. Image sources: thenounproject.com

Moreover, this consultation aims to be complemented by experts external to PLASMAR project, at the main Universities in Macaronesia or key sectoral experts. Similarly, experts will be selected per sector in each University (Figure 9). This selection can be based on three methods:

- If available, governmental experts' database;
- Snowball sampling, through the indication of experts by the previously consulted PLASMAR experts;

- Internet surveys on scientific platforms for authors of publications related to the sector in the region.

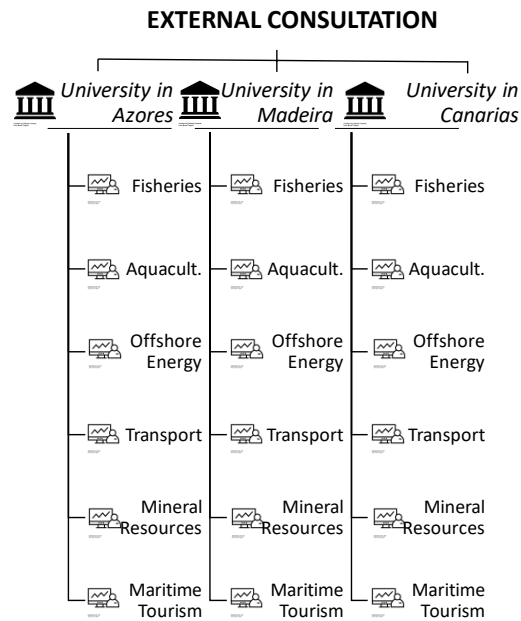


Figure 9: External consultation selection scheme. Image sources: thenounproject.com.

Forman and Peniwati (1998) identify two ways of aggregating individual preferences into a group preference, given the group synergy. The authors observe when individuals are willing to act in concert and pool their judgments in a way that the group becomes a 'new individual', aggregating individual judgments (AIJ) must be used. On the other hand, when individuals are each acting in his/her own right, and aggregation of individual priorities (AIP) must be adopted.

Considering the consultation will take place among experts only and the grades will be given per sector and per region separately, even though the experts will not necessarily act as one single individual once the consultation will be individual, it is assumed initially that the AIJ will be adopted. In this manner, in the aggregation where the reciprocal property is assumed, the geometric mean should be used instead of the arithmetic mean (Forman and Peniwati, 1998; Ossadnik, Schinke and Kaspar, 2016). Nonetheless, the aggregation will be based on a *post hoc* analysis. Moreover, it is important to observe that mathematical aggregation implies in transparency and clarity of results, however, it might not reflect the individual preferences (Ignaccolo *et al.*, 2017).

3.3 Specifying preferences

Considering the benefits previously discussed in the use of AHP methodology, this method will be adopted in the determination of the weight coefficients for the criteria. The methodology will be further explained in steps.

3.3.1 Step 1: Determination of the weight coefficients for the criteria

As previously referred, the AHP method consists on the pairwise comparison of criteria in a matrix and a subsequent comparison of alternatives per criteria in order to output a rank of alternatives (Saaty, 1990). As a result, this method demands the confrontation of the alternatives per criteria, in order to define a final grading.

Considering that in this analysis the alternatives are the maritime sectors defined by PLASMAR as: aquaculture, fisheries, maritime transport, offshore wind energy, aggregate extraction and maritime tourism. Considering also that the confrontation of alternatives – maritime sectors – was not plausible, since the outcome of one specific sector must be seen in the context of this sector and cannot be used for other sectors, and must consider characteristics such as institutional capacity, existent infrastructure for the sector, etc. (Soma, 2003). As a result, the computation of the alternatives scoring was not developed, and the method compared the parameters and clusters for each alternative (maritime sector). The adoption of AHP only in the weight definition had being largely observed in the literature as part of another multicriteria analysis (MCA) method (Babic and Plazibat, 1998; Ragu and Pillai, 1999; Macharis et al., 2004; Bisel Ufuk et al., 2006 apud Konidari and Mavrakakis, 2007; Botelho, A.Z. et al. 2015; Soma et al., 2012).

Based on the goal of the PLASMAR action 2.1.2., the identification of areas for blue growth, the pairwise comparison will be performed by cluster-cluster (level 1) per alternative (maritime sector) and later by criteria-criteria (level 2) per alternative (maritime sector). In short, the pairwise comparisons to be performed, based on the cluster (x_1), criteria (x_2) and alternatives (x_3), are the following: (x_1)-(x_1) per (x_3), (x_2)-(x_2) per (x_3). Moreover, if necessary, sub-criteria – sub-criteria comparisons might be taken.

All the pairwise comparisons should be done for both, contribution and impact (Figure 4). This analysis will be performed through questionnaires to characterize the preferences of the identified experts and later transferred to the pairwise comparison matrixes.

The relative importance for grading the analysis is based on Table 3, scale recommended by Saaty (1990). Fixed point scoring has the advantage of forcing participants to make trade-offs in a decision problem (Hajkowicz et al., 2000). Moreover, Saaty (1990) argues that the AHP is rigorously concerned with the scaling problem and how to correctly combine the priorities resulting from them and, as a result, the scale was maintained in this study.

Table 3: Relative importance scores. Source: Adapted from Saaty (1987).

Intensity of importance	Definition	Explanation
1	Criteria are equally important	Two criteria contribute equally to the objective
3	One criterion is slightly more important than the other	Experience and judgment favor one criterion over another
5	One criterion is more important than the other	Experience and judgment strongly favor one criterion over another
7	One criterion is strongly more important than the other	A criterion is strongly favored, and its dominance is demonstrated in practice
9	One criterion is absolutely more important than the other	The evidence favoring one criterion over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values	Intermediate values

The different examples of matrices' structures are presented below. In the matrices, each element represents the comparative of the element in the row with the element in the column. For instance, the value a_{12} represents the importance of criteria 1 compared to criteria 2.

Table 4: Pairwise comparison between clusters $(x_1)-(x_1)$

CLUSTER	1. MSFD GES	2. MPA	3. Land cover & use	4. Oceanography	5. Maritime Activities
1. MSFD GES	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
2. MPA	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
3. Land cover & use	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
4. Oceanography	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
5. Maritime Activities	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

Table 5: Examples of pairwise comparison between criteria $(x_2)-(x_2)$ within the cluster MPA, for the sectors maritime tourism and aggregate extraction.

MARITIME TOURISM				AGGREGATE EXTRACTION			
MPA	1. Nationally designated areas	2. Natura 2000	3. No take zone	MPA	1. Nationally designated areas	2. Natura 2000	3. No take zone

1. Nationally desig. areas	a_{11}	a_{12}	a_{13}
2. Natura 2000	a_{21}	a_{22}	a_{23}
3. No take zone	a_{31}	a_{32}	a_{33}

1. Nationally desig. areas	a_{11}	a_{12}	a_{13}
2. Natura 2000	a_{21}	a_{22}	a_{23}
3. No take zone	a_{31}	a_{32}	a_{33}

3.3.2 Step 2: Calculating the weights per sector

In order to compute the weights for the criteria in AHP from the cluster and criteria matrices, as recommended by Saaty (1990), the normalized values must be derived from each matrix, in which every element in a matrix is divided by the sum of the elements in the column, as observed below.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{k=1}^n a_{kj}}$$

Posteriorly, a weight vector is calculated through the average of the normalized elements in each row, through the following equation.

$$w_j = \frac{\sum_{k=1}^n \bar{a}_{ik}}{n}$$

The final output of this step is one vector of weights \mathbf{W} with n elements per maritime sector, as observed below, for cluster and criteria.

$$\mathbf{W} = \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{bmatrix} = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \end{bmatrix}$$

3.3.3 Step 3: Calculating the consistency ratio (CR)

Consistency implies that if $a > b$; $b > c$ then $a > c$ (Soma, 2003). In AHP, the consistency ratio is calculated in order to check the consistency of the analysis (for each matrix) and is a result of the consistency index (CI) per random index (RI) and $CI / RI < 0.1$.

The index is calculated by $CI = \lambda_{\max} - n / n - 1$, where λ_{\max} is the maximum eigenvalue of the matrix and n is the size of the matrix. The λ_{\max} must be calculated like so (Saaty, 1977 cited in Franek and Kresta, 2014):

$$\lambda_{\max} = \sum_{j=1}^n \frac{(A \cdot W)_j}{n \cdot W_j},$$

where **A** represents the pair-wise comparison matrix and **W** the eigenvector.

The values for the RI for small problems are shown in Table 6.

Table 6: Values of the Random Index (RI): Source: (Franek and Kresta, 2014)

Size	2	3	4	5	6	7	8	9	10	11	12
RI	0	0.525	0.882	1.110	1.250	1.341	1.404	1.451	1.486	1.514	1.536

In order to avoid inconsistent values, the selection of the critical criteria through the significant parameters was developed to define a clear hierarchy of importance of the different parameters, as well as to reduce the number of criteria to be compared in the pairwise analysis. Moreover, it is important to observe that, in order to achieve a consistent result, the matrix should be reviewed by the respondent in case the CR > 0.1. However, considering that this practice could generate some inflexibility for the respondents and discourage participation, it was not adopted.

3.3.4 Step 4: Calculating the final weight

The final product of this analysis will be two or four matrices for each sector, one for “Contribution” and one for “Impact”, and other two for the medium and high significant parameters if analysed separately. These matrices will contain the weights of the critical criteria per sector, as observed in the example below.

Table 7: Example of structure of the final output of the weight analysis

HIGH/MEDIUM RELEVANCE PARAMETERS							
CONTRIBUTION/IMPACT MATRIX							
Cluster	Criteria	Maritime Activities weights					
		Aquaculture	Fisheries	M. Transp.	O. W. Energy	Aggregat e E.	Maritime Tourism
U S	Descriptor 1						

	Descriptor 2						
	Descriptor <i>n</i>						
MPA	Nationally designated						
	Natura 2000 by EEA						
	No take zone						
Land use/cover	CORINE						
	Land use						
	Distance to the coast						
	Point and lineal coastal pressures						
Oceanography	SST mean						
	SBT mean						
	Sea salinity						
	Currents Vel. max						
	Wave height Med						
	Wind Vel. Max						
	Salinity Med						
	Mixed layer thickness Med						
Maritime pressures	Aquaculture facilities						
	Maritime traffic lanes						
	Fishery areas						
	Harbours/ports						
	Coastal point pressures (submarine outfalls, gullyies...)						
	Aggregate extraction						

	Maritime tourism						
	Cables						
	Research area						
	Military area						
	Cruise Tourism						
	Coastal Tourism						
	Artificial reefs						
	Deep sea mining						
	Blue biotech						
	Seaweed cultivation						
	Diving						
	Windsurfing						
	Wreck						
	Ship building						
	Dredging / Sand extraction						
	Fossil fuel extraction						
	Dumping						
	Desalination						
	Offshore supply/bunkering						

The input values must be the calculated by the multiplication of the cluster weight (W_{x1}) by the correspondent criteria weight vector (W_{x2}) per sector, as presented below:

$$W_{x1} \cdot W_{x2} \text{ (Per sector)}$$

4 Methodology Remarks

In this report, a methodology is proposed for the weight attribution to the parameters created under the PLASMAR project based on the aggregate extraction analysis. This proposal aimed to adapt the AHP methodology to the project's goal, and, as a result, to achieve a hierarchy definition for the different parameters within each sector for the Macaronesia region. Currently, a pilot questionnaire is being applied in order to test and improve the methodology. Moreover, an excel table based on Goepel (2013) will be provided for the methodology data analysis. Nevertheless, some considerations need to be done about the methodology.

First, this methodology is based on the analysis of the goals/objectives, clusters, criteria and alternatives. Those different analysis structures implied in the limitation of the analysis by the selection and definition given to these structures. In other words, the selection and definition of the aforementioned analysis components over other possibilities have direct impact on the final results, e.g. the incorporation of the environmental component in the criteria instead of the sectors can imply in a sectoral approach in the environmental evaluation.

Second, the application of questionnaires without a workshop to create an open space for trade-offs to define the weights is a limiting factor of this methodology. Moreover, engaging a wider representation of stakeholders and basing group decision on consensus, when possible, results in more democratic and fair results (Ignaccolo *et al.*, 2017).

Finally, the outcomes must be updated along time, with the changes in the sectors and in the parameters studied (Soma, 2003).

References

- Aguarón, J., Escobar, M. T. and Moreno-Jiménez, J. M. (2016) 'The precise consistency consensus matrix in a local AHP-group decision making context', *Annals of Operations Research*. Springer US, 245(1–2), pp. 245–259. doi: 10.1007/s10479-014-1576-8.
- Botelho, A. Z. et al. (2015) *Fase III – Determinação de locais para aquicultura nas águas costeiras/offshore*. Ponta Delgada.
- Durham, E. et al. (2014) *The BiodivERsA Stakeholder Engagement Handbook*. Annex 1. Paris. Available at: <https://www.biodiversa.org/702>.
- Elliott, M. et al. (2018) 'Using best expert judgement to harmonise marine environmental status assessment and maritime spatial planning', *Marine Pollution Bulletin*. Elsevier, 133(April), pp. 367–377. doi: 10.1016/j.marpolbul.2018.05.029.
- Forman, E. and Peniwati, K. (1998) 'Aggregating individual judgments and priorities with the Analytic Hierarchy Process'.
- Franek, J. and Kresta, A. (2014) 'Judgment Scales and Consistency Measure in AHP', *Procedia Economics and Finance*. Elsevier, 12, pp. 164–173. doi: 10.1016/S2212-5671(14)00332-3.
- Hajkowicz, S. A., McDonald, G. T. and Smith, P. N. (2000) 'An evaluation of multiple objective decision support weighting techniques in ...', *Journal of Environmental Planning and Management*, 43(4), pp. 505–518.
- Huang, I. B., Keisler, J. and Linkov, I. (2011) 'Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends', *Science of the Total Environment*, 409, pp. 3579–3594. doi: 10.1016/j.scitotenv.2011.06.022.
- Ignaccolo, M. et al. (2017) 'Combining Analytic Hierarchy Process (AHP) with role-playing games for stakeholder engagement in complex transport decisions', *Transportation Research Procedia*. Elsevier B.V., 27, pp. 500–507. doi: 10.1016/j.trpro.2017.12.069.
- Konidari, P. and Mavrikis, D. (2007) 'A multi-criteria evaluation method for climate change mitigation policy instruments', *Energy Policy*, 35(12), pp. 6235–6257. doi: 10.1016/j.enpol.2007.07.007.
- Krejčí, J. and Stoklasa, J. (2018) 'Aggregation in the analytic hierarchy process: Why weighted geometric mean should be used instead of weighted arithmetic mean', *Expert Systems With Applications*. Elsevier Ltd, 114, pp. 97–106. doi: 10.1016/j.eswa.2018.06.060.
- Mach, K. J. et al. (2017) 'Unleashing expert judgment in assessment', *Global Environmental Change*. Pergamon, 44, pp. 1–14. doi: 10.1016/J.GLOENVCHA.2017.02.005.
- Majumder, M. (2015) 'Impact of Urbanization on Water Shortage in Face of Climatic Aberrations', pp. 35–48. doi: 10.1007/978-981-4560-73-3.
- Marttunen, M., Lienert, J. and Belton, V. (2017) 'Structuring problems for Multi-Criteria Decision Analysis in practice: A literature review of method combinations', *European*

Journal of Operational Research. Elsevier B.V., 263(1), pp. 1–17. doi: 10.1016/j.ejor.2017.04.041.

Ossadnik, W., Schinke, S. and Kaspar, R. H. (2016) 'Group Aggregation Techniques for Analytic Hierarchy Process and Analytic Network Process : A Comparative Analysis'. Springer Netherlands, pp. 421–457. doi: 10.1007/s10726-015-9448-4.

Saaty, R. W. (1987) 'The analytic hierarchy process-what it is and how it is used', *Mathematical Modelling*, 9(3–5), pp. 161–176. doi: 10.1016/0270-0255(87)90473-8.

Saaty, T. L. (1990) 'How to make a decision : The Analytic Hierarchy Process', *European Journal of Operational Research*, 48, pp. 9–26.

Soma, K. (2003) 'How to involve stakeholders in fisheries management — a country case study in Trinidad and Tobago', *Marine Policy*, 27, pp. 47–58.

Soma, K. *et al.* (2012) *Deliverable D4.1: Framework for Multi-objective Quantitative and Qualitative Evaluation of Marine Spatial Management in Coastal Zones* Organisation name of lead contractor : LEI , part of WUR.