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ENVIRONMENTAL PERFORMANCE VALUE OF PROJECTS: AN ENVIRONMENTAL IMPACT ASSESSMENT TOOL

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ABSTRACT

The aim of this research is to provide a common methodology for setting environmental performance (EP) values in various projects/activities and involve public in the decision-making process. To hierarchically evaluate the contribution of every environmental component to the environment of the study area, the assessor evaluates the existing as well as the potential situation of the environment by providing different weights to a set of environmental components. Various features of project's impact on each environmental component are assessed both in the construction and the operational phase. A final environmental evaluation grade for every project evokes for every assessor by the use of a series of simple formulae. To illustrate the use of the proposed tool, the results of its application to 14 cases are presented. The proposed tool uses common criteria and scales to all environmental impact assessment judgments, integrates public participation in the process and concludes, through a uniform methodology, with EP values that should lead either to the acceptance or rejection of a project execution.

Keywords: Decision-making, environmental impact assessment, multicriteria analysis, public participation.

1 INTRODUCTION

Environmental impact assessment (EIA) is a complex issue as it seeks to determine the basic components responsible for the overall environmental burden of the project/activity so as to plan suitable measures to mitigate these impacts. The evaluation of impact significance is considered as one of the most difficult, critical and vital element of the process. There are many tools and techniques that have facilitated the impact assessment processes such as scoping, checklists, matrices, qualitative and quantitative models, literature reviews and decision support systems [1,2]. There is also a vast multicriteria decision-making literature, which deals with EIA problems and the application of multicriteria assessment (MCA) methods to support complex environmental decision making has gained great interest in the last decades [3–5]. The number of multicriteria decision analysis papers published in the area of EIA overwhelm relevant papers dealing with other application areas [6]. This tendency highlights the need to better conceive these methods and understand how they could actually improve the decision making [7] in order to conclude to the less complicated, most appropriate and easily applied ones. The proposed EIA methodology includes different environmental components and modified assessment criteria compared with previous methods. Moreover, it introduces the assessment of both existing and potential environmental conditions.

Another major issue concerning the EIA process is the issue of public participation. Public involvement should appear at almost every stage of the process, including scoping, impact analysis, mitigation and impact management and reporting. Momtaz and Gladstone [8] highlight amongst the objectives of public participation: (a) information sharing, (b) involvement of the community at an early stage of decision making, (c) consideration of community aspirations and (d) the chance of community to influence the outcome of decision making. Moreover, the subjectivity of either the proponent or the stakeholders complicates the evaluation process since views about the importance

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of particular environmental impacts diverge in accordance with their personal values and attitudes [9], leading to the necessity of public involvement in decision making. Although public participation is widely accepted in the literature as being a valuable component of the EIA process, it is apparent that the degree to which each of the practice evaluation criteria is fulfilled depends upon the public participation methods, as well as upon the personal beliefs of the stakeholders [10]. Although there are many that argue that it is unethical or undemocratic for the public not to be involved in the decision-making process, as it has relevant environmental and social impacts [11], there is still no effective way to undertake it.

The aim of this paper is to provide an integrated and uniform methodology for attributing environmental values in projects and incorporate this methodology into a user-friendly tool that can be used by anyone interested to participate in the EIA process. Thus, this research contributes to the environmental decision-making literature as well as to public participation in the EIA process. The rest of the paper is organized as follows: In Section 2, the content and the calculations performed of the proposed EIA tool are described. In Section 3, the function of the proposed EIA tool is presented. In Section 4, the proposed EIA Tool (EIAT) methodology is applied to evaluate different projects on the grounds of their overall environmental impacts. Finally, in the last section, conclusions and suggestions for further study are provided.

2 ASSESSMENT METHODOLOGY

The procedure of the proposed methodology is summarized in Fig. 1.

Certain environmental components and evaluation criteria are selected to include in the analysis through literature review, EIA studies and legislative requirements. Assessors include a wide range of people (public, interested public, consulted authorities, competent authorities, administering bodies, environmental permitting council and certified evaluators). Each assessor evaluates qualitatively all environmental issues in two timing periods (baseline and potential condition). The impacts of the construction and operation phase of the project are assessed through five assessment criteria and a final environmental score (ES) for the project evokes for every assessor by the use of the weighted sum model. The average value of all ESs constitutes the final ES for the assessed project.

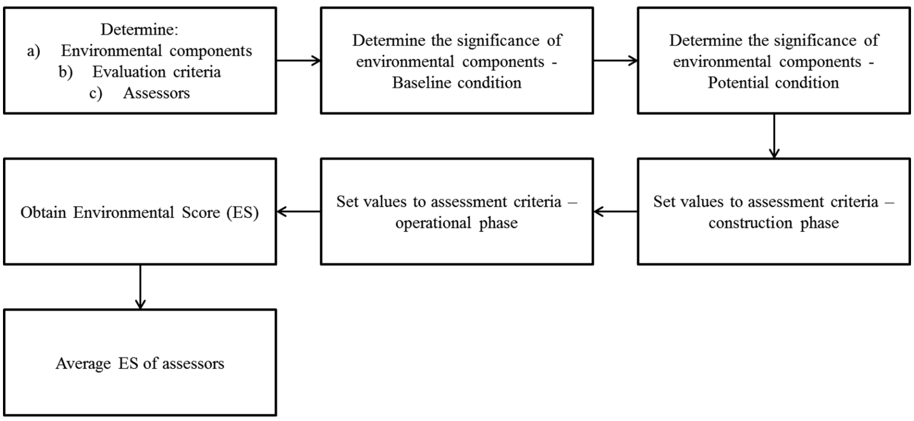

Figure 1: Procedure of the proposed methodology.

2.1 Environmental components

EIA studies refer to the change of some conditions in the ecosystem and/or the anthropogenic environment caused by the development and implementation of a project. In many cases, insufficient consideration of the significance of social and economic effects, and a failure to appreciate the implications for significance determination of the differences between socioeconomic and bio-physical impacts have been noticed [12].

In the area of multi-criteria analysis, the Rapid Impact Assessment Matrix (RIAM), which was introduced by Pastakia and Jensen [13] provides a tool that requires environmental components that fall into one of the following four categories: physical/chemical, biological/ecological, sociological/cultural and economic/operational. Although RIAM method was originally developed for comparison of alternatives within one project, Kuitunen *et al*. [14] later proved that RIAM can effectively be used to compare the environmental and social impacts of projects even when the cases assessed are different and share only a few common characteristics. In a modified RIAM, Ijäs *et al*. [15] categorized the impacts of the projects into three components: environmental impacts, social impacts and socioeconomic impacts.

In this study, the EIAT includes specific assessment components/criteria that are defined through the process of scoping, cover all aspects of abiotic, natural and anthropogenic environment and include the components described in Table 1.

The significance of the components mentioned in Table 1 is attributed using a weight, ranging from 1 (very low) to 5 (very high). Thus, all environmental issues are qualitatively evaluated, in two timing periods (baseline and potential condition), identifying the aspects that are the most urgent and critical for ensuring sustainability of the area.

2.2 Assessment criteria

An impact can be defined as the change of some conditions in the environment caused by the development and implementation of a project. Many criteria have been used so long, in order to determine what impacts may occur as a result of a project, activity or strategy.

Pastakia and Jensen [13] used assessment criteria that fall into two groups: (a) criteria that are of importance to the condition, that individually can change the score obtained (group A: importance of condition – A1 and magnitude of change/effect – A2) and (b) criteria that are of value to the situation, but should not individually be capable of changing the score obtained (group B: permanence – B1, reversibility – B2 and cumulative – B3). The judgments on each component are performed in accordance with certain criteria and scales. The scoring system requires simple multiplication of the scores given to each of the criteria in group (A). Scores for the value criteria Group (B) are added together to provide a single sum. The final assessment score for the condition is found by multiplying the sum of Group B scores by the result of the Group A scores. The ES ranges from −108 to 108, including 11 range bands.

Ijäs *et al*. in their study [15] modified the scoring system of RIAM by adding a sixth criterion (susceptibility of the target environment) to the framework and extending the ordinal scales used in criteria class B. The ES ranges from −192 to 192, including 9 range bands.

The assessment criteria used in EIAT are distinguished into two main groups: primary criteria (PC) that include nature of impact (P1) and magnitude of impact (P2) and secondary criteria (SC) that include permanence of impact (S1), reversibility of impact (S2) and confrontability of impact (S3). The scaling of the evaluation criteria is presented in Table 2.

Table 1: Description of environmental components.

C1: climate	The statistics of temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and other meteorological elemental measurements in a given region over long periods
C2: bioclimate	A climate, as it influences, and is influenced by, biological organisms
C3: morphology	The study of landforms, their nature, origin, processes of development and material composition
C4: aesthetics/visional features	The appearance of the land, including its shape, texture and colours
C5: geology	Pre-superficial formations and superficial deposits
C6: tectonics	The structures within the lithosphere of the Earth as well as the forces and movements that have operated in a region to create these structures
C7: Soils	A component of terrestrial ecosystems (top layer of the land surface), providing a growing medium for flora, and a habitat for fauna
C8: natural environment	The protected areas, the flora and fauna of the region
C9: land uses	Land use involves the management and modification of natural environment (fields, pastures, settlements, etc.) and contributes to the distinction of land use types in zoning
C10: built environment	The human-made surroundings that provide the setting for human activity
C11: historical and cultural environment	Archaeological, cultural and other historical resources
C12: socio-economic environment	Demographic features, population change, employment, occupation, education, income patterns
C13: infrastructure	The technical structures that support a society (roads, water supply, sewers, electrical grids, telecommunications, etc.)
C14: air quality	Air pollutants that affect health in varying degrees of severity. The emission of carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO and NO_2), ozone (O_3) and total suspended particulates mainly forms the quality of atmospheric environment
C15: acoustic environment – noise	The level of noise that prevails in the study area
C16: vibrations	Periodic or random mechanical oscillations about an equilibrium point
C17: radiation	The travel of energetic particles or energetic waves through a medium (ionizing, non-ionizing)
C18: surface waters and groundwater	Water collecting on the ground or in a stream, river, lake, wetland, or ocean as well as water located beneath the ground surface in soil pore spaces and in the fractures of rock formations

Table 2: Assessment criteria.

Criteria	Scaling	Description/explanation
P1	(1)	Improvement in status quo (+)
	(0)	No change (0)
	(−1)	Negative change to status quo (−)
P2	(1)	Low
	(2)	Moderate
	(3)	Significant
S1	(1)	Temporary/short term (few days, weeks, months)
	(2)	Temporary/medium term (approximately 1–10 years)
	(3)	Permanent/long term (more than 10–15 years)
S2	(0)	Not applicable (for positive impact)
	(1)	Reversible impact (mild changes – quick restoration of the environment)
	(2)	Slowly reversible impact (substantial changes – many years necessary for restoration)
	(3)	Irreversible (permanent changes – at least 15 years for restoration)
S3	(0)	Not applicable (for positive impact)
	(1)	Manageable (measures can totally eliminate the impacts)
	(2)	Partially manageable (measures can mitigate the impacts)
	(3)	Unmanageable (no measures can be adopted to confront the impacts)

2.3 Performance values

The impact significance is modeled as a multicriteria problem. The basic formula for the performance value (a_{ij}) is inspired by the ES provided by Pastakia and Jensen [13] and is as follows (eqns (1)–(3)):

$$(P1) \times (P2) = PT \tag{1}$$

$$(S1) + (S2) + (S3) = ST \tag{2}$$

$$(PT) \times (ST) = ES = a_{ij} \tag{3}$$

The total environmental performance (EP) of the project/activity is obtained using the weighted sum model, which is the simplest multi-criteria decision-making method for evaluating a number of alternatives in terms of a number of decision criteria. In this study, the four different alternatives are derived by combining the baseline and potential environmental condition of the environmental criteria in the study area with the construction and operational phase of the project life cycle.

The total value of each component of each alternative Ai is defined as follows:

$$Ai = w_j a_{ij}, \text{ for } i = 1, 2, 3, 4$$

Table 3: Environmental performance values and range bands.

Major positive impacts $6 < EP \le 9$	Significant positive impacts $4 < EP \le 6$	Moderate positive impacts $2 < EP \le 4$	Slight positive impacts $0 < EP \le 2$	No change – status quo 0
Slight negative impacts $-6 \le EP < 0$	Moderate negative impacts $-12 \le EP < -6$	Significant negative impacts $-18 \le EP < -12$	Major negative impacts $-27 \le EP < -18$	

EP, environmental performance.

where:
j = 1–18 Environmental components (C1–C18)
i = 1–4 1: existing condition (EC), construction phase (CP)
2: existing condition (EC), operation phase (OP)
3: potential condition (PC), construction phase (CP)
4: potential condition (PC), operation phase (OP)

As the negative impacts of an activity/project on the environment mainly forms the decision of whether to approve or not, the EP of the project/activity is calculated by summing up the minimum derived values of the environmental components of each alternative [16].

The EP fluctuates from −27 to 9 and the range bands are described in Table 3.

The assessment categories of major positive impacts to moderate negative impacts can be grouped together for interpretation purposes and suggest acceptance of the project or acceptance under either flexible or strict assumptions and restrictions. Thus, the critical boundary is that between moderate negative impacts and significant negative impacts, because these grades are awarded to projects where changes are accepted, with or without environmental conditions of approval, or totally rejected.

3 THE EIA TOOL

3.1 Administration panel

The administration panel is managed only by the administrator (relevant authorities could undertake this role), who is responsible for creating new projects and activities that are under the EIA procedure. It includes two cards entitled: (a) name of the projects and (some basic information about the project is entered and (b) user data for each project, the number of participants is revealed and the average EP is calculated. The results are stored in a database (CVS format) and statistical analysis can be performed in order to obtain all judgments concerning the EP of the proposed project. The administration panel is available at http://dimvag.webpages.auth.gr/ppieiap/admin/admin.php (contact the author: dimvag@auth.gr, for user name and password).

3.2 User interface

The whole system is a web application and each participant after selecting the appropriate project (Fig. 2), follows five simple steps and completes the relevant information. The user interface can be found at http://dimvag.webpages.auth.gr/ppieiap/.

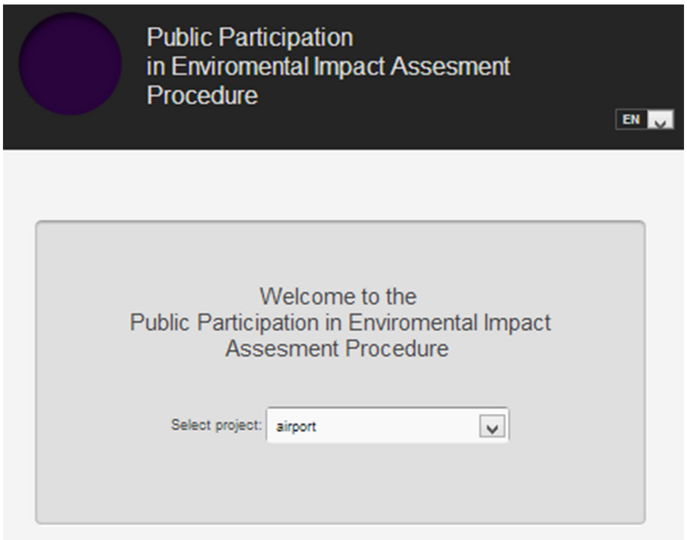

Figure 2: Selection of the desired project.

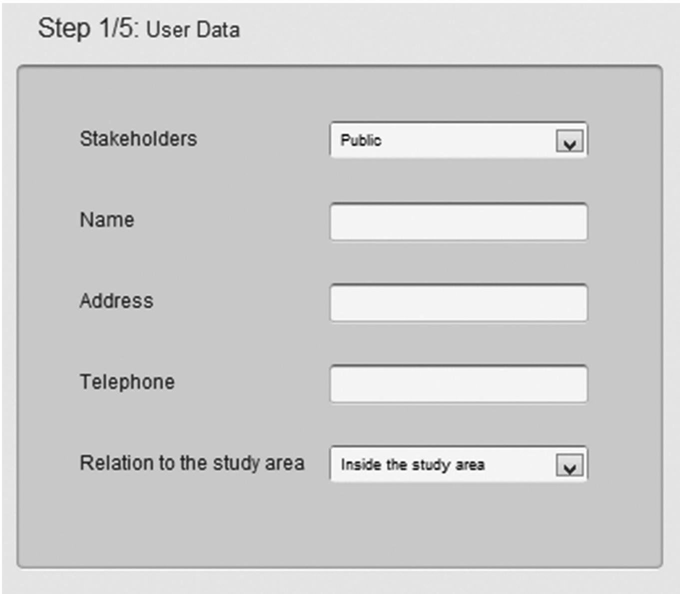

Figure 3: EIA tool – user data.

Step 1: Information about the user

In this step, the end-user fills down some optional information and states his affiliation (Fig. 3). For consulted authorities, who are considered as decision-making groups, a password is required in order to proceed to the next step. This protected field ensures the security and safety of the system

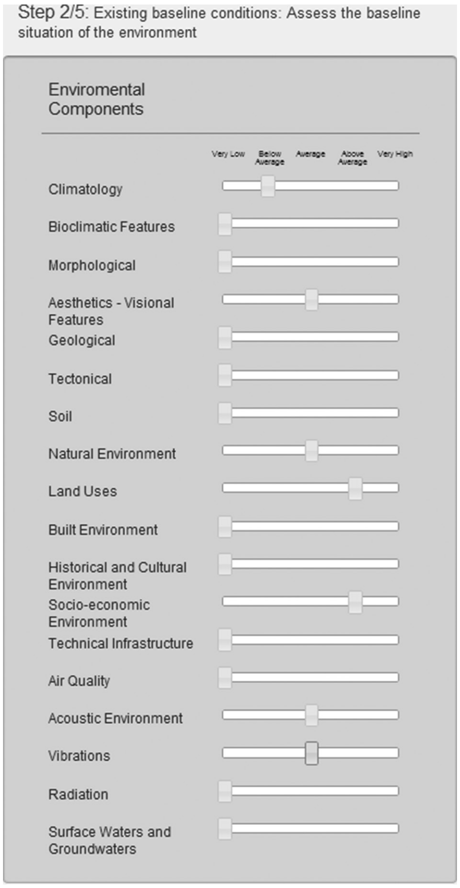

Figure 4: EIA tool – existing baseline conditions.

and the integrity and validity of the results. For public participation, this field is not protected and the uniqueness of their registration is checked by their Internet Protocol (IP) address. The users in this card also declare their relation to the study area.

Step 2–3: Existing and potential baseline environmental conditions

The user reveals his perception of the current (Fig. 4) and future (without the project) state of the environment and sets weights to each environmental component, using a five value scale.

Step 4–5: Impact assessment

The user assesses the impacts of the project under study on each environmental component, under certain criteria, by checking the relevant box (Fig. 5). The whole assessment is performed, considering the construction phase (Step 4) as well as the operational phase (Step 5) of the project. If the user enters the zero value in the field of nature, the options of the rest criteria (magnitude, duration, reversibility and confrontation) are automatically deactivated, while if the user selects the positive value in the field of nature, the options of reversibility and confrontation are deactivated.

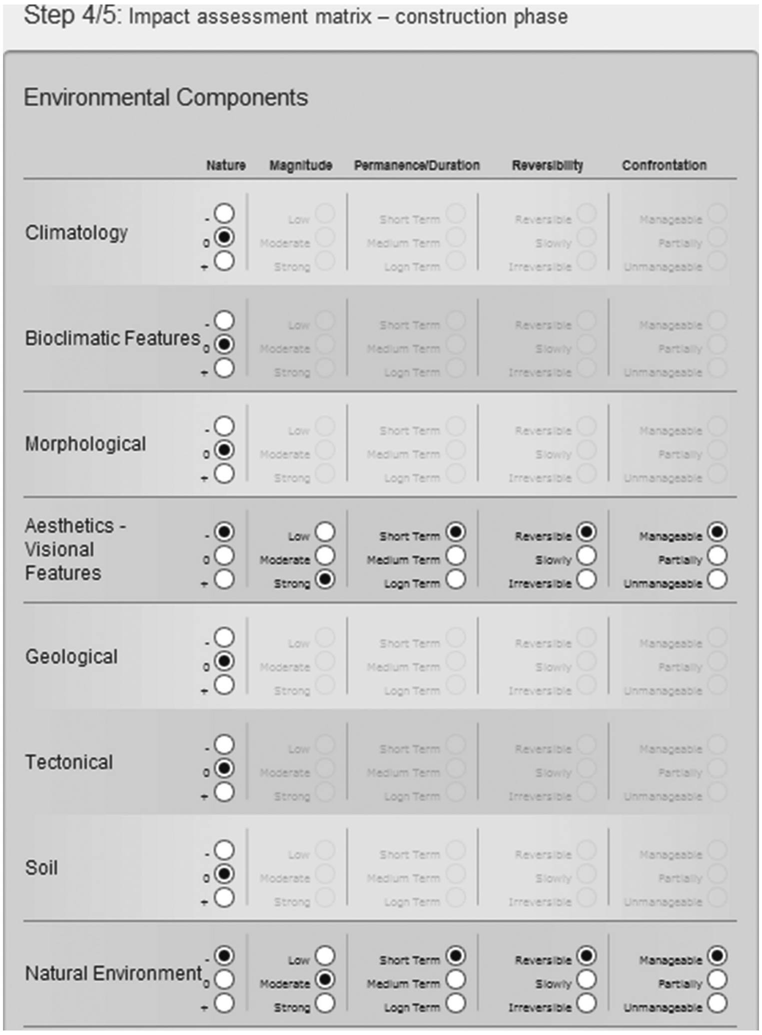

Figure 5: EIA tool – impact assessment (construction phase).

4 RESULTS

4.1 Application of the EIA tool

The EIA tool is used in order to evaluate the impact of different projects and actions that had been applied under the EIA process in Greece. The sample consists of 14 cases varying from tourism establishments and wind farms to wastewater management plants and mining industries. More specifically, four wind farms (EN1–EN4), two photovoltaic parks (EN5–EN6), two hotel resorts (TA1, TA2), one mining (M1), one waste water treatment plant (IP1), one airport (IP2), one river diversion project (IP3), one livestock unit (O1) and one poultry unit (O2) are examined. Table 4 presents the classification of the proposed project according to the Law 4014/2011.

The cases are evaluated by an assessment panel of 20 people, who are specially trained in environmental issues and are familiar with EIA studies. The evaluation process consists of two stages: the first stage includes a detailed presentation of EIA reports conducted by the proponent (Table 5), whereas the second one refers to the assessment of the panel through the proposed EIA tool.

Table 4: Background information of the assessed projects.

Project	Group	Category
EN1	Renewable Energy Resources – Group 10	A2
EN2	Renewable Energy Resources – Group 10	A1
EN3	Renewable Energy Resources – Group 10	B
EN4	Renewable Energy Resources – Group 10	A1
EN5	Renewable Energy Resources – Group 10	B
EN6	Renewable Energy Resources – Group 10	A2
TA1	Tourist facilities and urban development projects, building sector projects, sport and recreation projects – Group 6	A1
TA2	Tourist facilities and urban development projects, building sector projects, sport and recreation projects – Group 6	A1
M1	Mining and related activities – Group 5	A1
IP1	Environmental infrastructure systems – Group 4	B
IP2	Hydraulic projects – Group 2	A1
IP3	Land and air transport projects – Group 1	A1
O1	Livestock and poultry facilities – Group 7	B
O2	Livestock and poultry facilities – Group 7	A2

Table 5: Contents of EIA report.

Geographical and administrative location of the project
Aim and scope
Importance and necessity
Correlation with other projects
Detailed description of the project – development
Processes and technologies during construction and operation phase
Types and quantities of waste and residuals
Description of alternatives
Indication of likely area to affected
Description of the natural and anthropogenic environment of the study area
Identification and evaluation of key impacts (verbal assessment)
Proposed mitigation measures and monitoring rules
Supporting documentation (maps and drawings)

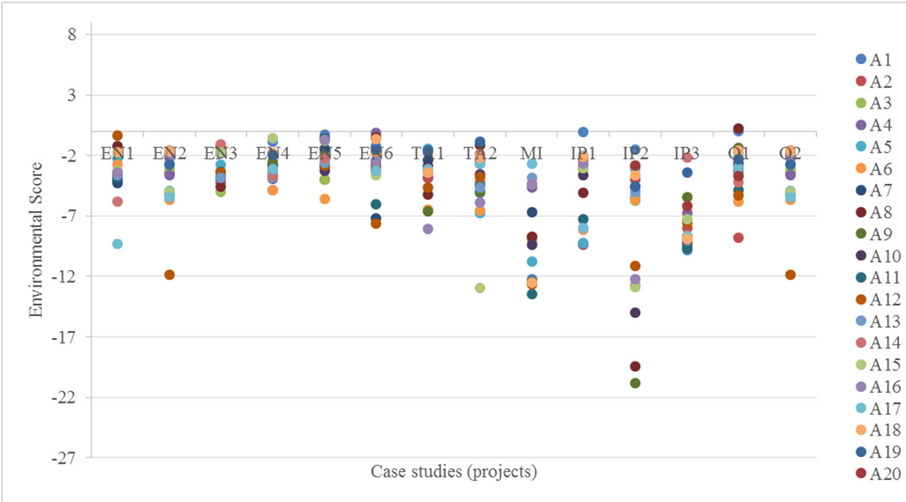

Figure 6: Environmental performance values.

The EP value of each project provided by each assessor individually (A1–A20) is depicted in Fig. 6.

4.2 Environmental performance values

The EP of each project given by each assessor arise from the calculations described in Section 2.3. The average value of all the assessments of each project forms the EP value of the project and is the final output of EIA tool (Fig. 7).

All the proposed projects are acceptable for implementation, if appropriate mitigation measures are followed. The mining industry (MI), the hydraulic project (IP2) and the airport (IP3) should necessarily conform to the proposed environmental rules, as they are expected to cause moderate negative impacts. The scores obtained are dependent on the character of the project with the energy-related projects to appear almost the same EP value.

Any assessment of the impacts is subjective, which means that despite the formula of EIA tool, the assessment may produce varying results depending on the assessor. This is verified by the findings provided in Fig. 8, where the impact significance categories of the projects provided by the assessment panel are revealed.

Most of the projects are evaluated by the majority of the assessors as changing the existing situation of the environment only slightly and having only low negative impacts. However, there is a minority of panelists that supports that some projects (TA2: grand hotel resort, MI: mining industry, IP2: hydraulic project, O2: poultry unit) should alter extremely negatively the characteristics of the environment and should be rejected.

The less and most important environmental components of each case study are presented in Table 6. Priority values of environmental components are strongly related to the baseline environmental conditions of the study area and may be indirectly connected to the type of the project.

Finally, the difference in how the different evaluation criteria are expressed in the final significant ratings of the proposed method was examined. A Spearman's Rank Order correlation was run to

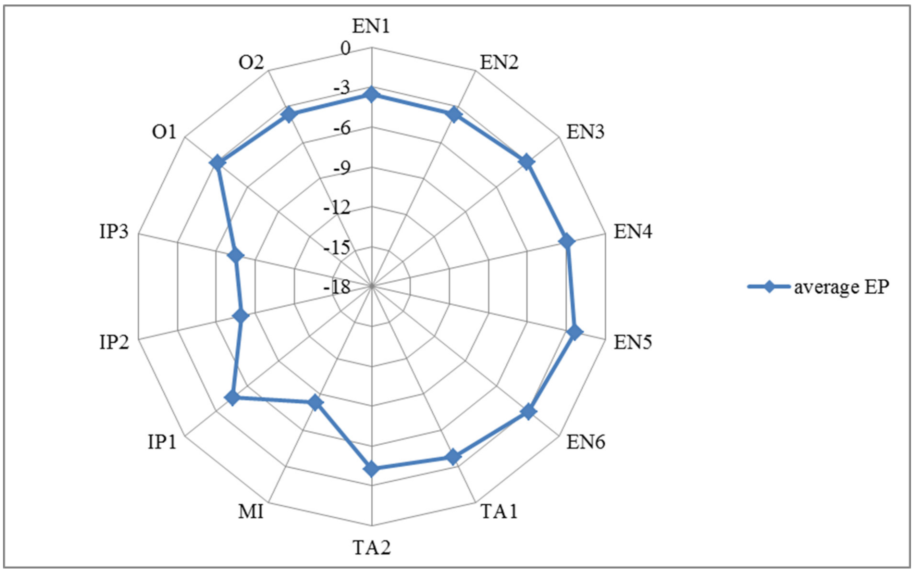

Figure 7: Significance evaluation of the assessed cases using the EIA tool.

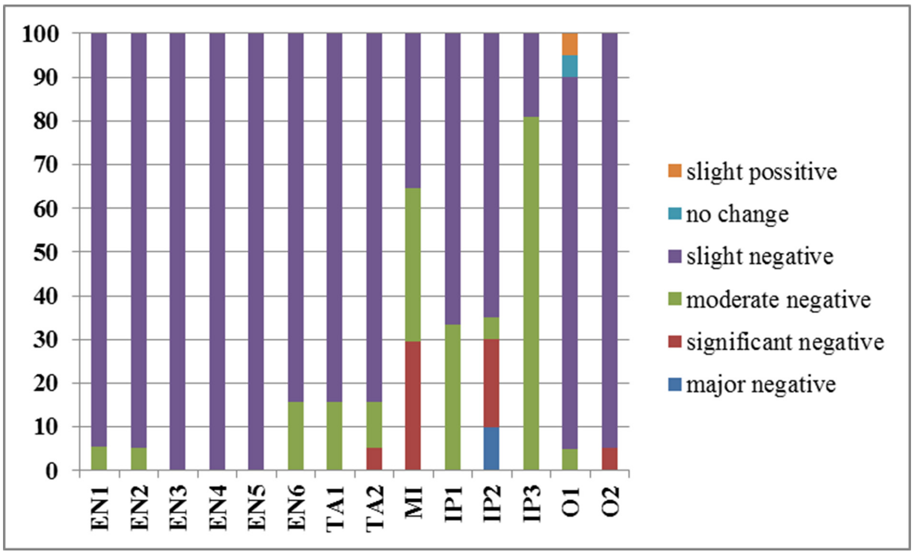

Figure 8: Significance evaluation of the assessed cases using the EIA tool.

determine the relationship between: ES, P1 × P2 and ES, S1 + S2 + S3. There was a strong, positive correlation between ES and primary criteria, which was statistically significant ($r_s = 0.783$, $p < 0.01$). With the sum of secondary criteria, the correlation was slightly smaller ($r_s = 0.719$, $p < 0.01$), indicating that both the values of primary criteria and secondary criteria explain the same the variation in the final EP.

Table 6: Lower and upper priority values of environmental components.

Proposed projects	Less important	Most important
EN1	Radiation	Natural environment
EN2	Historical and cultural environment	Socio-economic environment
EN3	Radiation	Aesthetics-/visional features
EN4	Radiation	Socio-economic environment
EN5	Historical and cultural environment	Socio-economic environment
EN6	Historical and cultural environment	Socio-economic environment
TA1	Radiation	Socio-economic environment
TA2	Historical and cultural environment	Socio-economic environment
MI	Radiation	Geology
IP1	Historical and cultural environment	Natural environment
IP2	Radiation	Surface waters and groundwater
IP3	Radiation	Acoustic environment – noise
O1	Radiation	Surface waters and groundwater
O2	Historical and cultural environment	Socio-economic environment

5 CONCLUSIONS

This research focuses on creating a useful tool that through a uniform multicriteria analysis methodology sets EP values in various projects/activities. This tool is expected to contribute to EIA procedures that are less biased, more collaborative and more effectively linked to EIA practice and decision making. The application of this tool will interest a wide range of people, from proponents, researchers, consultants, academics, regulators of EIA to non-governmental organizations, authorities and general public.

The proposed EIA tool could be used as an instrument to compare the environmental components even when projects are completely different. The method could be useful both for the proponents and relevant authorities, as it provides the necessary input to be taken into account for assessing the importance of different environmental components.

With the help of weighting the environmental components, the intrinsic values of the target area are brought to the evaluation process. Environmental components are of great importance for the general public when judging the predicted impacts and their significance. The number and the variety of environmental components (18 environmental components) broaden the framework on which evaluation process is performed, enabling the detailed definition of the impacts. The susceptibility of the target environment, which in previous methods [15] is considered as an assessment criterion, is investigated in this study as a separate environmental condition (potential environmental condition), including all the environmental components, defining in this way precisely the components that are susceptible to future changes.

The use of five different assessment criteria forces the participants to evaluate the environmental impacts with reference to many different features, which might otherwise be omitted during the assessment process. Although the primary criteria (nature of impact and magnitude of impact) generally dominate in the evaluation process, the role of secondary criteria is also proved to be significant (permanence of impact, reversibility of impact and confrontability of impact).

The use of the proposed methodology could be interpreted not only as giving absolute environmental values, but also as offering a framework on which the discussion about the environmental impacts of projects and activities can be based.

The EIA tool provides a brief, comprehensive and common for all types of projects report for EIA methodology that should contribute to the final decision upon projects and activities and therefore to the implementation of environmental and social accepted projects, contributing to the sustainable development of regions.

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