Integrating Social Impact Assessment and Environmental Conflict Analysis on a Hydrocarbon Exploration Project in Spain

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Abstract—Social impact assessment (SIA) has become a key factor for environmental conflicts prevention, which makes necessary to integrate SIA and environmental conflict analysis (ECA). In this article, we integrate SIA and ECA using a method based on grey systems and Shannon entropy. A case study was conducted on a hydrocarbon exploration project located in the Sea of the Gulf of Valencia, Spain. Four stakeholder groups and four evaluation criteria were identified. The results revealed that for group of specialists the project would have negative social impact; and contrary perceptions were found between the group ofprimary activities populationand the group of retirees. It was also noted that the criteria most likely to generate environmental conflicts were the percentage of unemployment and the GDP per capita. These results could help central and community governments to make the best decision on the project. The method showed interesting results and could be apply to manage other projects or programs from point of view of social factors.

Keywords: SIA, ECA, Grey systems, Shannon entropy, Hydrocarbon exploration project.

I. INTRODUCTION

Social impact assessment (SIA) is an important factor to prevent environmental conflicts caused by implantation of investment projects on natural resources[1]. SIA has been mainly conducted by qualitative methods, as evidenced by studies based on public participation [2], or game theory [3].In this study, we apply a quantitative method for SIA: the grey clustering method (The GC method), which is based on grey systems theory.Moreover,SIA is characterized by its high level of uncertainty [4]. Therefore, SIA should be conducted by a method, which considers the uncertainly. The GC method is an approach that considers the uncertainty within its analysis, and also it enables the classification of observed objects into definable classes, called grey classes [5], as evidenced by the studies on a water rights allocation system [6], or the classification of innovation strategic alliances [7]. Grey systems theory,which was established by Julong Deng, focuses on the study of problems with small samples or limited information available [8]. In the real world, there are many uncertain systems with small samples or limited information, this fact determines a broad range of applicability of the grey systems. For example: geographical information systems [9], health management [10], optimization [11], or safety management [12].

In turn, environmental conflict analysis (ECA) also is a key factor to prevent conflicts during planning and implementation of projects and programs, as evidenced by the studies on conflicts related to ecological tourism [13], or water management [14], [15]. ECA has been mostly conducted using qualitative methods, as showed by the study on environmental conflict from an infrastructure project [1], which was based on the capability perspective. In this study, we apply a quantitative method for ECA: the entropy-weight method (the EW method), which is based on Shannon entropy theory. Shannon proposed the concept of entropy as a measure of uncertainty in information, formulated in terms of probability theory [16]. The concept of entropy is well suited to identify the contrast criteria for decision-making [17].Subsequent research on Shannon entropy has contributed to the resolution of problems in areas such as: pollution [18], water quality [19], management [20], or fault detection [21].

Furthermore, stakeholders are an important dimension for integrated assessment [22], and environmental conflicts are generated between stakeholder groups within affected population [23], [24]. Therefore, first SIA should be conducted for each stakeholder group, and then by ECA, the differences between them should be determined, in order to prevent possible environmental conflicts [1].This fact makes that SIA and ECAshould be

integrated. The combination of the GC method and the EW method could integrate SIA and ECA. First, the GC method assesses social impact by quantifying of information from stakeholder groups. And then, the EW method identifies criteria, for which, there is the most divergence between stakeholder groups within of project under scrutiny.

Subsequently, in order to apply and test the integrated method, we conducted a study of SIA and ECA on a hydrocarbon exploration project in the Sea of the Gulf of Valencia, Spain.This hydrocarbon exploration project consists of the application of ultrasound technology, in order to determine the existence of hydrocarbon deposits in the marine subsoil [25]. The company presented environmental impact assessment (EIA) to Spain government in 2012, but at the present (2016) this project is paused due to the fact that a part of the population of Valencia city manifests opposition to the implementation of the project.

The specific objectives of this article are to:

1. Integrate SIA and ECA using the GC method and the EW method.

2. Apply the integrated method to the concrete context of the hydrocarbon exploration project in the Sea of the Gulf of Valencia, Spain.

Section 2 provides details of the methodology to integrate SIA and ECA. In Section 3 the case study is described, followed by the results and discussion in Section 4. Conclusions are provided in Section 5.

II. METHODOLOGY

This section describes SIA using the GC method, ECA using the EW method, and provides the details of the integrated method for SIA and ECA.

A. The GC method for SIA

The GC method was developed to classify objects of observation into definable classes, and can be performed by means grey incidence matrices or whitenization weight functions. Whitenization weight functions are mainly used to test whether the objects of observation belong to predetermined classes. In this study, we use center-point triangular whitenization weight functions (CTWF), because typically people tend to be more certain about the center-points of grey classes in comparison with other points of the grey class. So, the conclusions based on this cognitive certainty could be more scientific and reliable [5].

The GC method based on CTWF can be described as follows [5], [7], [26]: first, assume that there are a set of m objects, a set of n criteria, and a set of s grey classes; according to the sample value x_{ij} (i=1, 2 ,…, m; j=1, 2, …, n). Then, the steps of the GC method based on CTWF can be developed as follows:

Step 1: The ranges of the criteria are divided into s grey classes, and then center-points $\lambda_1, \lambda_2,…, \lambda_s$ of grey classes 1, 2, …, s are determined.

Step 2: The grey classes are expanded in two directions, adding the grey classes 0 and (s+1) with their center-points λ_0 and λ_{s+1} respectively. The new sequence of center-points is $\lambda_0, \lambda_1, \lambda_2,…, \lambda_s, \lambda_{s+1}$, see details in Fig. 1. For the kth grey class, k=1, 2,…, s, of the jth criterion, j=1, 2,…, n, for an observed value x_{ij}, the CTWF is calculated by Eq. (1).

$$f_j^k(x_{ij}) = \begin{cases} 0 & , \quad x \notin [\lambda_{k-1}, \lambda_{k+1}] \\ \dfrac{x - \lambda_{k-1}}{\lambda_k - \lambda_{k-1}}, & x \in [\lambda_{k-1}, \lambda_k] \\ \dfrac{\lambda_{k+1} - x}{\lambda_{k+1} - \lambda_k}, & x \in [\lambda_k, \lambda_{k+1}] \end{cases} \qquad (1)$$
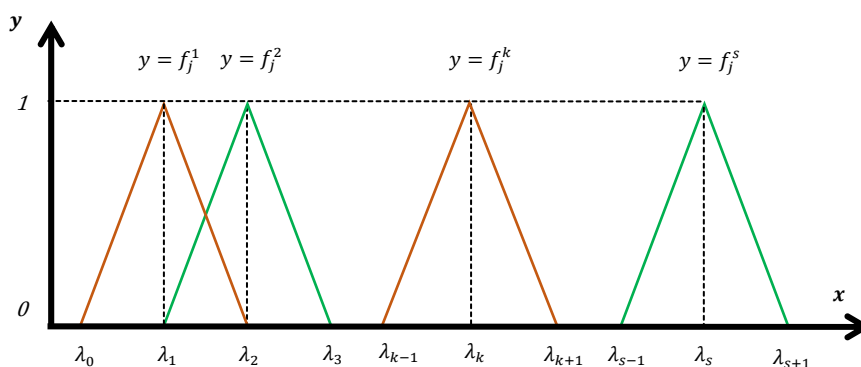

Fig. 1. CTWF [5]

Step 3: The comprehensive clustering coefficient σ_i^k for object i, i=1, 2,…, m, with respect to the grey class k, k=1, 2,…, s, is calculated by Eq. (2).

$$\sigma_i^k = \sum_{j=1}^{n} f_j^k(x_{ij}) . \eta_j \qquad (2)$$

where $f_j^k(x_{ij})$ is the CTWF of the kth grey class of the jth criterion, and η_{lj} is the weight of criterion j.

Step 4: If $\max_{1 \le k \le s}\{\sigma_i^k\} = \sigma_i^{k*}$, we decide that object i belongs to grey class k*. When there are several objects in grey class k*, these objects can be ordered according to the magnitudes of their comprehensive clustering coefficients.

B. The EW methodfor ECA

The EW method can be developed as follows [26]–[28]: first, assume that there are m objects for evaluation and n evaluation criteria, which form the decision matrix $Z = \{z_{ij}; i = 1, 2, ..., m; j = 1, 2, ..., n\}$. Then, the steps of the EW method can be expressed as follows:

Step 1: The decision matrix $Z = \{z_{ij}; i = 1, 2, ..., m; j = 1, 2, ..., n\}$ is normalized for each criterion C_j (j=1, 2,..., n). The normalized values P_{ij} are calculated by Eq. (3).

$$P_{ij} = \frac{z_{ij}}{\sum_{i=1}^{m} z_{ij}} \qquad (3)$$

Step 2: The entropy H_j of each criterion C_j is calculated by Eq. (4).

$$H_j = -k \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \qquad (4)$$

k is a constant, let k = (ln(m))$^{-1}$.

Step 3: The degree of divergence div_j of each criterion C_j is calculated by Eq. (5).

$$div_j = 1 - H_j \qquad (5)$$

Step 4: The entropy weight w_j of each criterion C_j is calculated by Eq.(6).

$$w_j = \frac{div_j}{\sum_{j=1}^{n} div_j} \qquad (6)$$

C. Integrating SIA and ECA

The integrated method consists of five steps, of which the three first steps correspond to SIA, which are based on the GC method; and the two final steps correspond to ECA, which are based on the EW method, as shown in Fig. 2.
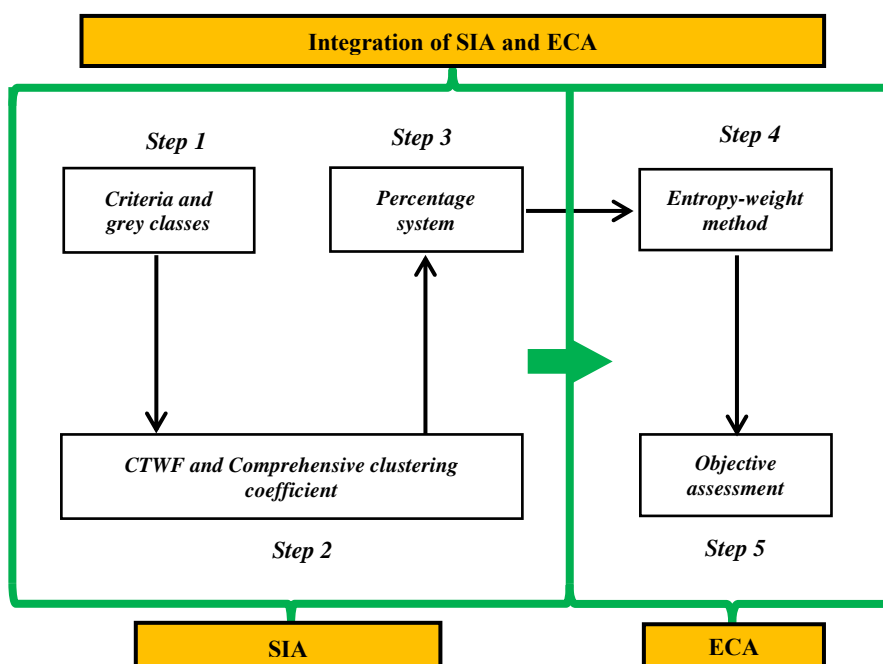

Fig. 2. Schema of the integration of SIA and ECA

First, the integrated method can be described by means the following sets:

- A set of m stakeholder groups called G = {G_1, G_2,..., G_m}
- A set of n criteria called C = {C_1, C_2,..., C_n}
- A set of s grey classes called V = {V_1, V_2,..., V_s}
- A set of evaluation values called X = {x_{ij}, i = 1, 2,..., m; j = 1, 2,..., n} of G_i (i = 1, 2,..., m) with respect to the criterion C_j(j = 1, 2,..., n)

Then, the steps of the Integrated method are described as follows [26]:

Step 1:Criteria and grey classes

A set of n criteria for SIA, determined by C_j (j=1, 2,…, n), is established; and a set of s grey classes, determined by V_k (k=1, 2,…, s), is defined.

Step 2:CTWF and Comprehensive clustering coefficient

The CTWF values of each stakeholder group are obtained using Eq. (1). Then, the comprehensive clustering coefficients σ_i^k for object i, i=1, 2,…, m, with respect to the grey class k, k=1,…, s, are calculated using Eq. (2).

Step 3:Percentage system

SIA finishes with a percentage system [26], [29], defined by the values α_1, α_2, α_3,…, and α_s, where α_s=100, α_1=100/s, α_2=α_1+α_1, α_3=α_1+α_2, …, and α_{s-1}=α_1+α_{s-2}; s is the number of grey classes defined. The results for each stakeholder group are given by Eq. (7).

$$z_j^i = \sum_{k=1}^{s} f_j^k(x_{ij}) \cdot \alpha_k \tag{7}$$

where $f_j^k(x_{ij})$ is CTWF of the kth grey class of the jth criterion and α_k is the percentage value of each grey class. The results are represented by the matrix determined by Eq. (8).

$$Z = z_j^i = \{z_{ij}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n\} \tag{8}$$

Step 4:Entropy-weight method

ECA is carried out by applying the EW method. First, using Eq. (3). The normalized values P_{ij} of the matrix $Z = z_j^i = \{z_{ij}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n\}$ are calculated. Then, H_j, div_j and w_j are determined using Eqs. (4)-(6).

Step 5:Objective assessment

The final step of ECA involves calculating the objective assessment [20], [26] of each stakeholder group i, i=1, 2,…, m, for each criterion C_j(j=1, 2,..., n). The objective assessment value is defined by Eq. (9).

$$Q_{ij} = w_j z_{ij} \tag{9}$$

where w_j is the entropy weight for each criterion C_j and z_{ij} is the result of SIA for each stakeholder group. The results are represented by the matrix defined by Eq. (10).

$$Q_{ij} = \begin{bmatrix} w_1 z_{11} & w_2 z_{12} & \ldots & w_n z_{1n} \\ w_1 z_{21} & w_2 z_{22} & \ldots & w_n z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1 z_{m1} & w_2 z_{m2} & \ldots & w_n z_{mn} \end{bmatrix} \tag{10}$$

III.CASE STUDY

SIA and ECA were performed for a project located in the Sea of the Gulf of Valencia in Spain, as shown in Fig. 3. The concerned company proposes to conduct the hydrocarbon exploration by means a campaign of 3D seismic acquisition in zones B, G, AM-1 and AM-2, indicated on the map [25]. Ultrasound technology was proposed to be used to determine the existence of hydrocarbon deposits in the marine subsoil. This study was conducted on the city of Valencia, located into the zone of influence of the project.
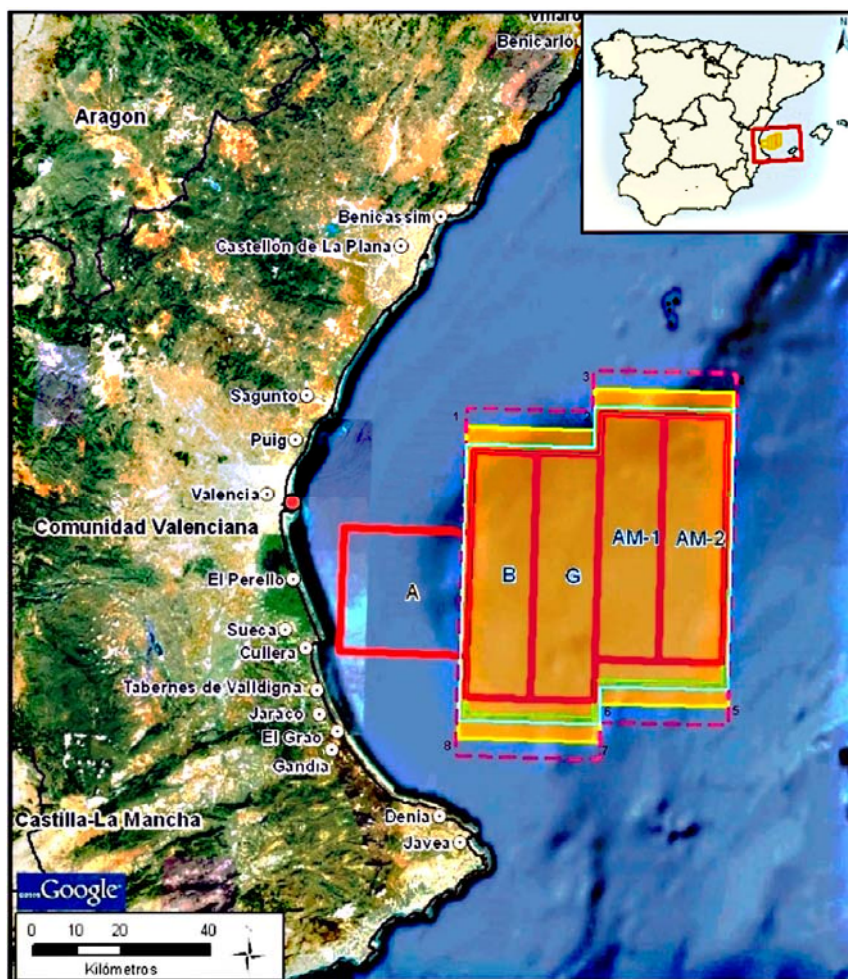
Fig. 3. Project location[25]

A. Stakeholder Groups

During the field work, we identified four different stakeholder groups (k=4), the composition of these groups was determined according to similarities found during the overall assessment on the hydrocarbon exploration project [26]. The sample size in each group was determined by means the principle of saturation of discourse, which establish that information gathering should end when respondents do not produce new information relevant to object of study [30]. The stakeholder groups are presented in Table I:

TABLE I. Stakeholder groups in the case study

Stakeholder group	Description
G1: Primary activities population	It was composed of those members of the population who are directly linked with the impacts of the project, consisting of people undertaking productive activities related to fishing or tourism (see Fig. 4). This group was made up of thirty interviewees.
G2: University students	It was composed of students with no links to productive activities related to fishing or tourism (see Fig. 5). This group was made up of thirty interviewees.
G3: Retirees	It was composed of retirees (see Fig. 6). This group was made up of fifteen interviewees.
G4: Specialists	It was composed of experts from different fields who are familiar with the area of influence and the characteristics of the environmental and social impacts of hydrocarbon exploration projects (see Fig. 7). This group was made up of eight interviewees.

Fig. 4. Directly affected populationFig. 5. University students

Fig. 6. RetireesFig. 7. Specialists

B. Calculations using the integrated method

The calculations for the case study, based on the integrated method, are preceded as follows.

Step 1: Criteria and grey classes

a.   Evaluation criteria

The criteria for the case study were established by taking into account to the economic and social situation of the city of Valencia and the characteristics of the project, and by consulting with experts. The social criteria are directly linked to the economic criteria, due to the fact that social conflicts in Spain are related to the economic crisis facing the country. Four criteria (n=4) were identified as shown in Fig. 8.
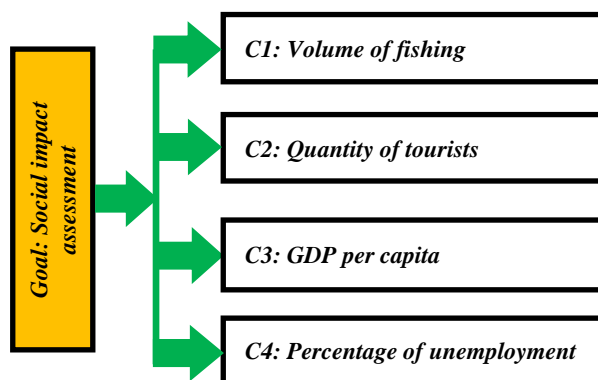

Fig. 8. Criteria system of the case study

The established criteria are described in Table II.

TABLE II. Evaluation criteria in the case study

Criterion	Description
C1	It measured the change in the volume of fishing in the ComunitatValenciana, with the baseline figure being taken as the volume of fishing in 2013, which was 31,29 thousand tonnes of fish [31].
C2	It measured the change in the number of foreign tourists visiting the ComunitatValenciana, with the baseline figure being taken as the number of foreign tourists in 2013, which was 5.97 million [31].
C3	It measured the change in quantity of GDP per capita in the ComunitatValenciana, with the baseline figure being the GDP per capita in 2013, which was 19,500 euros per year [32].
C4	It measured the change in the percentage of unemployment in the ComunitatValenciana, with the baseline figure being the unemployment rate in 2013, which was 28.05% [31].

b. Grey classes

Five grey classes (s = 5) for the case study were established according to the historical information from 2009 to 2013 [31], [32], and by the consultation with experts, in order to satisfy the need to reflect the characteristics of the specific region as accurately as possible [5]. All the criteria had the same weight ($\eta_j = 0.250$), as they are social criteria [30]. The grey classes established for each criterion are shown in Table III.

TABLE III. Grey classes for each criterion in the case study

Criterion	Grey classes				
	Very Negative (V1)	Negative (V2)	Normal (V3)	Positive (V4)	Very Positive (V5)
C1	$25.07 \leq x_1^1 \leq 27.56$	$27.56 \leq x_1^2 \leq 30.05$	$30.05 \leq x_1^3 \leq 32.54$	$32.54 \leq x_1^4 \leq 35.03$	$35.03 \leq x_1^5 \leq 37.52$
C2	$04.78 \leq x_2^1 \leq 05.26$	$05.26 \leq x_2^2 \leq 05.73$	$05.73 \leq x_2^3 \leq 06.21$	$06.21 \leq x_2^4 \leq 06.68$	$06.68 \leq x_2^5 \leq 07.16$
C3	$18.66 \leq x_3^1 \leq 19.00$	$19.00 \leq x_3^2 \leq 19.33$	$19.33 \leq x_3^3 \leq 19.67$	$19.67 \leq x_3^4 \leq 20.00$	$20.00 \leq x_3^5 \leq 20.34$
C4	$33.52 \leq x_4^1 \leq 37.16$	$29.87 \leq x_4^2 \leq 33.52$	$26.23 \leq x_4^3 \leq 29.87$	$22.58 \leq x_4^4 \leq 26.23$	$18.94 \leq x_4^5 \leq 22.58$

Step 2: CTWF and the comprehensive clustering coefficient

The data obtained from the stakeholder groups were processed using CTWF. The grey classes were extended in two directions by adding the grey classes V_0 and V_6 ("extra negative" and "extra positive", respectively), with their center-points λ_0 and λ_6. Therefore, the new sequence of center-points was λ_0, λ_1, λ_2, λ_3, and λ_6, as shown in Table IV and Fig. 9.

Table IV. Center-points of the extended grey classes in the case study

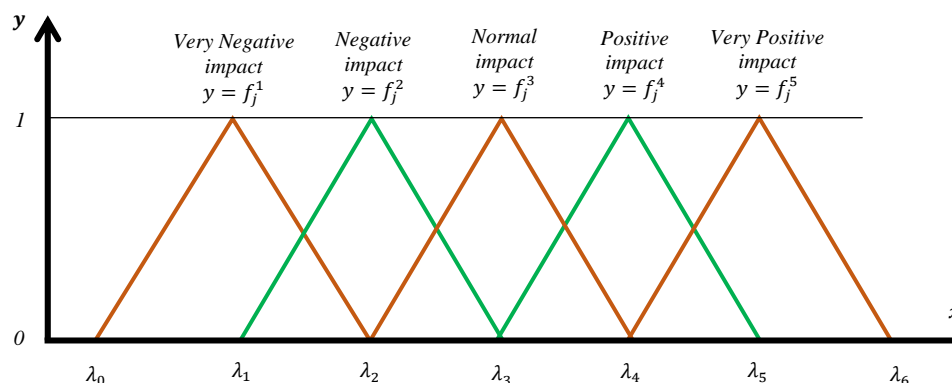| Criterion	Center-points of the extended grey classes						
	Extra negative impact (λ_0)	Very negative impact (λ_1)	Negative impact (λ_2)	Normalimpact (λ_3)	Positive impact (λ_4)	Very positive impact (λ_5)	Extra positive impact (λ_6)
C1	23.82	26.31	28.80	31.29	33.78	36.27	38.76
C2	04.55	05.02	05.50	05.97	06.45	06.92	07.40
C3	18.50	18.83	19.17	19.50	19.84	20.17	20.51
C4	38.99	35.34	31.70	28.05	24.41	20.76	17.12

Fig. 9. CTWF for the case study

As illustration, for the first criterion C1 (j=1) shown in the first row of Table III and Table IV, we have the grey classes: V_1= [25.07; 27.56], V_2= [27.56; 30.05], V_3= [30.05; 32.54], V_4= [32.54; 35.03], and V_5= [35.03; 37.52]; with their center-points: λ_1=26.31, λ_2=28.80, λ_3=31.29, λ_4=33.78, and λ_5=36.27. The grey classes were then expanded in two directions by adding the grey classes V_0= [22.58; 25.07] and V_6 = [37.52; 40.01], with their centres λ_0=23.82 and λ_6=38.76. Thus, we obtained a new sequence of centres: λ_0, λ_1, λ_2, λ_3, and λ_6. The values were substituted into Eq. (1), to obtain the CTWF of the five grey classes. The results for the first criterion C1 are shown in Eqs. (11)-(15):

$$f_1^1(x) = \begin{cases} 0, & x \notin [23.82\,, 28.80] \\ \dfrac{x - 23.82}{2.49}, & x \in [23.82\,, 26.31] \\ \dfrac{28.80 - x}{2.49}, & x \in [26.31\,, 28.80] \end{cases} \quad (11)$$

$$f_1^2(x) = \begin{cases} 0, & x \notin [26.31\,, 31.29] \\ \dfrac{x - 26.31}{2.49}, & x \in [26.31\,, 28.80] \\ \dfrac{31.29 - x}{2.49}, & x \in [28.80\,, 31.29] \end{cases} \quad (12)$$

$$f_1^3(x) = \begin{cases} 0, & x \notin [28.80\,, 33.78] \\ \dfrac{x - 28.80}{2.49}, & x \in [28.80\,, 31.29] \\ \dfrac{33.78 - x}{2.49}, & x \in [31.29\,, 33.78] \end{cases} \quad (13)$$

$$f_1^4(x) = \begin{cases} 0, & x \notin [31.29, 36.27] \\ \dfrac{x - 31.29}{2.49}, & x \in [31.29\,, 33.78] \\ \dfrac{36.27 - x}{2.49}, & x \in [33.78\,, 36.27] \end{cases} \quad (14)$$

$$f_1^5(x) = \begin{cases} 0, & x \notin [33.78\,, 38.76] \\ \dfrac{x - 33.78}{2.49}, & x \in [33.78\,, 36.27] \\ \dfrac{38.76 - x}{2.49}, & x \in [36.27\,, 38.76] \end{cases} \quad (15)$$

The information from stakeholder groups was gathered by means of direct interviews using a structured questionnaire based on the evaluation criteria and grey classes established for the case study. The questions used are presented in Table V.

TABLE V. Questions used in the questionnaire for the case study

Question		Grey classes				
		VeryNegative(V$_1$)	Negative (V$_2$)	Normal (V$_3$)	Positive (V$_4$)	Very Positive (V$_5$)
1	What effect would the project have on the volume of fishing?	Decrease noticeably	Decrease	No effect	Increase	Increase noticeably
2	What effect would the project have on the quantity of tourists?	Decrease noticeably	Decrease	No effect	Increase	Increase noticeably
3	What effect would the project have on the GDP per capita?	Decrease noticeably	Decrease	No effect	Increase	Increase noticeably
4	What effect would the project have on the percentage of unemployment?	Increase noticeably	Increase	No effect	Decrease	Decrease noticeably

Table VI shows the overall results of evaluation from four stakeholder groups (m = 4) for each criterion. These data were aggregated using the arithmetic mean [33].

TABLE VI. Aggregated values of each criterion for groups G1, G2, G3 and G4

Group	C1	C2	C3	C4
G1	26.81	05.16	18.85	34.98
G2	26.89	05.59	19.53	26.96
G3	30.13	05.88	19.92	22.22
G4	27.87	05.61	19.42	27.14

Then, for group G1, the values of CTWF were calculated using Eqs. (11)-(15). Subsequently, the comprehensive clustering coefficient (σ_i^k) was calculated for each stakeholder group using Eq. (2). The values of CTWF and σ_i^k obtained for group G1 (m=1) are shown in Table VII.

TABLE VII. Values of CTWF and σ_i^k for group G1

$f_j^k(x)$	C1	C2	C3	C4	σ_i^k
$f_j^0(x)$	0.8000	0.7000	0.9333	0.9000	0.8333
$f_j^1(x)$	0.2000	0.3000	0.0667	0.1000	0.1667
$f_j^2(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
$f_j^3(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
$f_j^4(x)$	0.0000	0.0000	0.0000	0.0000	0.0000

Step 3: Percentage system

The final stage of SIA for the case study involved the employment of a percentage system defined by the values α$_1$, α$_2$, α$_3$, α$_4$, and α$_5$; where α$_5$=100, α$_1$=100/5=20, α$_2$=α$_1$+α$_1$=40, α$_3$=α$_1$+α$_2$=60, and α$_4$=α$_1$+α$_3$=80; according to five grey classes established, as shown in Table VIII. Then, SIA for group G1 was calculated using Eq. (7). The results are presented in Table IX.

TABLE VIII. The percentage system determined in the case study

Impact class	Interval	$α_k$
Very negative	[20, 30]	20
Negative	[30, 50]	40
Normal	[50, 70]	60
Positive	[70, 90]	80
Very positive	[90, 100]	100

TABLE IX. Results of SIA for group G1

Impact class	$α_k$	C1	C2	C3	C4	Total
Very negative	20	16.00	14.00	18.67	18.00	16.67
Negative	40	08.00	12.00	02.67	04.00	06.67
Normal	60	00.00	00.00	00.00	00.00	00.00
Positive	80	00.00	00.00	00.00	00.00	00.00
Very positive	100	00.00	00.00	00.00	00.00	00.00
	SIA	24.00	26.00	21.33	22.00	23.33
		Very negative	**Very Negative**	**Very negative**	**Very negative**	**Very negative**

The values of SIA for groups G2, G3 and G4 were obtained using the same procedure as for group G1. The results for all stakeholder groups are presented in Table X.

TABLE X. Results of SIA for groups G1, G2, G3 and G4

Group	C1	C2	C3	C4	Total	Impact class
G1	24.00	26.00	21.33	22.00	23.33	Very negative
G2	24.67	44.00	62.00	66.00	49.17	Negative
G3	50.67	56.00	85.33	92.00	71.00	Positive
G4	32.50	45.00	55.00	65.00	49.38	Negative

Step 4: Entropy-weight method

ECA for the case study was carried out by applying the EW method. First, the criteria values shown in Table X were normalized using Eq. (3). The normalized values are shown in Table XI. Then, H_j, div_j, and w_j were calculated using Eqs. (4)-(6). The results are shown in Table XII.

TABLE XI. Normalized results of SIA for groups G1, G2, G3 and G4

Group	C1	C2	C3	C4
G1	0.182	0.152	0.095	0.090
G2	0.187	0.257	0.277	0.269
G3	0.384	0.327	0.382	0.376
G4	0.247	0.263	0.246	0.265

TABLE XII. Values of H_j, div_j and w_j for each criterion

	C1	C2	C3	C4
H_j	0.964	0.976	0.932	0.930
div_j	0.036	0.024	0.068	0.070
w_j	0.182	0.123	0.343	0.353

Step 5: Objective assessment

ECA for the case study was completed by calculating objective assessment of each stakeholder group i, i=1, 2, 3, 4, for each criterion C_j (j=1, 2, 3, 4). The results were obtained using Eq. (9), as shown in Table XIII.

TABLE XIII. Objective assessment scores for each group

Group	C1	C2	C3	C4
G1	04.36	03.20	07.31	07.76
G2	04.48	05.41	21.24	23.28
G3	09.21	06.89	29.23	32.45
G4	05.91	05.53	18.84	22.92

IV. RESULTS AND DISCUSSION

The results and discussion, according to objectives in this study, are presented below.

A. The potential of the integrated method to SIA and ECA

First, SIA is a topic with high level of uncertainty; therefore, it should be analysed by methods, which consider the uncertainty. Some classical approaches of multi-criteria analysis, such as Delphi [34], [35] or analytic hierarchy process (AHP) [36], [37], do not consider the uncertainty within their analysis, due to the fact that the importance degrees of criteria and performance scores of alternatives are assumed to be known precisely [38]. In addition, some options to model the uncertainly can be fuzzy logic approaches [39], probabilistic approaches [40] or grey systems approaches [5].

Second, Approaches based on fuzzy logic, such as fuzzy analytic hierarchy process (FAHP) [39], [41], emphasize the investigation of problems with cognitive uncertainty, which research objects possess the characteristic of clear intention and unclear extension. The focus of approaches based on grey systems theory is on the uncertainty problems, which the research objects possess the characteristic of unclear intention and clear extension [5]. SIA has clear extension of the criteria on a study determined; for example, in a historic range of five years, we can know the minimum and maximum value of a social variable under analysis. In addition, affected population of a determined project could be clear about when things were good or bad: before or after project implementation [26].

Third, in statistical approaches the concept of large samples represents the degree of tolerance to incompleteness [5], and considering that one of the criteria for evaluating methods can be the cost [4], in this aspect an approach based in grey systems would have a lower cost with respect to a statistical approach, due to the fact that sample size influences on the cost during the field work. In addition, in 1994, JiangpingQiu and Xisheng Hua established a comparison between statistical regression model and grey model on the deformation and leakage data of a certain large scale hydraulic dam. Their work showed that their grey model could provide a better fit than the statistical regression model [5].

Therefore, it could be argued that the GC method based on grey systems theory would benefit SIA, as it considers the uncertainty within its analysis. In addition, the grey clustering method would be more adequate than approaches based on fuzzy logic, as it considers clear extension for evaluation criteria. Furthermore, the GC method could be more effective and would have a lower cost than other statistical approaches during its application.

In turn, ECA is a social topic, which also has high level of uncertainty. ECA could be conducted by classical multi-criteria methods [4], or by statistical approaches [5]. However, classical multi-criteria methods do not consider the uncertainty within their analysis [38]. In addition, statistical approaches would have high cost during the field work [4]. ECA could be carried out by means the EW method based on Shannon entropy, which is a method that also considers the uncertainty within its analysis [17]. Therefore, the EW method and the GC methodare a good option to integrate SIA and ECA,both under the same philosophy.

B. The case study

1. Analysis of findings from calculations

The calculations for the case study produced three important findings, which are discussed below.

First, the major tensions among stakeholder groups were identified. Fig. 10 (based on Table X) shows a strong antagonism between groups G1 (primary activities population) and G3 (retirees), despite the fact that the specialists (G4) expressed the opinion that the project would have a negative social impact. The results indicate that G1 and G3, presented contradictory views on the project, these differences suggest potential conflicts between G1 and G3 groups. In order to analyse and more fully understand the mechanisms and forces at play, we need to look at the specific criteria of conflict between G1 and G3, which points to our second important finding.
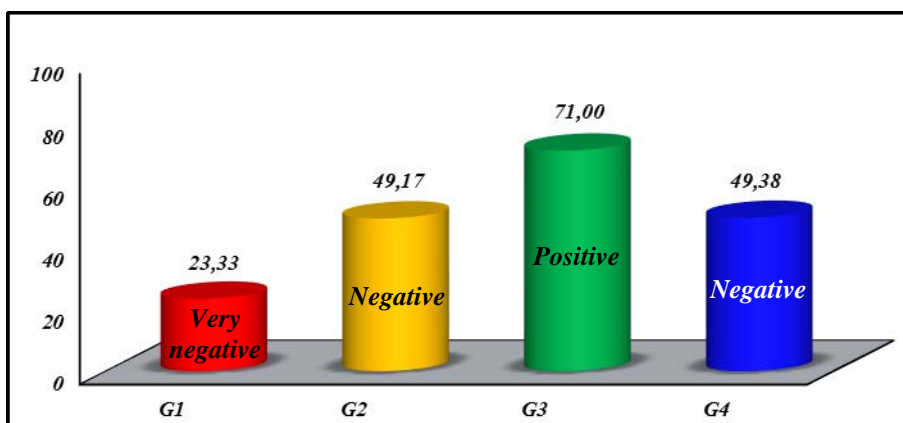
Fig. 10. Values of SIA of each group

Second, Figure 11 based on Table X shows the behaviour of the criteria for G1 and G3 groups: for group G1, all the criteria are in the "very negative" range; for group G3, C1 and C2 are placed in the range of "normal", C3 is found in the range of "positive", and C4 is in the range of "very positive". These results suggest a specific comparison of all these criteria, in order to identify the most controversial criteria among them.
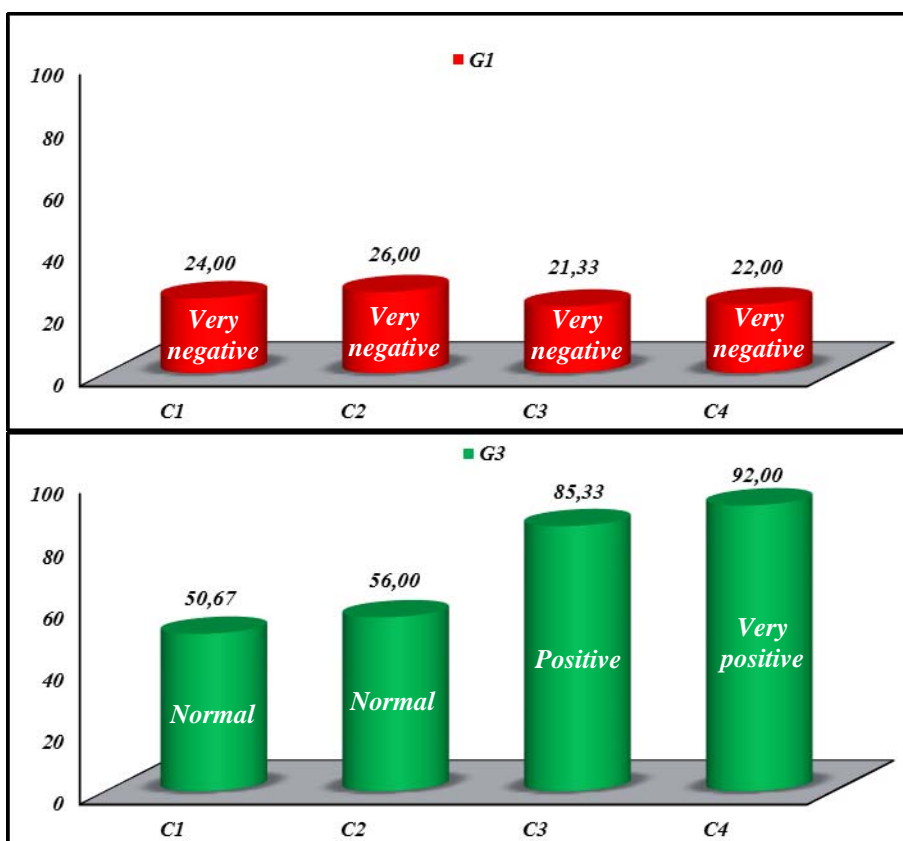

Fig. 11. Values of SIA of each criterion for groups G1 and G3

Third, the most divergent criteria between the stakeholder groups, which could imply potential causes of conflicts, were identified. Fig. 12, which is based on Table XIII, shows that the stakeholder groups converge for criteria C1 (volume of fishing) and C2 (quantity of tourists) and diverge for criteria C3 (GDP per capita) and C4 (percentage of unemployment). The convergent criteria can be considered as strengths and the divergent criteria as threats in a possible environmental conflict. The criterion with the greatest divergence is related to unemployment, followed by GDP per capita. Therefore, these issues should be taken into account when implementing measures to prevent environmental conflicts on the hydrocarbon exploration project.
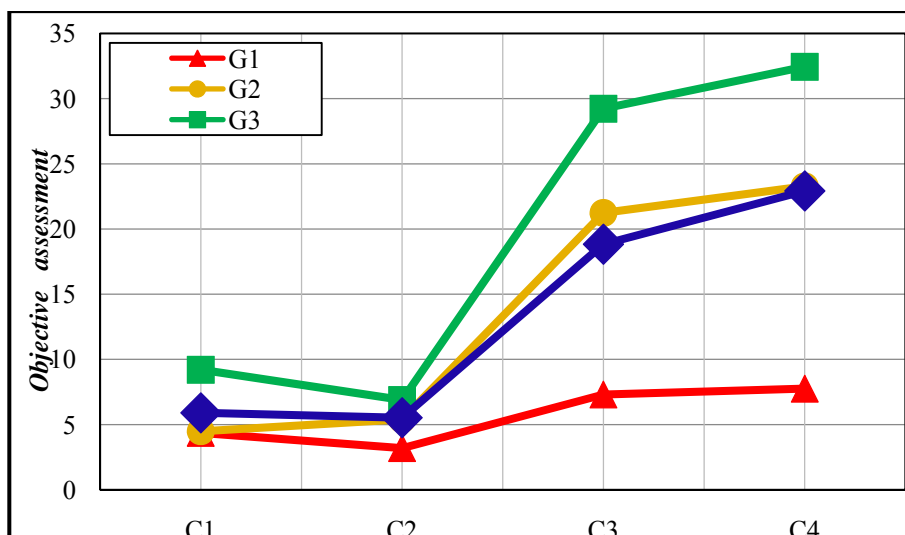
Fig. 12. Objective assessment for each group

2. Analysis of conflictive criteria

a. Percentage of unemployment

The group G3 (retirees) believe that the project will generate direct and indirect employment, as the hydrocarbon industry demands supplies that would increase the employment in all economic sectors. However, the group G1 (Primary activities population), in concordance with the groups G2 (university students) and G4 (specialists), strongly believe that the project will destroy the employment in sensitive sectors, such as tourism and fishing. Therefore, this fact generates discomfort on a part of the population in Valencia (see Fig. 13), as unemployment is a social problem in Spain, which increased since year 2009, due to the fact that the economic crisis in Europe and particularly in Spain impacts on the unemployment; for example, in Valencia in 2009 was 20.76%, and in 2013 was 28.05% [31].

b. GDP per capita

The group G3 believe that the project will increase the GDP per capita, as there will be investment from the company that will impulse other sectors of the economy. However, for groups G1, G2 and G4, the project will affect to the more important economic sectors of Valencia, which are tourism and fishing. For example, a part of group G1, the fishing cooperative of Valencia strongly believes that the project will affect their economic income, considering the context of lack of employment (see Fig. 14). This fact could be understudied, asin the ComunitatVelenciana, the GDP per capita has been decreased according to increasing of economic crisis since 2009; for example, in 2009 was 20170 euros per year, and in 2013 was 19500 euros per year [31]. This is due to the fact that the employment and the salary have decreased notably.

Fig. 13. Opposed citizens to the project

Fig. 14. Fishing cooperative of Valencia

V. CONCLUSIONS

The methodology applied in this article made possible to integrate SIA and ECA. SIA was conducted by means the GC method, which quantified the qualitative information collected from stakeholder groups, and ECA was performed by means the EW method, which identified the controversial criteria. The results obtained on the hydrocarbon exploration project in the Sea of the Gulf of Valencia, Spain, could help to central government or authorities of the community to make the best decision to manage the use of the Gulf of Valencia.

The main advantages of the integrated method could be summarized as follows: the integrated method would be more effective than other classical multi-criteria methods, as it considers uncertainty within its analysis; would be more appropriate than other approaches based on fuzzy logic, as it considers clear extension of criteria within its analysis;and would have a lower cost than other statistical approaches during its application.

The main limitations of the integrated method could be summarized as follows: the approaches based on grey systems or Shannon entropy are not widely diffused compared to approaches based on multi-criteria analysis, fuzzy logic or statistics models; the Integrated method presents still subjective aspects, during information gathering and the establishment of limits of grey classes; and the calculations are still tedious during the application of the integrated method, this fact could be improved by implementing a computer system.

Finally, the integrated method could be applied, in future studies on social impact assessment and environmental conflict analyses, to other types of programs or projects. The number of stakeholder groups and criteria could be determinate according to each type of project or program and the concrete social situation of the zone of influence.

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