Social impact assessment on a hydrocarbon proyect using triangular whitenization weight functions

Alexi Delgado, I. Romero

***Abstract*—Social impact assessment (SIA) has become an important factor for social conflicts prevention. In this study, we conducted SIA using the center-point triangular whitenization weight functions (CTWF) method, which is based on grey systems theory. A case study was conducted on a hydrocarbon exploration project located in the Gulf of Valencia, Spain. Two stakeholder groups and four evaluation criteria were identified. The results revealed that for the group of the directly linked population, the project would have very negative social impact; and for the group of indirectly linked citizens, the project would have negative social impact. The 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 SIA of other projects or programs.**

***Index Terms*—— CTWF, Grey systems, SIA.**

I. Introduction

SOCIAL impact assessment (SIA) is an key factor to prevent social conflicts caused by development of projects [1]. SIA has been mainly conducted by qualitative methods, such as, public participation [2], or game theory [3]. In this study, we apply a quantitative method to SIA, the center-point triangular whitenization weight functions (CTWF) method, which is based on grey systems theory. In addition, SIA is a topic characterized by its high level of uncertainty [4]. Therefore, SIA should be conducted by a method, which considers the uncertainly. The CTWF method is an method 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]. Moreover, the CTWF method help us to collect information, as 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].

Moreover, stakeholders are an important dimension for integrated assessment [8], and social conflicts are generated between stakeholder groups within affected population [9], [10]. Therefore, first SIA should be conducted for each stakeholder group, and then, to obtain total SIA of the project under scrutiny.

Subsequently, in order to apply and test the CTWF method, we conducted a SIA on a hydrocarbon exploration project in 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 [11]. 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 objective of this article is to apply the CTWF method on the SIA of the hydrocarbon exploration project in the Gulf of Valencia, Spain.

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

II. Method

In this section, we described the CTWF method, which can be described as follows: 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 CTWF method can be developed as follows [5], [7], [12]:

Step 1: The ranges of the criteria are divided into s grey classes, and then their center-points λ_1, λ_2,…, and λ_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 λ_0, λ_1, λ_2,…,λ_s, and λ_{s+1}, see details in Fig. 1. For the kth grey

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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.

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

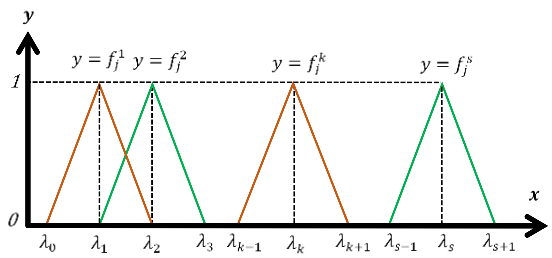

Fig. 1. CTWF [5]

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.

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

Where $f_j^k(x_{ij})$ is the CTWF of the kth grey class of the jth criterion, and η_j 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.

III. Case Study

SIA was conducted on a project located in 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 [11]. Ultrasound technology was proposed to be used to determine the existence of hydrocarbon deposits in the marine subsoil. SIA was conducted on the city of Valencia, located into the zone of influence of the project.

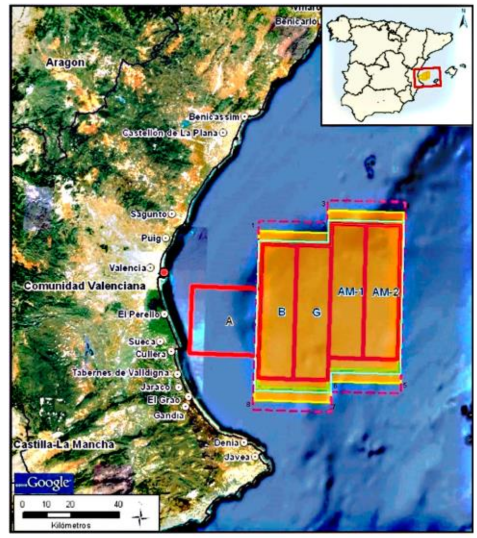

Fig. 2. Project location [11]

A. Stakeholder Groups

In this study, we identified two different stakeholder groups, the composition of these groups was determined according to similarities found during the overall assessment on the hydrocarbon exploration project [12]. 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 [13]. The stakeholder groups are presented in Table I:

TABLE I. Stakeholder Groups in the Case Study

Stakeholder group	Description
G1: Directly linked 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. This group was made up of thirty interviewees.
G2: Indirectly linked citizens	It was composed of citizens and students with no links to productive activities related to fishing or tourism. This group was made up of thirty interviewees.

B. 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. Nowadays, 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 Table II.

TABLE II. EVALUATION CRITERIA IN THE CASE STUDY

Criterion	Description
C1	It measured the change in the volume of fishing in the Comunitat Valenciana, with the baseline figure being taken as the volume of fishing in 2013, which was 31,29 thousand tonnes of fish [14].
C2	It measured the change in the number of foreign tourists visiting the Comunitat Valenciana, with the baseline figure being taken as the number of foreign tourists in 2013, which was 5.97 million [14].
C3	It measured the change in quantity of GDP per capita in the Comunitat Valenciana, with the baseline figure being the GDP per capita in 2013, which was 19,500 euros per year [15].
C4	It measured the change in the percentage of unemployment in the Comunitat Valenciana, with the baseline figure being the unemployment rate in 2013, which was 28.05% [14].

C. Calculations using the CTWF method

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

Step 1:

The grey classes were established according to the historical information of the criteria from 2009 to 2013 [14], [15], in order to satisfy the need to reflect the characteristics of the specific region as accurately as possible [5]. The ranges of the criteria are divided into five grey classes, and then their center-points λ_1, λ_2, λ_3, λ_4, and λ_5, were determined. The center-points established for each grey class are shown in Table III.

TABLE III. GREY CLASSES FOR EACH CRITERION IN THE CASE STUDY

Criterion	Very negative class (λ_1)	Negative class (λ_2)	Normal class (λ_3)	Positive class (λ_4)	Very positive class (λ_5)
	k=1	k=2	k=3	k=4	k=5
C1	26.31	28.80	31.29	33.78	36.27
C2	05.02	05.50	05.97	06.45	06.92
C3	18.83	19.17	19.50	19.84	20.17
C4	35.34	31.70	28.05	24.41	20.76

Step 2:

The grey classes were extended in two directions by adding the grey classes "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

Criterion	Center-points of the extended grey classes						
	λ_0	λ_1	λ_2	λ_3	λ_4	λ_5	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

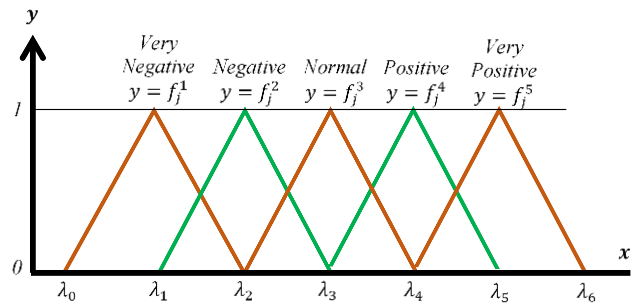

Fig. 3. CTWF for the case study

Now, as illustration, for the first criterion C1 (j=1) shown in the first row of Table IV, we have the center-points: λ_0=23.82, λ_1=26.31, λ_2=28.80, λ_3=31.29, λ_4=33.78, λ_5=36.27, and λ_6=38.76. This values were substituted into Eq. 1, to obtain the CTWF of the five grey classes. The results are shown in Eqs. 3-7:

$$f_1^1(x) = \begin{cases} 0, & x \notin [23.82, 28.80] \\ \dfrac{x - 23.82}{2.49}, & x \in [23.82, 26.31] \\ \dfrac{28.80 - x}{2.49}, & x \in [26.31, 28.80] \end{cases} \quad (3)$$

$$f_1^2(x) = \begin{cases} 0, & x \notin [26.31, 31.29] \\ \dfrac{x - 26.31}{2.49}, & x \in [26.31, 28.80] \\ \dfrac{31.29 - x}{2.49}, & x \in [28.80, 31.29] \end{cases} \quad (4)$$

$$f_1^3(x) = \begin{cases} 0, & x \notin [28.80, 33.78] \\ \dfrac{x - 28.80}{2.49}, & x \in [28.80, 31.29] \\ \dfrac{33.78 - x}{2.49}, & x \in [31.29, 33.78] \end{cases} \quad (5)$$

$$f_1^4(x) = \begin{cases} 0, & x \notin [31.29, 36.27] \\ \dfrac{x - 31.29}{2.49}, & x \in [31.29, 33.78] \\ \dfrac{36.27 - x}{2.49}, & x \in [33.78, 36.27] \end{cases} \quad (6)$$

$$f_1^5(x) = \begin{cases} 0, & x \notin [33.78, 38.76] \\ \dfrac{x - 33.78}{2.49}, & x \in [33.78, 36.27] \\ \dfrac{38.76 - x}{2.49}, & x \in [36.27, 38.76] \end{cases} \quad (7)$$

Step 3:

The information from stakeholder groups was gathered by means of direct interviews using a structured questionnaire based on the evaluation criteria and the grey classes established for the case study [12]. The questions used are presented in Table V.

TABLE V. QUESTIONS USED IN THE QUESTIONNAIRE FOR THE CASE STUDY

	Question	Grey classes				
		λ_1	λ_2	λ_3	λ_4	λ_5
1	What effect would the project have on the volume of fishing?					
2	What effect would the project have on the quantity of tourists?					
3	What effect would the project have on the GDP per capita?					
4	What effect would the project have on the percentage of unemployment?					

Table VI shows the overall results of evaluation from two stakeholder groups and total result, for each criterion. These data were aggregated using the arithmetic mean [16].

TABLE VI. AGGREGATED VALUES OF EACH CRITERION FOR EACH GROUP

Group	C1	C2	C3	C4
G1	26.81	5.16	18.85	34.98
G2	27.97	5.69	19.66	25.38
Total	27.39	5.42	19.26	30.18

Then, as illustration, for group G1, the values of CTWF were calculated using Eqs. 11-15. Subsequently, the comprehensive clustering coefficient (σ_i^k) was calculated using Eq. 2. All the criteria had the same weight (η_j = 0.250), as they are social criteria [13]. The values of CTWF and σ_i^k obtained for group G1 are shown in Table VII.

TABLE VII. VALUES OF CTWF AND σ_i^k FOR GROUP G1

G1	C1	C2	C3	C4	σ_i^k
$f_j^1(x)$	0.8000	0.7000	0.9333	0.9000	0.8333
$f_j^2(x)$	0.2000	0.3000	0.0667	0.1000	0.1667
$f_j^3(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
$f_j^4(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
$f_j^5(x)$	0.0000	0.0000	0.0000	0.0000	0.0000

The values of SIA for group G2 and total SIA were obtained using the same procedure as for group G1. The results are presented in Table VIII.

TABLE VIII. RESULTS OF SIA FOR GROUP G2 AND TOTAL SIA

G2	C1	C2	C3	C4	σ_i^k
$f_j^1(x)$	0.3333	0.0000	0.0000	0.0000	0.0833
$f_j^2(x)$	0.6667	0.6000	0.0000	0.0000	0.3167
$f_j^3(x)$	0.0000	0.4000	0.5111	0.2667	0.2944
$f_j^4(x)$	0.0000	0.0000	0.4889	0.7333	0.3056
$f_j^5(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**C1**	**C2**	**C3**	**C4**	σ_i^k
$f_j^1(x)$	0.5667	0.1500	0.0000	0.0000	0.1792
$f_j^2(x)$	0.4333	0.8500	0.7222	0.5833	0.6472
$f_j^3(x)$	0.0000	0.0000	0.2778	0.4167	0.1736
$f_j^4(x)$	0.0000	0.0000	0.0000	0.0000	0.0000
$f_j^5(x)$	0.0000	0.0000	0.0000	0.0000	0.0000

Step 4:

For G1, $\max_{1\le k\le s}\{\sigma_i^k\} = 0.8333$, where k=1. Therefore, G1 belongs to very negative grey class.

For G2, $\max_{1\le k\le s}\{\sigma_i^k\} = 0.3167$, where k=2. Therefore, G2 belongs to negative grey class.

For Total SIA, $\max_{1\le k\le s}\{\sigma_i^k\} = 0.6472$, where k=2. Therefore, Total SIA belongs to negative grey class.

IV. RESULTS AND DISCUSSION

The results and discussion, according to specific objective in this study, are presented as follows:

A. The case study

First, the total SIA of the hydrocarbon exploration project shown that the project would have a negative social impact, which indicate that the project will not be feasible from social point of view. In Addition, there is a slight difference between groups G1 (directly linked population), which statement that the project would have a very negative social impact; and G2 (indirectly linked Citizens), which opined that the project would a negative social impact.

Second, affected population, which were interviewed, indicated 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; 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 impacted on the unemployment; for example, in Valencia in 2009 was 20.76%, and in 2013 was 28.05% [14].

Third, a part of population, such as the fishing cooperative of Valencia strongly believes that the project will affect their economic income, considering the context of lack of employment. This fact could be understudied, as in the Comunitat Velenciana, 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 [14].

B. The CTWF method

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 [17], [18] or analytic hierarchy process (AHP) [19], [20], 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 [21].

Second, 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]; then, 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.

Therefore, it could be argued that the CTWF method based on grey systems theory would benefit SIA, as it considers the uncertainty within its analysis. In addition, the CTWF method would have a lower cost than other statistical approaches during its application.

V. Conclusions

The CTWF method applied to SIA quantified the qualitative information collected from stakeholder groups. The results obtained on the hydrocarbon exploration project in the Gulf of Valencia in Spain, could help to central government or authorities of the community to make the best decision about the project.

The main advantages of the CTWF method could be summarized as follows: it would be more effective than other classical multi-criteria methods, as it considers uncertainty within its analysis; and it would have a lower cost than other statistical approaches during its application. In addition, the main limitations could be summarized as follows: the approaches based on grey systems are not widely diffused compared to approaches based on multi-criteria analysis, or statistics models; and the calculations are still tedious during the application, this fact could be improved by implementing of a computer system.

Finally, the CTWF method could be applied, in future studies on SIA of other types of programs or projects. The number of stakeholder groups and criteria could be determined according to particularities of each type of project or program.

References

[1] P. V Prenzel and F. Vanclay, "How social impact assessment can contribute to conflict management," *Environ. Impact Assess. Rev.*, vol. 45, pp. 30–37, 2014.

[2] B. Tang, S. Wong, and M. C. Lau, "Social impact assessment and public participation in China: A case study of land requisition in Guangzhou," *Environ. Impact Assess. Rev.*, vol. 28, no. 1, pp. 57–72, 2008.

[3] N. van der Voort and F. Vanclay, "Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands," *Environ. Impact Assess. Rev.*, vol. 50, pp. 1–15, 2015.

[4] H. Wittmer, F. Rauschmayer, and B. Klauer, "How to select instruments for the resolution of environmental conflicts?," *Land use policy*, vol. 23, no. 1, pp. 1–9, 2006.

[5] S. Liu and Y. Lin, *Grey Systems: Theory and Applications*. Berlin: Springer, 2010.

[6] L. N. Zhang, F. P. Wu, and P. Jia, "Grey Evaluation Model Based on Reformative Triangular Whitenization Weight Function and Its Application in Water Rights Allocation System," *Open Cybern. Syst. J.*, vol. 7, no. 1, pp. 1–10, 2013.

[7] Y. Zhang, J. Ni, J. Liu, and L. Jian, "Grey evaluation empirical study based on center-point triangular whitenization weight function of Jiangsu Province industrial technology innovation strategy alliance," *Grey Syst. Theory Appl.*, vol. 4, no. 1, pp. 124–136, 2014.

[8] S. H. Hamilton, S. ElSawah, J. H. A. Guillaume, A. J. Jakeman, and S. A. Pierce, "Integrated assessment and modelling: Overview and synthesis of salient dimensions," *Environ. Model. Softw.*, vol. 64, pp. 215–229, 2015.

[9] E. Arun, "Towards a shared systems model of stakeholders in environmental conflict," *Int. Trans. Oper. Res.*, vol. 15, pp. 239–253, 2008.

[10] V. Luyet, R. Schlaepfer, M. B. Parlange, and A. Buttler, "A framework to implement Stakeholder participation in environmental projects," *J. Environ. Manage.*, vol. 111, pp. 213–219, 2012.

[11] Environmental Resources Management Iberia, *Documento Ambiental para la Campaña de Adquisición Sísmica 3D en los Permisos B, G, AM-1 y AM-2 en el Golfo de Valencia*. Madrid; España: ERM Iberia, S.A., 2012.

[12] A. Delgado and I. Romero, "Environmental conflict analysis using an integrated grey clustering and entropy-weight method: A case study of a mining project in Peru," *Environ. Model. Softw.*, vol. 77, pp. 108–121, 2016.

[13] P. Corbetta, *Metodología y técnicas de investigación social*. Madrid: McGRAW-HILL, 2007.

[14] INE-España, "Instituto Nacional de Estadística de España," 2014. [Online]. Available: http://www.ine.es/. [Accessed: 15-Jun-2014].

[15] Datos Macro, "Evolución anual PIB per capita Comunidad Valenciana," 2014. [Online]. Available: http://www.datosmacro.com/pib/espana-comunidades-utonomas/valencia. [Accessed: 30-Jun-2014].

[16] J. Aznar and F. Guijarro, *Nuevos métodos de valoración, modelos multicriterio*, vol. 2ª. Valencia: Universitat Politèctica de València,

2012.

[17] J. Landeta, *El método Delphi, Una técnica de previsión del futuro*. Barcelona, España: Editorial Ariel, 2002.

[18] V. Campos-Climent, A. Apetrei, and R. Chaves-Ávila, "Delphi method applied to horticultural cooperatives," *Manag. Decis.*, vol. 50, no. 7, pp. 1266–1284, 2012.

[19] T. L. Saaty, "The Analytic Hierarchy Process," McGraw-Hill, New York, 1980.

[20] M. Sadeghi and A. Ameli, "An AHP decision making model for optimal allocation of energy subsidy among socio-economic subsectors in Iran," *Energy Policy*, vol. 45, pp. 24–32, 2012.

[21] A. Baykasoğlu and İ. Gölcük, "Development of a novel multiple-attribute decision making model via fuzzy cognitive maps and hierarchical fuzzy TOPSIS," *Inf. Sci. (Ny).*, vol. 301, pp. 75–98, 2015.