International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V71I1P206

Volume 71 Issue 1, 53-61, January 2023

Original Article

Socio-economic Impact Assessment from a Scholarship Program Founded by Mining Project using Grey Systems

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Received: 11 September 2022 Revised: 27 December 2022 Accepted: 07 January 2023 Published: 24 January 2023

Abstract *- The large-scale mining operations around indigenous and rural populations, despite their tremendous profit for Peru's economy, have usually been accompanied by limited improvement in wealth and standards of living and thus leading currently to a rise in social conflict and violence. A case study was carried out on a scholarship programme founded by the mining company Las Bambas surrounding the community of Fuerabamba. This study was conducted using a method based on grey systems. One main stakeholder group and four evaluation criteria were recognized. The result has reported that the program has a positive social impact on the sponsored students, thus contributing to closing education gaps in the country and promoting diversity. The method showed interesting results and could be applied to future socio-economic evaluations of programs that offer significant opportunities for young people, especially those founded by mining companies.*

Keywords *- Grey systems, Socio-economic impact, Mining project.*

1. Introduction

Nowadays, corporate social responsibility is a key practice in organizations, whether public or private and is currently gaining more significance worldwide. It is especially crucial in large companies involved in the more sensitive sectors, such as the extractive industry. Social corporate responsibility demands that organizations fulfil their obligations to all the actors surrounding them. Corporate indifference to the problems and needs of the communities could generate conflicts of an economic, political and social nature, leading to organizational destabilization.

The methodology applied to the present study is the grey clustering method (The GC method), which is based on grey systems and allows work considering uncertainty and complex data [1][2]. Therefore, due to quite relative nature of this social research, the application of this method is appropriate. Determining the center-point triangular whitenization weight functions (CWTF) will allow defining to which gray class the studied social parameter belongs [1].

The social conflict in which the mining company and the Fuerabamba peasant community are involved is based on a relocation agreement made by the former owners, Glencore. This agreement generated disputes accompanied by protests because the community refused to move to "Nueva Fuerabamba" due to the peasant community's expressing concern about water contamination [18]. Likewise, non-compliance commitments are associated with the Glencore company towards the communities that ceded the piece of ground for the relocation of the Fuerabamba community [4].

For that reason, young people from the Fuerabamba peasant community located in Challhuahuacho district, Cotabambas province, Apurímac department, have been selected as the object of study; to evaluate the company social responsibility of the Las Bambas mining company in the education sector. The company tries to benefit the community by investing in developing and strengthening young people's skills, allowing them to generate better economic opportunities. In 2008, the "Higher Education Scholars Care System" (SABES) was implemented, which aims to evaluate its benefit in relation to the satisfaction level of students, employment opportunities, graduates' degree of satisfaction and opportunities to get a promotion taking into account the Likert scale.

The main objective of this report is based on knowing the influence of the mining canon in the education sector by the mining company Las Bambas applying the Gray Clustering method, which evaluates the impact by quantifying information from the interest group. Likewise, this methodology allows us to know the level of satisfaction on the part of the community's young people in relation to the SABES scholarships. It will enable us to estimate the community's social development because when young people finish their studies, they worry about the economic growth of Fuerabamba [5].

There have been previous works on the use of Grey Clustering in communities; for example, Chapilliquen, in 2017, studied the mining activity of the Yanacocha mining company in the province of Cajamarca and the impact on the quality of life of the population during the period 1993-2012, raised that the mining activity that is developed in the province of Cajamarca has generated positive impacts on the quality of life [6].

Of the population of the environment of the Yanacocha Mining Company in the period of analysis. The fourth highest malnutrition rate, a low percentage of fifth-grade students who achieved "sufficient" performance in mathematics, and a low percentage of homes with access to public sewage. The lowest percentage of homes, at the national level, with access to electric lighting [7].

Delgado, in 2021, applied the Grey Clustering method to evaluate the social impact in a hydrocarbon project using triangular whitening weight functions. This project involves a hydrocarbon exploration with a 3D seismic acquisition campaign in the Gulf of Valencia in Spain. For this purpose, the results of two groups were used: directly linked population and indirectly linked citizens [19].

The parameters evaluated were: change in the volume of fishing in the Comunitat Valenciana, change in the number of foreign tourists visiting the Comunitat Valenciana, change in the amount of GDP per capita in the Comunitat Valenciana and change in the percentage of unemployment in the Comunitat Valenciana. The results show that the hydrocarbon exploration project would have a negative social impact, indicating that the project will not be socially viable [9].

Our work mainly differs in that we have embraced the signs of disinterest in the students, especially being our only and primary object of study, identifying criteria of students' satisfaction level, employment opportunities, etc. To find out how a support program (SABES) is changing these students' lives, which are generally not taken into account because mining companies generally prefer to deal with the urgent demands of the communities, such as environmental or public health issues [10]. The main problem explained above indicates that it is necessary to analyze the surveys precisely with Mitchell, Agle and Wood's model. It was developed to classify monitoring objects into definable classes.

2. Methodology

This section describes the social impact assessment using the Grey Clustering method, which was created to assort monitoring objects into definable classes. To test if these objects are part of the above classes, center-point triangular whitenization functions are used [11]. Figure 1 shows the steps of the modified CTWF.

Every step of the method will be described in the next paragraphs.

2.1. Step 1

First, it is required to collect all the Xij values for each 'i' object of study and each 'j' criterion defined. Then, we divide into 'p' grey classes the ranges of the criteria and determine the center-points λ1, λ2… λp of each class [11].

2.2. Step 2

It is necessary to transform to dimensionless values both the real or sample data and the standard data. An average of the center-points should be obtained for each criterion and then divided by each center-point in its respective criterion. This process will be repeated with the collected values [20].

2.3. Step 3

The grey classes are expanded in two directions, adding the grey classes 0 and (p+1) with their center- points λ0 and λp+1, respectively. The new sequence of center-points is λ0, λ1, λ2… λp and λp+1 (Figure 2). For the kth grey class, k=1, 2… p, of the jth criterion, j=1, 2… n, for an observed value Xij, the CTWF is defined by Eq. (1). [11].

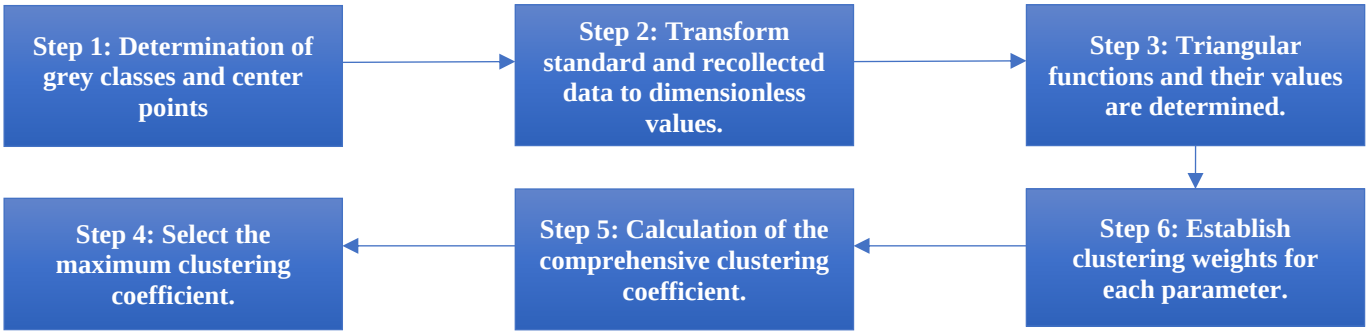

Fig. 1 CTFW Method Flow Chart

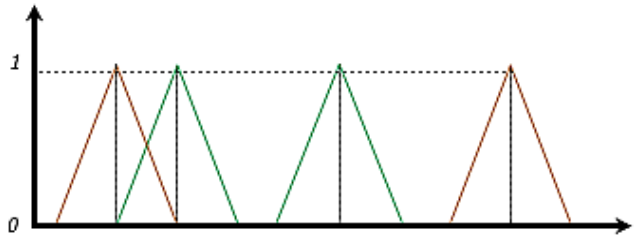

Fig. 2 CTWF [11]

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

2.4. Step 4

In this step, it is determined the clustering weights for each parameter λpj using the harmonic mean. The values are calculated by Eq. (2)

$$n_{pj} = \frac{\frac{1}{\lambda_{pj}}}{\sum_{i=1}^{j} \frac{1}{\lambda_{pj}}} \quad (2)$$

2.5. Step 5

Using Eq. (3), we calculated the comprehensive clustering coefficient σk for each object i, where i = 1, 2 … m, with respect to the grey classes k=1, 2 … p [11].

$$\sigma_i^k = \sum_{j=1}^{n} f_j^k(x_{ij}) n_{pj} \quad (3)$$

2.6. Step 6

Finally, the maximum clustering coefficient is calculated using Eq. (4). The objects of study that belong to grey class k* are decided. When too many of them aren't grey class k*, the objects can be ranked according to the values of their comprehensive clustering coefficients [11].

$$\max\{\sigma_i^k\} = \sigma^{k^*}, k = 1,2 \ldots . . p \quad (4)$$

3. Case of Study

The social impact analysis was carried out in the Challhuahuacho district, belonging to the province of Cotabambas, in the department of Apurímac, as seen in Figure 3. In this district is located the Fuerabamba community adjoining the mining company Las Bambas, which is responsible for the social conflict. (Fig.4)

After being transferred from Glencore to MMG, Las Bambas decided to transport the mineral by land; this was the trigger for social problems because the roads that lead to Las Bambas cross lands that belonged to different peasant communities. Some 40 communities have complained about using the land, which, according to their representatives, the State incorporated into a road corridor without their consent. Since the beginning of the conflict, several dialogue tables have been formed with high-ranking state officials and representatives of Las Bambas without much success. In this sense, Las Bambas Mining seeks to contribute to human development, investing in the development and strengthening of local capacities that allow the generation of better economic opportunities. In 2008, the "Higher Education Scholars Service System (SABES)" was implemented under the following improvement options:

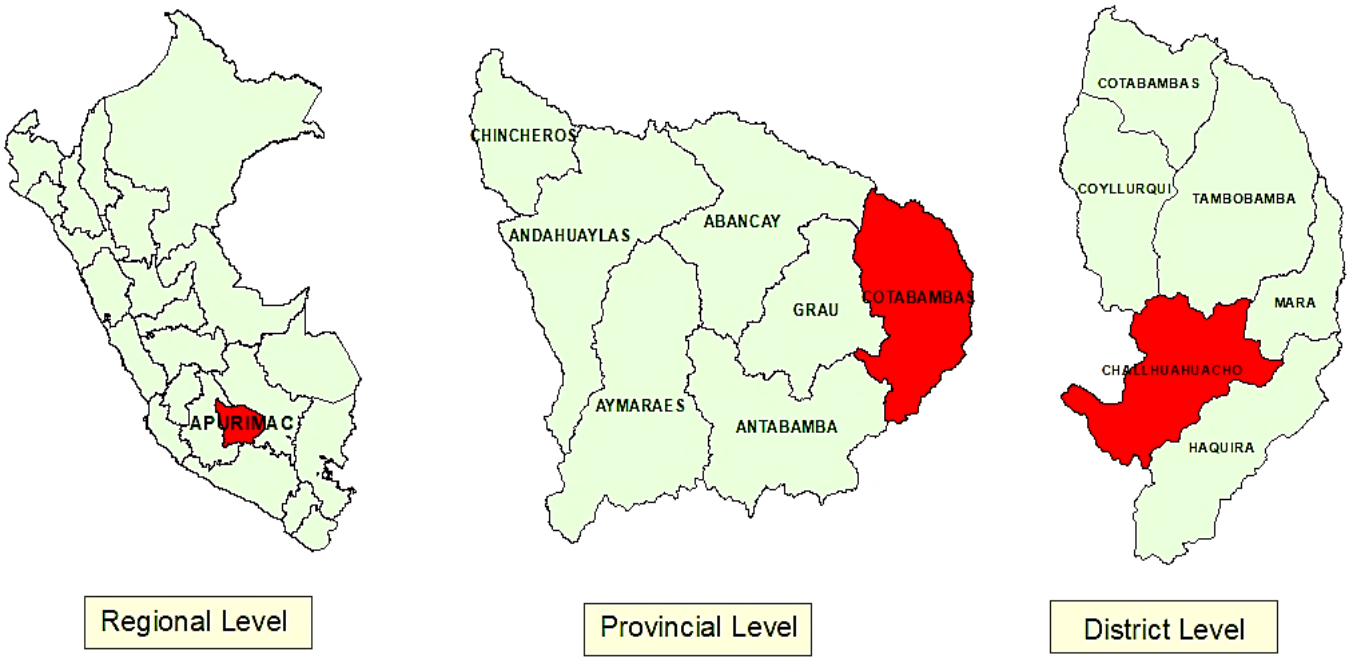

Fig. 3 Location at different levels of the Fuerabamba community

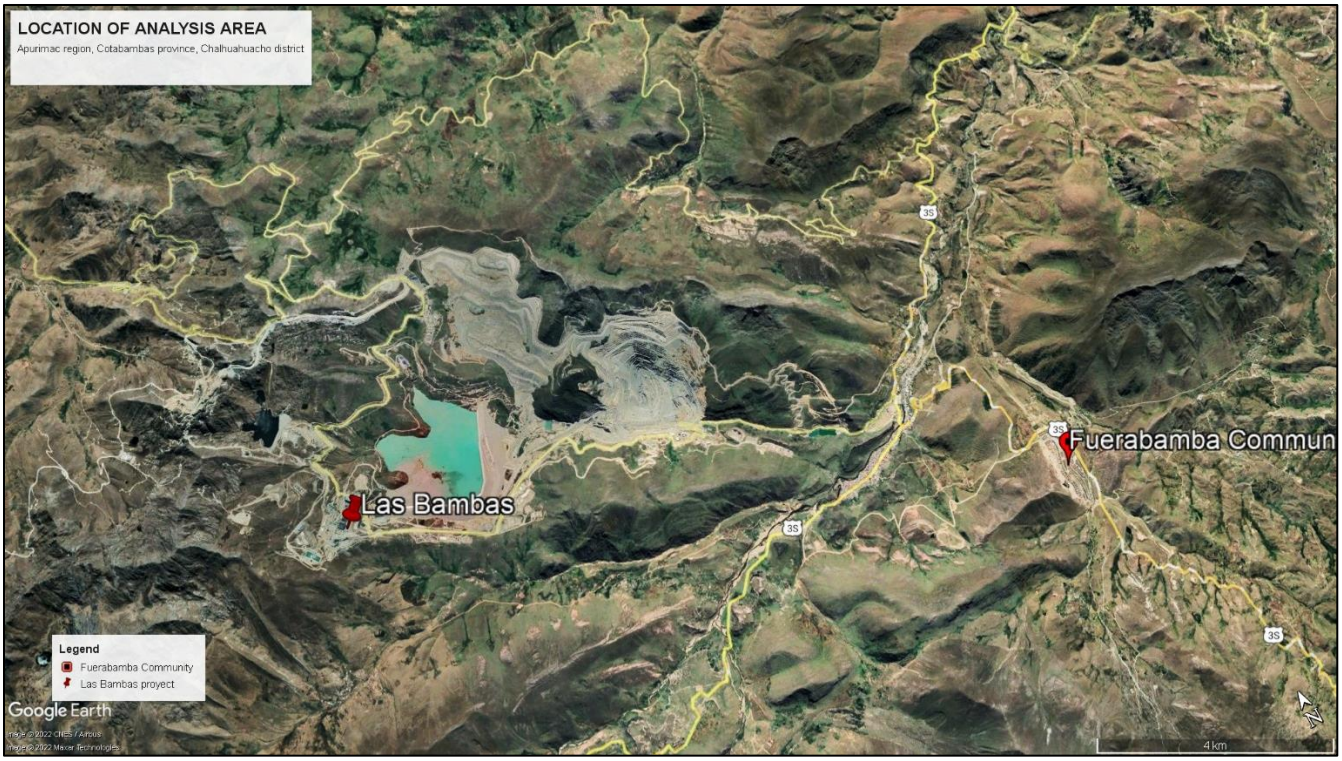

Fig. 4 Location of the analysis area from Google Earth

- Lack of opportunities that young people have in many areas of our country, especially in rural areas.
- The low expectations that young people have about their future are either due to false beliefs that education is only for people with high incomes or low self-esteem related to the self-perception that their abilities are insufficient.
- The lack of information or ignorance about the benefits or returns generated by more years of education or having a technical or university degree.

3.1. Definition of Study Objects

For the evaluation of the analysis of the impact of the "SABES" scholarship in the Fuerabamba community, the information was collected based on surveys developed in a thesis titled "Corporate social responsibility (CSR): Impact of company's higher education scholarship program mining, Las Bambas in the quality of life of the young people of the peasant community Fuerabamba 2018. In this study, the analysis is done during the years 2017 and 2018. It will be detailed in Table 1.

3.2. Definition of Assessment Criteria

The criteria were chosen based on the capacity of the program SABES to provide young scholarship holders in technical or university careers from the Fuerabamba community a better economic, social and cultural status [5].

Table 1. Stakeholder groups

Stakeholder group	Description
G1:Students	It consists of young people from the Fuerabamba Community who received a scholarship from the SABES Program, who successfully completed their studies, and who could be contacted by phone or email. This group was made up of 51 interviewees.

Table 2. Evaluation criteria in the case study

Criterion	Description
C1	It measured the satisfaction level of students regarding the scholarship SABES.
C2	It measured the employment opportunity after receiving the scholarship SABES.
C3	It measured the graduates' degree of satisfaction related to their current salary.
C4	It measured the opportunities to get a promotion at the current job or another company.

Table 3. 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	[0, 20[	[20, 40[	[40, 60[	[60, 80[	[80, 10[
C2	[0, 20[	[20, 40[	[40, 60[	[60, 80[	[80, 10[
C3	[0, 20[	[20, 40[	[40, 60[	[60, 80[	[80, 10[
C4	[0, 20[	[20, 40[	[40, 60[	[60, 80[	[80, 10[

Table 4. Questions used in the questionnaire for the case study

Criterion	Question	Grey Classes				
		Very negative (V1)	**Negative (V2)**	**Normal (V3)**	**Positive (V4)**	**Very Positive (V5)**
C1	How do you consider the scholarship you received from the Las Bambas mining company?	Very Bad	Bad	Not good/ Not Bad	Good	Very good
C2	In your opinion, did the scholarship granted by the Las Bambas mining company help you get a better jobs?	Never	Rarely	Sometimes	Usually	Always
C3	How do you consider the income you receive?	Very Bad	Bad	Not good/ Not Bad	Good	Very good
C4	Do you consider that you have opportunities to access a better position in the company where you work?	Totally disagree	Disagreement	indifferent	Agreed	Strongly agreed

Table 5. Central values of the parameters

Criterion	Grey Classes				
	Very negative (V1)	**Negative (V2)**	**Normal (V3)**	**Positive (V4)**	**Very Positive (V5)**
C_1	1	3	5	7	9
C_2	1	3	5	7	9
C_3	1	3	5	7	9
C_4	1	3	5	7	9

Table 6. Non-dimensional values

Criterion	Grey Classes				
	Very negative (V1)	**Negative (V2)**	**Normal (V3)**	**Positive (V4)**	**Very Positive (V5)**
C1	1	0	0	0	6
C2	2.73	0	0	0	4.27
C3	0.5	0	3.36	0	3.15
C4	1.68	0	0	0	5.32

3.3. Definition of the Grey Classes

We will use 5 gray classes based on the Likert scale, a psychometric tool commonly used in social science research using questionnaires, based on the following classes: very negative, negative, normal, positive and very positive. [13]. The grey classes established for each criterion are shown in Table 3.

3.4. Calculations using the CTWF method

The calculations for the case study are presented below:

3.4.1. Step 1

The central values of the parameter to be analyzed is obtained based on the Linkert scale and shown in Table 4.

3.4.2. Step 2

The non-dimensioned standard values for each parameter are presented in Table 5.

3.4.3. Step 3

The triangular functions of the five Grey classes for each parameter were obtained. These functions apply to all

criteria "j" since they all have the same central points, as shown in Equations 5-9 and Figure 5 [14].

$$f_j^1(x) = \begin{cases} 0; x \notin [0,3] \\ 1; x \in [0,1] \\ \frac{3-x}{2}; x \in [1,3] \end{cases} \quad (5)$$

$$f_j^2(x) = \begin{cases} 0; x \notin [1,5] \\ \frac{x-1}{2}; x \in [1,3] \\ \frac{5-x}{2}; x \in [3,5] \end{cases} \quad (6)$$

$$f_j^3(x) = \begin{cases} 0; x \notin [3,7] \\ \frac{x-3}{2}; x \in [3,5] \\ \frac{7-x}{2}; x \in [5,7] \end{cases} \quad (7)$$

$$f_j^4(x) = \begin{cases} 0; x \notin [5,9] \\ \frac{x-5}{0.4}; x \in [5,7] \\ \frac{9-x}{2}; x \in [7,9] \end{cases} \quad (8)$$

$$f_j^5(x) = \begin{cases} 0; x \notin [7,10] \\ \frac{x-7}{2}; x \in [7,9] \\ \frac{10-x}{2}; x \in [9,10] \end{cases} \quad (9)$$

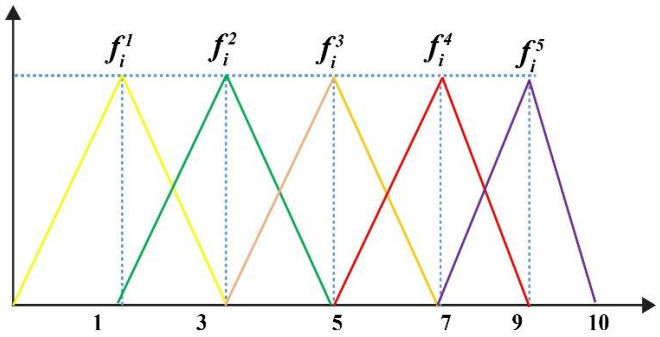

Fig. 5 CTWF for the case study

Then, we obtain each criterion's added value by making a weighted average with the results and the value each gray class grants. As a result, we obtain the real data that we will use in the Gray Clustering method.

Next, we evaluate the actual data in the table 7 at the center-point triangular functions. The results obtained are shown in Table 8.

3.4.4. Step 4

The clustering weight of each parameter was determined using a harmonical main. The values are present in Table 9.

3.4.5. Step 5

The values of the clustering coefficients were calculated using Eq. 3. The results are shown in Table 10.

Table 7. Weighted data

	C_1	C_2	C_3	C_4
O_1	7.857	1.176	1.304	1.416

Table 8. Values of ctwf for each criterion

	C1	C2	C3	C4
f1	0	0	0	0
f2	0	0	0	0
f3	0	0.56	0.24	0
f4	0.56	0.44	0.76	0.96
f5	0.44	0	0	0.04

Table 9. Values of ctwf for each criterion

Criterion	Grey Classes				
	Very negative (V1)	Negative (V2)	Normal (V3)	Positive (V4)	Very Positive (V5)
C1	0.25	0.25	0.25	0.25	0.25
C2	0.25	0.25	0.25	0.25	0.25
C3	0.25	0.25	0.25	0.25	0.25
C4	0.25	0.25	0.25	0.25	0.25

Table 10. Values of ctwf and clustering coefficients

	C_1	C_2	C_3	C_4	σ
fj 1 (x)	0	0	0	0	0
fj 2 (x)	0	0	0	0	0
fj 3 (x)	0	0.56	0.24393724	0	0.200
fj 4 (x)	0.57142857	0.44	0.75606277	0.96	0.681
fj 5 (x)	0.42857143	0	0	0.04	0.117

Table 11. Social impact level results

	Stakeholders	σ	Level
O_1	Students	0.6819	Positive

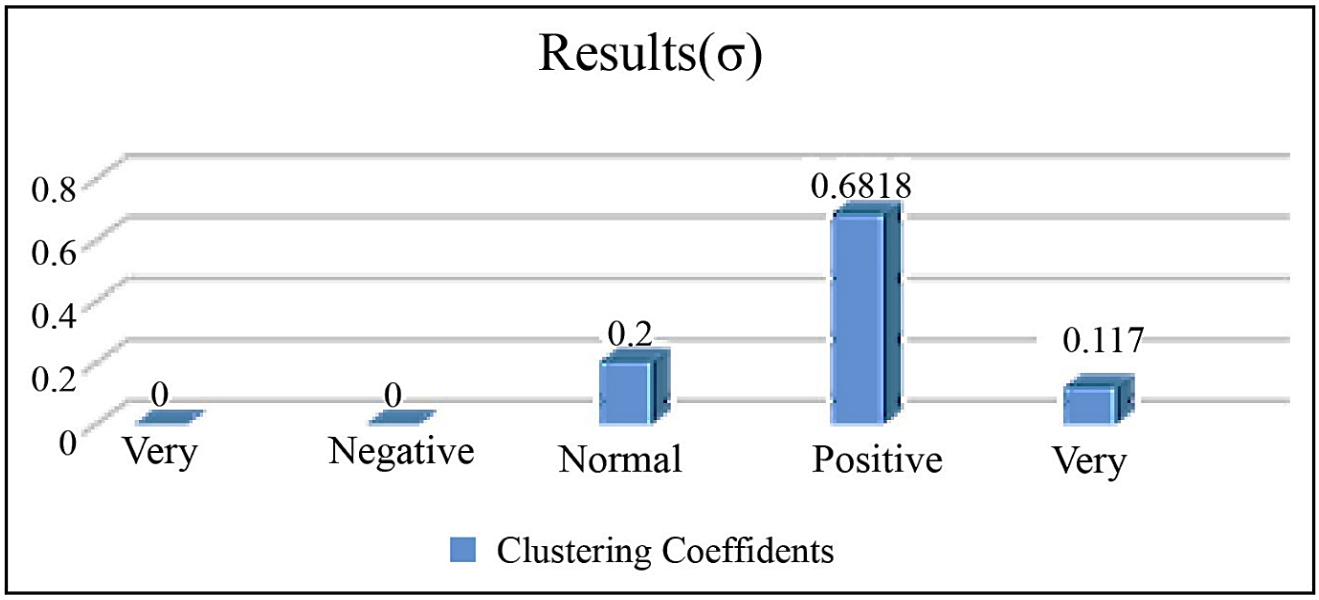

Fig. 6 Values of clustering coefficients of group 1.

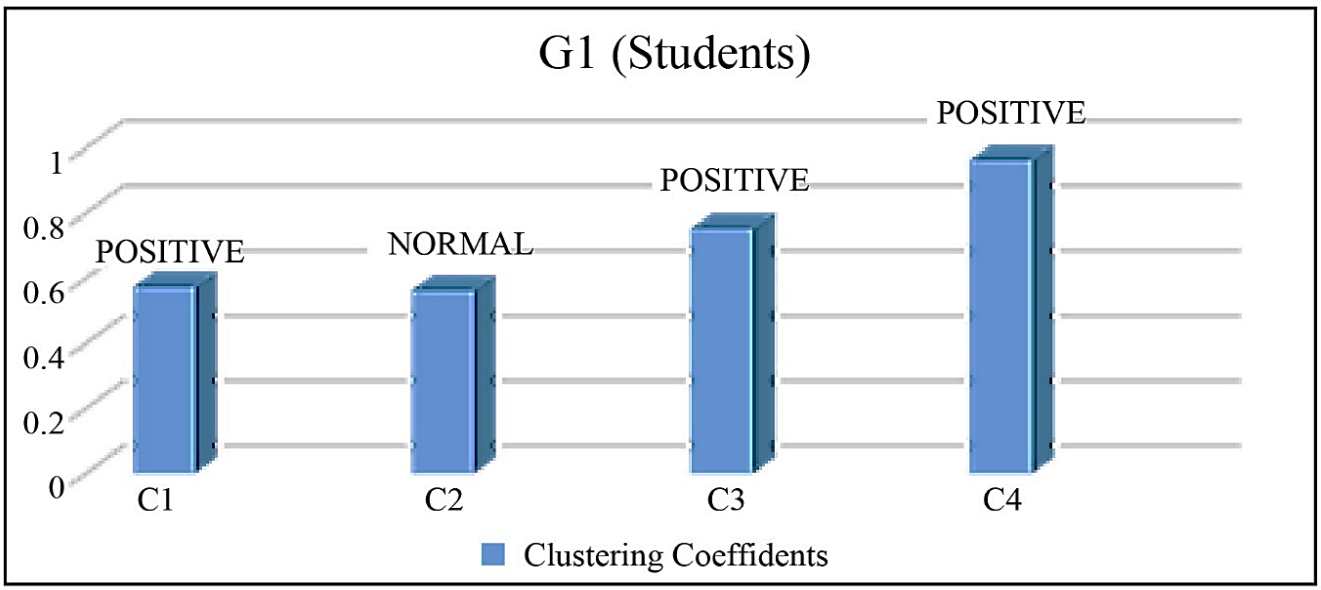

Fig. 7 Values of clustering coefficients of each criterion for group 1.

3.4.6. Step 6

Finally, the condition was applied: if $m\{\sigma_i^k\} = \{\sigma_i^{k*}\}$, it is decided that the object "i" belongs to the Grey class k*; for each department in analysis. The results are shown in Table 11.

4. Results and Discussion

4.1 About the Case Study

The critical evaluation criteria are those that obtained the lowest scores in the evaluation using the Gray Clustering method. However, it's observed that the study doesn't present any criteria of this type because the people surveyed didn't present disagreement related to the criteria proposed in this analysis. The "employment opportunities" criterion obtained a score of 0.56; therefore, It's considered a normal criterion according to the established scoring system. Consequently, students do not perceive employment opportunities as a significant criterion for obtaining the SABES scholarship.

Regarding the criteria "satisfaction level of students", "graduates' degree of satisfaction related to their salary", and "opportunities to get a promotion", they obtained scores of 0.57, 0.75 and 0.96, respectively; therefore, they're considered within the positive category, due to the fact that a lot of students who participated in the surveys presented conformity with these criteria; likewise, it was corroborated using the Gray Clustering methodology. Therefore, they indicate that these criteria are considered attractive for students to obtain the SABES scholarship. Considering all the evaluation criteria, it's concluded that the beneficiary students of the SABES scholarship from the Fuerabamba community rate with a positive level, according to the Likert scale, the benefit of the scholarship provided by Las Bambas.

After analyzing the situation in Apurimac Region, it can affirm that they have had a higher educational development. The results of the 2017 census carried out by the National Institute of Statistics and Informatics (INEI), according to educational level, show that the highest percentage of the population reached secondary education (36.6%), followed by those who could study higher education (25. 1%); In addition, when comparing the 2007 and 2017 censuses, It can be seen that the proportion of people with higher education increased [15]. This is evidenced by the "positive" level they have maintained. It's concluded from this investigation that the economic resources received from the mining canon and other resources help young people to be able to study and become future professionals to benefit the Fuerabamba community.

4.2. About the Methodology

First, the grey clustering method is excellent for measuring the social impact assessment because it considers the inaccuracy within the analysis [16]. Moreover, according to Delgado, this approach would be more suitable than methods based on diffuse logic due to the fact that it considers a higher range for the evaluation criteria.

In addition, the CTWF method was helpful to implement to determine the clustering coefficient because it is more exact about the center-points of the grey classes defined in contrast to other points of the grey class [16]. For this reason, it was possible to assess whether the implementation of the scholarship programme was positive or negative for the students. In addition, a good advantage of this method is that it lets the mining company know immediately if they should provide better opportunities to the community.

5. Conclusion

To conclude, since a clustering coefficient of 0.6819 was obtained, the SABES program positively benefits students. In addition, criterion 3: the degree of satisfaction of the graduates, and criterion 4: the opportunities to obtain a promotion, have been the ones that scored the best. It means that the performance of the SABES program was concentrated on these criteria.

The methodology in this article made it possible to study Likert gray classes using the gray clustering methodology, which quantifies the information obtained from the interest group surveys. By following the steps mentioned in the topography at the letter's request, reasonable values were obtained. This study could benefit the authorities in understanding how the programs of mining operations really influence the performance of the people in the area for better management.

Finally, the method used could be applied in future studies on evaluating the social impact of other types of programs or projects of operations in these areas, which are often not taken into account despite being directly influenced by mining companies. The number of interest groups and the criteria could be determined according to each type of project or program and the specific social situation of the area of influence.

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