

Stakeholders and Criteria on a Mining Project using AHP and Entropy-Weight Methods



Solange Ríos, Alexi Delgado

Abstract: *The abundance and evolution of mining industry for the Peruvian government is of great relevance nowadays, due to the economic impact, this entails in order to increase the gross domestic product and reduce the poverty index. Nevertheless, in the last few years this production sector suffered numerous problems because of the complicated social relationships with the rural communities near the mining projects. The purpose of this study is to analyze the probability of a social conflict due to the appearance of a mining project in Macusani (Puno-Peru), using the AHP (Analytic Hierarchy Process) methodology to evaluate the stakeholders and the entropy-weight method for the criteria. In order to accomplish the evaluation, we interview seven experts in community relationships that gave us their perspectives through the polls. In terms of results, we determine that the stakeholders in order of importance were communal authorities, alpaca livestock, local and regional government, farmers and merchants. By the other hand, the strongest variables in a social conflict were pollution, poverty level, employment, health, economy, water access and security. The analysis of this case of study can improve new innovative techniques to affront the potential appearance of a social conflict, in order to create a social responsibility awareness. This can generate a positive impact expressed in benefits for the local communities, the government and the enterprise.*

Keywords: *AHP, Entropy-weight, Lithium Mining project, Stakeholders, Social Conflict.*

I. INTRODUCTION

The social factor is becoming more important for the development of a mining project. Currently, one of the biggest obstacles that mining companies must overcome is the social factor since it is the most difficult to predict and, therefore, to control. This is basically due to the difference in worldviews that both the rural sector and the urban sector have. This difference is most evident when it comes to gaining access to the surface terrain. This permission may be inconvenient if not obtained, as "one of the fundamental challenges for mining projects is to secure the consent of local communities for future access to land, and to minimize the community's exposure to business uncertainty" [1].

It is essential that there is a predisposition for understanding and tolerance on both sides, which could be achieved by implementing an active and assertive dialogue. Such dialogue would be feasible if there is a prior study of everything that encompasses the community. For instance, the analysis of traditions, customs celebrations, main economic activity, levels of poverty and education, among others.

All this information is necessary as it is an effective means of rapprochement that will help to carry out assertive dialogues [2]. "Stakeholder analysis is a process that seeks to identify and describe the interests and relationships of all the stakeholders in a given project" [3]. In general, this analysis is a necessary precondition to participatory planning and project management. For this reason, it is very important, in the planning stage, to determine the different existing stakeholders in the communities and the variables that could affect each one of them.

The present scientific article, seeks to accurately identify the above mentioned using a quantitative method. Among the possible methods to use, we can mention the application of Delphi method [4], AHP method and FAHP method [5], Grey Systems [6], Shannon entropy [7], Machine Learning [8], among others. These methods make it possible to quantify the data obtained from qualitative research, this is because "qualitative data are presented in the form of responses to standardized questionnaires" [9].

In this way, we can mention some social cases in which these methods were applied. It is important to mention that many of them were not linked to mining. For example, in the international framework, we can mention a study carried out in an exploration of hydrocarbons in the Gulf of Valencia, Spain [10]. In this study, the use of ultrasound technology was proposed to determine the existence of hydrocarbon deposits in the subsoil. This proposal would generate an environmental impact, which is why Shannon's entropy was implemented with the objective of conducting environmental conflict analysis (ECA).

On the other hand, in the national context, there is a research carried out for the Conga Project in Cajamarca, in which the entropy of Shannon and the grey clustering method were implemented to determine the ECA and the social impact assessment (SIA), respectively. This study proved the efficiency of combining both methods for the evaluation of socio-environmental conflicts, since it provides very detailed results regarding the variables that are used for their resolution [11].

The case study for this article was the new lithium and uranium project, Macusani, which is located in the province of Carabaya, district of Macusani in Puno department, Peru.

Manuscript published on November 30, 2019.

* Correspondence Author

Solange Ríos*, Mining Engineering Program, Pontificia Universidad Católica del Perú, Lima, Peru. Email: solange.rios@pucp.pe

Alexi Delgado*, Department of Engineering, Mining Engineering Section, Pontificia Universidad Católica del Perú, Lima, Peru. Email: kdelgadov@pucp.edu.pe

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

This project is in the exploration stage, and with only 15% of the surface drilled, 2.5 million tons of lithium and 124 million pounds of uranium have been confirmed, that is why this project is heading to be the largest lithium mine not only in South America but in the world [12]. On the other hand, the company Plateau Uranium highlights the importance of the social aspect in an official document published by them, in which it says that " the Social Licence represents the most important step in any exploration and/or development mining project in Peru" [13], for this reason " the relationships with the Local Communities must be of a permanent nature with implementation as per signed and negotiated agreements " [13].

For this study, it was essential to identify the economic activities developed in the area of impact of the project. For example, among the most important, we can mention alpaca breeding, agriculture and tourism. All these activities involve groups of people who could be affected by the Macusani Project. In order to determine the stakeholders and the variables that could affect them, mathematical methods were used that can convert qualitative data into quantitative data.

In this case, the method chosen to determine the Macusani district's stakeholders was AHP method, since it allowed us to "combine all the judgments or opinions in a whole, in which the alternatives are organized from the best to the worst" [14]. Thus, this method was based on the evaluation of alternatives (taking into account various criteria) and on the fact that the experience and knowledge of the experts reflected in the surveys had the same predominance as the data used in the process [15]. It is important to mention that this method used matrices and the Saaty scale, which provided a more complex and precise analysis than would have been obtained if a qualitative method had been used.

On the other hand, thanks to the entropy-weight method, an ordering of alternatives was obtained for the general variables that could affect these stakeholders. This methodology consists of a sequence of steps to determine the entropic weights of the criteria. This was made with the purpose of ranking the variables through the multiplication of matrices. Additionally, the surveys were applied to the same experts and using the same Saaty scale [16].

The objective of this paper was to determine both the most important stakeholders and the variables that affect them using the AHP method and the entropy-weight method.

In order to achieve this, it was necessary to carry out some previous steps (specific objectives) such as, for example, reviewing the existing literature of all possible methodologies that could be applied, surveying the experts and applying the two methodologies selected for the hierarchy of stakeholders and variables.

The paper will present the following structure; first, in Section 2, both methods will be developed in a specific way, in order to understand its methodology. In addition, in Section 3, the mining project that was developed in the case study will be explained, along with its possible stakeholders and variables. Subsequently, the results obtained will be discussed in Section 4, in order to interpret them correctly and make conclusions in Section 5.

II. METHODOLOGY

The methodologies to be used were AHP for the hierarchy of the stakeholders, and the entropy-weight method for the hierarchy of the variables.

It is important to mention that a total of seven experts (E1, E2, E3, ..., E7) in topics related to environment, engineering, mining and sociology of Peru participated. This very varied set of experts was very beneficial for our research work, as it allowed us to obtain more objective and real results.

2.1. Analytic Hierarchy Process (AHP)

The AHP (Analytic Hierarchy Process) method was applied to rank the stakeholders and from there, work only with the five most important. This method is based on the evaluation of alternatives, taking into account several criteria, which are based on the fact that the experience and knowledge of the participants enjoy the same predominance as the data used in the process [17]. The values given come from the Saaty scale [14]; this scale was adapted to this social context and its structure can be seen in Table 1.

Table 1. Scale of Saaty [18]

Value of a_{jn}	Interpretation
1	j and k are equally important
3	j is slightly more important than k
5	j is more important than k
7	j is strongly more important than k
9	j is absolutely more important than k

This study was worked with 7 alternatives (represented by stakeholders) and four criteria. The steps followed in this methodology (AHP) are detailed below [14]:

Step 1: Criteria Comparison

A criteria comparison matrix was developed with the following structure [14]. This matrix is shown in Equation 1.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \quad (1)$$

The sequence of this step is as follows:

- Add the values in each column of the criteria comparison matrix
- Divide each element of such matrix between the total of its column; the resulting matrix is called the normalized paired comparison matrix.
- Calculate the average of the elements of each region of the relative priorities of the elements that are compared.

The purpose of these four steps is the following matrix in Equation 2 [14]:

$$\begin{bmatrix} P'_1 \\ P'_2 \\ \dots \\ P'_m \end{bmatrix} \quad (2)$$

Where m is the number of criteria and P'j is the priority of criterion j with respect to the overall goal, for j = 1, 2, ..., m. In this case, the criteria, as investigated, were four.

Step 2: Stakeholders vs. Criteria comparison



The alternative comparison matrix is developed and steps 2, 3 and 4 are also applied [14].

Subsequently, the sequence of this step is as follows:

-A matrix of priorities is obtained for each alternative according to the criteria, as observed in Equation 3 (Annex), in which P_{ij} is the priority of stakeholder "i" with respect to criterion "j".

$$\begin{bmatrix} P_{12} & P_{13} & \dots & P_{1m} \\ P_{21} & P_{22} & \dots & P_{2m} \\ \dots & \dots & \dots & \dots \\ P_{n1} & P_{n2} & \dots & P_{nm} \end{bmatrix} \quad (3)$$

Where P_{ij} is the priority of alternative i with respect to criterion j, for $i = 1, 2, \dots, n$; and $j = 1, 2, \dots, m$.

-We make a sum-product between the priorities matrix with the criteria priorities vector [14]. The above mathematical operation is shown in Equation 4.

$$\begin{bmatrix} P_{11} & P_{12} & \dots & P_{1m} \\ P_{21} & P_{22} & \dots & P_{2m} \\ \dots & \dots & \dots & \dots \\ P_{n1} & P_{n2} & \dots & P_{nm} \end{bmatrix} \begin{bmatrix} P'_1 \\ P'_2 \\ \dots \\ P'_m \end{bmatrix} = \begin{bmatrix} P g_1 \\ P g_2 \\ \dots \\ P g_n \end{bmatrix} \quad (4)$$

Where $P g_1$ is the global priority (with respect to the global goal) of the alternative i ($i = 1, 2, \dots, n$).

Step 3: Consistency

The AHP offers a method to measure the degree of consistency between the paired opinions provided by the decision maker. If the degree of consistency is acceptable; you can continue with the process. The steps are the following:

-Matrix A $n \times n$ of paired comparisons is normalized.

-The rows of the normalized matrix are weighted.

-We produce a product of matrices between the matrix A and the weighted one (matrix P) [14]. This matrix multiplication is shown in Equation 5.

$$\begin{bmatrix} 1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & 1 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} n w_1 \\ n w_2 \\ \vdots \\ n w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (5)$$

-The column of the criteria priority matrix is added; this result is called n_{max} .

-The consistency index is found with the following Equation 6 [14].

$$IC = \frac{n_{max} - n}{n - 1} \quad (6)$$

Where n is the number of criteria

-The random consistency index has the following equality, as shown in Equation 7 [14].

$$IA = \frac{1.98(n-2)}{n} \quad (7)$$

-The consistency ratio is found with the following Equation 8 [14].

$$RC = \frac{IC}{IA} \quad (8)$$

If:

$RC \leq 0.10$: reasonable consistency

$RC > 0.10$: Inconsistency

2.2. The Entropy-Weight Method

The entropy-weight method can be developed as follows: It is necessary for this process to use this scale to standardize the answers of the surveyed.

Step 1: Assume that there are m objects for evaluation and n evaluation criteria, which form the decision matrix $Z = (z_{ij}; i=1, 2, \dots, m; j=1, 2, \dots, n)$ [19].

Step 2: The decision matrix $Z = \{z_{ij}; i=1, 2, \dots, m; j=1, 2, \dots, n\}$ is normalized for each criterion C_j ($j=1, 2, \dots, n$). The normalized values P_{ij} are calculated by the next Equation 9 [20].

$$P_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}} \quad (9)$$

Step 3: The entropy H_j of each criterion C_j is calculated by the next Equation 10.

$$H_j = -k \sum_{i=1}^m P_{ij} \ln(P_{ij}) \quad (10)$$

where k is a constant. $k = (\log(m))^{-1}$

Step 4: The degree of divergence div_j of each criterion C_j is obtained by the next Equation 11:

$$div_j = 1 - H_j \quad (11)$$

Step 5: The entropy weight W_j of each criterion C_j is calculated by Equation 12:

$$W_j = \frac{div_j}{\sum_{j=1}^n div_j} \quad (12)$$

Step 6: The matrix Q_{ij} is obtained with Equation 13 that indicates the weight that each variable has within each criterion.

$$Q_{ij} = w_j * z_{ij} \quad (13)$$

Step 7: Finally, each column is added to obtain the total weight of each variable and be able to compare with the others.

III. CASE STUDY

The case to be developed focused on the Macusani mining project, located in Puno (see Fig. 1). This project is a lithium and uranium deposit, which is projected to be one of the largest in the world due to its high metallic content. Below is the exact location of this project [21]:



Fig. 1. Macusani Project's Locality plan [21]

Eight stakeholders and ten variables were obtained from the literature, of which only the five stakeholders and seven most important variables were determined thanks to the application of the mathematical models AHP and entropy-weight.

Next, stakeholders and variables that were analyzed are explained.

3.1. Stakeholder groups

According to the literature, and to the research conducted on economic activities and the main sources of income for the Macusani community, the eight stakeholders would be the following:

3.1.1. Alpaca's herdsman (G1)

One of the most important economic activities in the Macusani region is the livestock of alpacas and llamas (mostly alpacas).

3.2.2. Local and regional government (G2)

The provincial municipality of Carabaya (whose capital is Macusani) presents a structural organization, whose representative is Mayor Fabio Vargas Huamantuco. This institution uses a web page as a tool to motivate direct interaction with its population.

3.2.3. Communal authorities (G3)

This group was composed of citizens from the rural areas near the exploitation site, there are three very important communities identified by the company, which are Tantamaco Community, Isivilla Community and Corani Community [13].

3.2.4. Farmers (G4)

Agricultural activity continues to be of vital importance for rural areas. For this reason, it is very important to identify the people who grow the main products for the region, such as potatoes, alfalfa and oats [22].

3.2.5. People who live on tourism (G5)

Since there are many lakes around the zone, many people make their living by the tourism income.

3.2.6. Merchants (G6)

Due to the diverse agricultural products that the community owns, such as potatoes, people see trade as a main activity that generates a monthly income.

3.2.7. Women Spinners (G7)

Thanks to the breeding of alpacas in the area, women see an opportunity the spinning mill and the tissues for general a secondary income.

3.2.8. Local professionals (G8)

They are people who reached a certain level of higher education and work in jobs with major responsibilities.

3.2. Variables

The variables were selected according to the most common problems that a region in the country can go through. Thus, the effect that the project would have on the locality can be measured in more real parameters.

3.2.1. Security (V1)

The integration of a new project generates new jobs, direct or indirect. It also generates many related activities that support mining activity. For this reason, the population is exposed to possible dangers due to the new social environment, which is composed of new foreign settlers.

3.2.2. Employment (V2)

The generation of jobs at the arrival of a new project is a reality. This can be a favorable variable for many of the stakeholders, since, according to the national household survey, the inactivity rate for Puno is 21.8% [23].

3.2.3. Health (V3)

In Puno, 31.92% of children die from infections in the respiratory tract. This is due to the extreme cold that exists in that area of Peru. Health, in children, adolescents and the elderly, is a factor of great importance and urgency in the region, which is expected to improve.

3.2.4. Poverty level (V4)

In the department of Puno, the rural population represents 46.2% [23]. Likewise, Puno is part of the Peruvian highlands, and according to statistics, the rural highlands have a 49.8% poverty, higher than the 21.6% that Peru presents as a country [22]. Therefore, the arrival of a new project could have a positive impact on the economy of the region, thereby reducing poverty rates.

3.2.5. Education level (V5)

This is an important factor because, in 2017, the illiteracy rate in Puno was 10.5% [23], higher than the 9.2% presented in 2016 [22]. On the other hand, if one analyses the illiteracy rate by sex in the last 10 years in Puno, the percentage of illiterate women is approximately four times higher than that of men. Thus, the percentage of illiterate women and men was 15% and 3.6%, respectively in 2017 [24].

3.2.6. Water access (V6)

Since Macusani is very close to the Madre de Dios basin, access to water by the mine would be a latent problem for the community, since a tension relationship would be established in case some body of water could be damaged by mining activities.

3.2.7. Pollution (V7)

Predominant variable in all mining projects to be established in any region. The project has high contents of uranium, a radioactive element, and currently, there is no legislation in Peru to control its extraction. It is for this reason that this variable can be fundamental for the social viability of the project because there is still not enough information about the effects that uranium and lithium have on the environment.

3.2.8. Cultural Difference (V8)

One of the inevitable consequences of a mining project in the communities is the arrival of foreign people. A clear example of this is the growth of social demands generated in a community due to the increase of its population, which generates pressure on the health sector and infrastructure systems [25].

The lifestyle of local people is going to undergo a transformation, this change "creates concern, fear, hopes and expectations and not everyone shares the same perspective, some people feel they are losing out, while others see new opportunities" [26]. In this way, a division can be generated in the community itself between those who are in favour of the mining project and those who are against it.

3.2.9. Economy (V9)

Mining activity does not necessarily bring about economic progress due to external factors that do not depend on it. In Peru, mining companies tax about 40% of all their utilities. In spite of this, poor institutionality causes distribution problems, which remains one of the fundamental causes of conflicts between mines and communities [27]. For this reason, it is important to identify the economic activities of the place in order to promote it and make them grow with the help of the state. It is extremely important that action plans are managed, as any lack of action can have adverse consequences. For example, the rental price of properties is likely to increase or transport lines are likely to become congested due to the completion of the mining project. This can lead to those who do not have the education or skills to participate in the boom being left behind [26]. For this reason, these action plans should strengthen local businesses and economies by involving active community participation [28]. The above will generate positive attitudes on the part of the community and, as a consequence, support for mining projects in the area.

3.2.10. Technological development (V10)

Lithium has become an essential element for current technological development, mainly in the field of the automotive industry. Thanks to it, the country of Bolivia is one of the centers of attention of the world-wide industry [29].

Through the extraction of lithium, one of the achievements of the government of Evo Morales in Bolivia is the technological evolution. This is because the policy promoted by the president strengthens the local economy of his country, a clear example of this is the inauguration of the first pilot plant of lithium-ion batteries located in the town of La Palca in 2017 [30]. This could be replicated in Puno and, in this way, it could become the leading department not only in poverty reduction, but also in technological advancement.

3.3. Criteria

The criteria were selected according to the parameters established for the project. That is, taking into account the main activities, stakeholders, etc.

3.3.1. Magnitude of social impact (C1)

The magnitude of the social impact implies the dimension that this could have, in case it is materialized, the level of violence that it can generate, the material damages, human losses, etc.

3.3.2. Extension (C2)

This criterion explains the arrival of the impact. It can be local, regional, even national. According to the magnitude of it.

3.3.3. Probability (C3)

The probability that a social conflict will occur according to each variable and stakeholder, according to the impact that the project has on them.

3.3.4. Governance (C4)

How a possible social conflict can impact on the governmental system of the locality, of the region; even of the country.

3.1. Calculations

Following the steps described in the methodology point, one of the examples developed using the AHP method and the entropy-weight method will be explained.

A. THE AHP METHOD

Step 1: Criteria Comparison

From the surveys conducted and the sequence in Step 1, the criteria comparison matrices were obtained for each expert. For example, in Table 2, the matrix carried out for expert E3 is shown.

Table 2. Criteria Comparison Matrix, expert E3

CRITERIA COMPARISON MATRIX									
CRITERIA	C1	C2	C3	C4	STANDARDIZED MATRIX				WEIGHT
C1	1	5	9	3	0.608	0.536	0.5	0.662	0.576
C2	1/5	1	3	0.333	0.122	0.107	0.167	0.074	0.117
C3	1/9	1/3	1	0.2	0.068	0.036	0.056	0.044	0.051
C4	1/3	3	5	1	0.203	0.321	0.278	0.221	0.256
TOTAL	1.644	9.333	18	4.533					

It should be noted that the experts surveyed were seven, so this matrix was carried out seven times.

Step 2: Stakeholders vs. Criteria comparison

By means the same scale, the stakeholders were compared for each established criterion. This is, according to each criterion, there was a matrix comparing the stakeholders among them and the same sequence as the previous step was performed.

Finally, for example, after applying Equation 4, the stakeholders prioritization matrix for expert E3 was obtained, this matrix is shown in Table 3.

Table 3. Stakeholders Prioritization Matrix, expert E3

stakeholder /criteria	C1	C2	C3	C4	PRIORITIZATION
G1	0.307	0.18	0.281	0.256	0.278
G2	0.107	0.169	0.145	0.151	0.128
G3	0.155	0.268	0.193	0.255	0.196
G4	0.068	0.081	0.122	0.13	0.088
G5	0.094	0.066	0.076	0.057	0.08
G6	0.088	0.036	0.066	0.051	0.071
G7	0.102	0.144	0.088	0.063	0.096
G8	0.079	0.056	0.03	0.036	0.063
WEIGHT	0.576	0.117	0.051	0.256	

By obtaining the prioritization of each stakeholder, it is possible to choose the five most important, according to this expert E3. Thus, in this case, the hierarchical order of the five main stakeholders was as follows: alpaca's herdsman, communal authorities, local and regional government, women spinners and farmers. It is important to mention that seven different prioritization matrices were obtained for each expert surveyed.

In this way, in order to know the final hierarchical order of the stakeholders, the average of all priority values was obtained.

Step 3: Consistency

In order to corroborate that the experts did not contradict each other during the conduct of the surveys, the Consistency Ratio (RC) for each of them was determined. For example, after applying Equations 5, 6, 7 and 8, an acceptable consistency ratio was obtained for expert E3, which is shown in Table 4.

Table 4. The Consistency Ratio, expert E3

	A X P		
	2.386	IC	0.038
	0.470	IA	0.990
	0.205	RC	0.038
	1.053		
n max	4.114		

From Table 4, the $RC=0.038 < 0.10$; therefore, the matrix was consistent. The same procedure was developed for seven experts.

B. THE ENTROPY-WEIGHT METHOD

Step 1: Variable vs. Criteria comparison

By means of the same scale, all the proposed variables were compared with each criterion. Hence, according to the importance that each variable has according to each criterion, it was given a value for further analysis, see Table 5.

Table 5. Variable vs criteria comparison matrix, expert E3

Variables/Criteria	C1	C2	C3	C4
V1	3	3	7	7
V2	5	3	3	1
V3	5	5	7	5
V4	1	1	7	5
V5	1	1	1	1
V6	1	1	1	1
V7	1	3	5	7
V8	5	3	5	7
V9	3	3	3	5
V10	3	1	3	1
SUM	28	24	42	40

Step 2: Standardized/Normalized matrix

Once the values for each variable have been obtained, all the values are standardized, using Equation 9, as shown in Table 6.

Table 6. Variable vs criteria comparison normalized matrix, expert E3

NORMALIZED MATRIX				
Variables/Criteria	C1	C2	C3	C4
V1	0.107	0.125	0.167	0.175
V2	0.179	0.125	0.071	0.025
V3	0.179	0.208	0.167	0.125
V4	0.036	0.042	0.167	0.125
V5	0.036	0.042	0.024	0.025
V6	0.036	0.042	0.024	0.025
V7	0.036	0.125	0.119	0.175
V8	0.179	0.125	0.119	0.175
V9	0.107	0.125	0.071	0.125
V10	0.107	0.042	0.071	0.025

Step 3: Calculation of entropy

To calculate the entropy, we proceed to use the Equation 10, provided that a value is obtained for each criterion, as shown in Table 8. In this case, the value of K was 1.

Table 8. Values of entropy for each criterion, expert E3

ENTROPY	
C1	0.919
C2	0.936
C3	0.932
C4	0.896

Step 4: Calculation of divergence

To calculate the value of the divergence, the Equation 11 was used, at each value of entropy previously found, as shown in Table 9.

Table 9. Values of divergence for each criterion, expert E3.

DIVERSITY	
C1	0.081
C2	0.064
C3	0.068
C4	0.104
SUM	0.316

Step 5: Calculation of criteria weight

To calculate the weight of each criterion, the values of diversity should be standardized, using the Equation 12. Then, multiply this value by one hundred to obtain a percentage as the weight of each criterion. The results are presented in Table 10.

Table 10. Values of criteria weight for each criterion, expert E3.

CRITERIA WEIGHT	
C1	25.526
C2	20.132
C3	21.51
C4	32.831

Step 6: The Matrix Q_{ij}

To order the variables according to the prioritization order given by the expert, it is necessary to use the Equation 13. Multiplying the value granted at the beginning by the expert, by the weight of each criterion, the results are presented in Table 11.

Table 11. The Matrix Q_{ij} , expert E3.

Variables/ Criteria	C1	C2	C3	C4	C1
V1	76.579	60.397	150.571	229.818	517.365
V2	127.632	60.397	64.53	32.831	285.39
V3	127.632	100.662	150.571	164.156	543.02
V4	25.526	20.132	150.571	164.156	360.386
V5	25.526	20.132	21.51	32.831	100
V6	25.526	20.132	21.51	32.831	100
V7	25.526	60.397	107.551	229.818	423.292
V8	127.632	60.397	107.551	229.818	525.398
V9	76.579	60.397	64.53	164.156	365.662
V10	76.579	20.132	64.53	32.831	194.073

Step 7: Prioritization of variables

Finally, all values are added per variable and a final value is obtained, which will represent the importance of each variable.

According to expert E3, the variables with the greatest influence in decreasing order would be health (V3), cultural difference (V8), security (V1), pollution (V7), economy (V9), poverty level (V4) and employment (V2). The above is shown in the Table 12.



Table 12. Variable prioritization matrix, expert E3

Variables/ Criteria	C1	C2	C3	C4	SUM
V1	76.579	60.397	150.571	229.818	517.365
V2	127.632	60.397	64.530	32.831	285.390
V3	127.632	100.662	150.571	164.156	543.020
V4	25.526	20.132	150.571	164.156	360.386
V5	25.526	20.132	21.510	32.831	100.000
V6	25.526	20.132	21.510	32.831	100.000
V7	25.526	60.397	107.551	229.818	423.292
V8	127.632	60.397	107.551	229.818	525.398
V9	76.579	60.397	64.530	164.156	365.662
V10	76.579	20.132	64.530	32.831	194.073

It is important to mention that seven different prioritization matrices were obtained for each expert surveyed. Thus, in order to know the final hierarchical order of the variables, the average of all priority values was calculated.

IV. RESULT AND DISCUSSION

4.1. Stakeholder analysis

According to Table 13, the most important stakeholders obtained by the application of the AHP method were the following:

Table 13. Stakeholders obtained by the AHP method

	Stakeholder Identification							Results
	E1	E2	E3	E4	E5	E6	E7	
G3	0.212	0.229	0.196	0.225	0.359	0.200	0.168	0.227
G1	0.337	0.253	0.278	0.123	0.140	0.149	0.198	0.211
G2	0.167	0.084	0.128	0.053	0.059	0.299	0.243	0.147
G4	0.076	0.097	0.088	0.313	0.089	0.102	0.123	0.127
G6	0.093	0.244	0.071	0.165	0.033	0.078	0.126	0.116
G7	0.015	0.045	0.097	0.018	0.148	0.035	0.038	0.056
G8	0.072	0.013	0.063	0.031	0.128	0.017	0.052	0.054
G5	0.029	0.035	0.080	0.073	0.045	0.048	0.051	0.052

4.1.1. Communal authorities (G3)

They were the most important in the hierarchy made by the AHP method. It is consistent because since for several years, mining companies in Puno have sought to work with them through workshops on mining, environment, social management, sustainable development and investment projects [31]. This proves that they are aware of the influence of this stakeholder.

4.1.2. Alpaca's herdsman (G1)

The population of this stakeholder is one of the largest in the department of Puno, and especially in the province of Carabaya. This is demonstrated by Puno's annual report published by the National Institute of Statistics and Informatics (INEI) in 2017.

This report shows a population growth of the alpaca from 2011 to 2016, this generates that the Alpaca's livestock add more power or influence in their locality.

For instance, in 2016 there was an average annual population of 280,110 alpacas in Carabaya [22], which represents 13.78% of the total population of alpacas in Puno.

Additionally, this economic activity generates the production of meat and fiber in Carabaya, using 72% of its total alpaca

cattle. As the previously explained, it can be shown in Table 14 [22].

Table 14. Population of Alpaca, Production of Meat y Fiber in Puno [22]

Province	Average population per year	Meat production		Fiber production	
		N° of heads	Tonnes	Animals in shearing	Tonnes
Puno	175,090	21,011	567	105,054	221
Azángaro	198,010	23,761	642	118,806	249
Carabaya	280,110	33,613	908	168,066	353
Chucuito	191,020	22,922	619	114,612	241
El Collao	182,340	21,881	591	109,404	230
Huancané	154,420	18,530	500	92,652	195
Lampa	293,080	35,170	950	175,848	369
Melgar	296,210	35,545	960	177,726	373
Moho	9,860	1,183	32	5,916	12
S.A. de Putina	142,110	17,053	460	85,266	179
San Román	56,630	6,796	183	33,978	71
Sandia	53,160	6,379	172	31,896	67
Yunguyo	450	54	1	270	1
TOTAL	2,032,490	243,898	6,585	1,219,494	2,561

4.1.3. Local and regional government (G2)

Currently, Puno is in a critical state in its governance since recently Walter Aduviri was elected as regional governor of Puno [32]. This generates a confusion in the mining companies that are carrying out projects in this area. Is because in 2006, Aduviri staged a violent protest against the Santa Ana project [33].

For this reason, he was sentenced to 7 years in prison after being appointed as author of the crime against public tranquility in his modality of crimes against public peace [32].

This panorama shows that the local and regional authorities are a determining stakeholder at present, since there is a lot of uncertainty in the governmental aspect. This means that the mining company must carry out a sustainable social management without neglecting this stakeholder.

4.1.4. Farmers (G4)

Another of the main economic activities of Puno is farming. In the INEI's 2017 annual report, it can observe a growing trend of hectares of the areas planted and harvested during the years 2006 and 2016. The main agricultural crops that we can mention are olluco and quinoa. The above mentioned is shown in Table 15 and Fig. 2 [22].

Table 15. Planted and harvested surface of principal agriculture crops in Puno [22]

Farming Year	Puno: Planted and harvested surface of principal agriculture crops (2016)										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Olluco	1.36	1.49	1.68	1.66	1.70	1.73	2.03	2.33	2.33	2.57	2.76
Quinoa	24,02	24,60	26,26	23,38	27,05	28,36	30,26	32,82	32,92	34,64	36,43
Cultivated pasture	5,18	5,79	66	5,40	507	532	8,01	8,91	9,04	9,50	10,66
Alfalfa	13,13	15,69	6,41	5,74	2,02	4,40	3,83	4,10	42,35	47,67	55,85



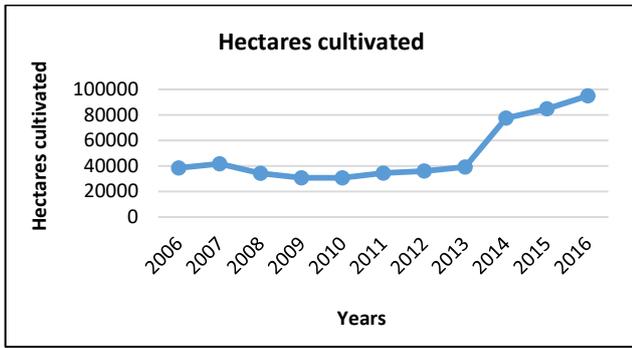


Fig. 2. Hectares cultivated in the last ten years in Puno

4.1.5. Merchants (G6)

The last main stakeholder is merchants, which have also been increasing since 2006 with 2,423 merchants until 2016 with 2,965 merchants [22], which represents a growth of 22.37%. It can be seen in Table 16 [22].

Table 16. Growing trend of merchants in the last ten years in Puno [22]

Principal Characteristics	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Agriculture/Fishing/Mining	4,503	4,153	4,121	4,115	4,042	4,143	4,039	4,048	4,114	4,283	4,293
Manufacture	1,403	1,599	1,634	1,605	1,641	1,548	1,627	1,590	1,507	1,502	1,542
Construction	539	613	655	738	842	866	918	975	1,014	1,044	997
Trading	2,423	2,527	2,518	2,682	2,648	2,789	2,939	3,009	3,007	2,890	2,965
Communications and Transport	893	1,017	1,109	1,111	1,130	1,226	1,190	1,205	1,270	1,315	1,362
Other services	3,923	4,289	4,421	4,647	4,786	4,735	4,829	4,857	4,885	4,887	5,039

4.2. Analysis of the variables

On the other hand, we can analyze the variables obtained by the entropy-weight method. The total results in hierarchical order are presented in Table 17.

Table 17. Variables obtained by the entropy-weight method

	Determination of variables							Results
	E1	E2	E3	E4	E5	E6	E7	
V7	888.508	900	423.292	925.706	900	749.528	500	755.2907
V4	748.553	900	360.386	772.65	574.513	700	645.676	671.6824
V2	749.162	580.46	285.39	462.427	900	690.967	754.324	631.8186
V3	435.464	840.23	543.02	317.934	551.743	645.008	700	576.1999
V9	627.855	654.092	365.662	215.484	637.256	700	631.913	547.4661
V6	748.553	240.23	100	657.957	700	709.039	478.836	519.2307
V1	620.698	341.557	517.365	270.991	533.77	771.279	365.986	488.8065
V5	360.045	577.046	100	125.706	500	700	787.485	450.0403
V8	423.972	377.046	525.398	168.541	437.256	700	471.099	443.3302
V10	311.492	120.749	194.073	117.128	100	300	596.987	248.6327

4.2.1. Pollution (V7)

According to the hierarchy, this variable is the most important of all, which means that any impact made on the environment, would have a very strong impact on the behavior of the community. According to 2017 annual report [22], it can be seen that the loss of forests per year in hectares has been increasing during the last 10 years, this causes the population to feel dissatisfied with this aspect. Additionally, if we add the perspective of Aduviri, the situation can be complicated since one of the basic points of his speech is that of pollution mitigation.

On the other hand, we can mention the loss of prestige of the Aruntani mine in the province of Lampa (Puno) due to the pollution of the Jatun Ayllu river [34]. This generates a distrust of the peasant community and it does not favor the prestige of mining in Puno. If this variable is negatively impacted, such affectation can generate very dangerous

social conflicts for the development of mining projects in the department of Puno in general.

4.2.2. Poverty Level (V4)

The level of poverty of rural communities in Peru amounts to 21.8%, of which, 34.6% is in Puno and 6.5% of that population belong to extreme poverty [35]. The Peruvian Institute of Economics (IPE) in 2017 reported that the province of Carabaya has 50% more incidence [35], as shown in Fig. 3. This shows that it is a very important variable since it is what most affects the stakeholders.

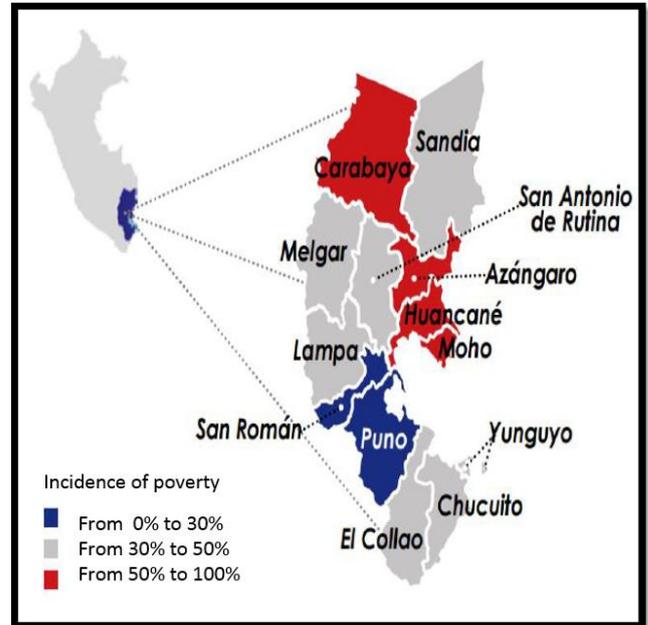


Fig. 3. Incidence of poverty in the provinces of Puno [35]

In addition, 5,423 people were registered in poverty, which represents 41.2% of the total population of Macusani; and 987 people in extreme poverty, which represents 7.5% [36]. However, it is important to mention that this district is incorporated into the National Multiannual System and Investment Management (INVIERTE.PE). In this way, this district has funding resources for projects that contribute to improving the living conditions of the population [36] and reduce the percentages of poverty.

4.2.3. Employment (V2)

The variable employment is of great importance since that is the first improvement that the community of a mining company directly perceives. If we analyze the case of Puno, this region "has a high percentage of informal employment", 85.3% is informal since only 22.6% of the PEA has at least higher education [35].

4.2.4. Health (V3)

The variable Health is one of the main deficiencies of the rural communities of Puno and Macusani district is not the exception. It has been recorded that the number of health facilities (26) in the province of Carabaya has remained constant despite the fact that the population has been increasing [22].



The population most affected by these problems are children, in Macusani, it is recorded that 29.1% of children under one year require additional attention monthly because they were born with less than 2.5 kilos of weight [36].

4.2.5. Economy (V9)

The economy is an important factor for the development of any community. For this reason, the mining company must know the main economic activities of the region and promote them. In the case of Macusani project, the economic activities are livestock, agriculture and commerce.

4.2.6. Water access (V6)

This variable has been one of the repetitive causes of many social conflicts that have occurred in Peru and throughout the world. The access to water that communities have is vital for the development of agriculture and livestock. The Yellowcake Company must inform the communities about the fair use of the water sources, or, on the contrary, the construction of water dams should be built. In this way, the mining activity will not affect the economic activities of the community.

4.2.7. Security (VI)

Rural communities in Peru have a low tolerance for criminal acts and Macusani is not the exception. It has been known that the guardians of the community have burned alive criminals without the local police could do something about it. We can conclude that a negative alteration to the communal security will be determinant for the occurrence of a social conflict, if they link this fact with the beginning of the operations of the mining company.

Finally, Table 18 shows the advantages and disadvantages that we perceive during the use of each methodology used to carry out our research [37][38].

Table 18 Advantages and disadvantages of both methods

	Advantage	Disadvantages
AHP	<ul style="list-style-type: none"> ↳ The procedure of the information was complicated since it is necessary to work with several matrices ↳ The correction of the matrix could be elaborated to avoid that the expert enters into contradictions. 	<ul style="list-style-type: none"> ↳ It was too tedious to carry out the survey, because many matrices had to be completed.
Entropy-weight	<ul style="list-style-type: none"> ↳ Easy to operate the data since it is only made with a hammer 	<ul style="list-style-type: none"> ↳ The expert could easily get into confusion because he only works with an extensive matrix. ↳ The correction of the matrix was not used to verify if the expert entered into contradiction.

V. CONCLUSION

The main stakeholders with the greatest influence in terms of criteria of magnitude, extent, probability and governance of the conflict were correctly determined using the AHP Method. On the other hand, the analysis of the variables applying each of the criteria in the entropy-weight method was important in determining which variables were going to have a significant impact on stakeholders. These results can be very useful to Plateau Uranium, as it will be able to identify its potential local suppliers and achieve negotiations that enrich the value of the company and the community. In addition, in terms of improving the local, regional and national Peruvian economy it is fundamental that the government, company and community can add together efforts to generate a sustainable development in the project

influence zone, with the aim of reducing the social gap reflected in the poverty index.

Furthermore, the investigation of the social issues applied in this mining project can be useful to establish a responsible mining sense focus on the participation and dialogue with the rural communities that are in the direct influence zones. This will improve the relationship between the company and the community in the long term, which will enhance its reputation in global markets, as well as the utilities increase by the reduction of conflicts to maintain a constant production.

The AHP method can be widely applied in the future social impact analysis for this mining project because it can receive the information given by a panel of experts according to their experience in matter. It is highly recommended to make a hierarchization of the more relevant stakeholders that take part in the conflict, in the same way, it prevents incompatibility of the information given from the experts by using a ponderation of the criterion matrix. In the other hand, the entropy-weight method is useful to make a quantification of the variables using a logarithmical function to stablish the weight of the answers.

Every single process of analysis evaluation is known to have limitations that come out afloat during the interview with the experts and their feedback given. For example, it is necessary to notice that the poll is given in a specific lapse time and that the scene can change in a political election context. Secondly, it is important that the facilitator who perform the poll can be prepare enough to elucidate all the questions and doubts of the experts in order to obtain specific answer to the questions that are indicated. However, it is important to note that the investigation refers to a study of people with different worldviews like rural communities, consequently the prediction of their behavior facing an impact such as a mining project cannot be a hundred percent trustworthy. For this reason, it is necessary to travel and know the place in situ to corroborate the information obtained and adjust our results.

Finally, thanks to the effective determination of the stakeholders and variables of the communities of direct influence of the Macusani project, several future studies can be carried out. First, for example, it is possible to determine Social impact assessment using some method like the mathematical model of grey glustering. On the other hand, another future study that could be carried out is the Environmental Conflict Analysis (ECA) for the same project. On the other hand, this methodological process can be applied in other mining projects in Peru and around the world in order to determine the probable causes that could generate a mining conflict, and thus be able to prevent them and work on them in advance.

REFERENCES

1. S. F. and L. Vergara, "Acceso a la Tierra y Planificación del Reasentamiento en La Granja," CSRМ Artículos ocasionales Desplazamiento y Reasentamiento inducido por la Minería, p. 1, 2015.
2. D. Arbeláez-Ruiz, "Diálogo, conflictividad y regulación de los Estudios de Impacto Ambiental en el Sistema minero," Australia, 2015.



3. ICMM, "Mining: Partnerships for development toolkit," Int. Counc. Min. Met. (ICMM), London, UK., 2011.
4. M. Kim, Y.-C. Jang, and S. Lee, "Application of Delphi-AHP methods to select the priorities of WEEE for recycling in a waste management decision-making tool," *J. Environ. Manage.*, vol. 128, no. 0, pp. 941–948, 2013.
5. E. S. T. Volaric, Tomislav; Brajkovic, "Selection of the Multimedia Applications for Learning using FAHP and," pp. 44–48, 2013.
6. C. Li, K. Chen, and X. Xiang, "An integrated framework for effective safety management evaluation: Application of an improved grey clustering measurement," *Expert Syst. Appl.*, vol. 42, pp. 5541–5553, 2015.
7. T. R. Wojcik and D. Krapf, "Solid-State Nanopore Recognition and Measurement Using Shannon Entropy," *IEEE Photonics J.*, vol. 3, no. 3, pp. 337–343, Jun. 2011.
8. C. Feng, S. Wu, and N. Liu, "A user-centric machine learning framework for cyber security operations center," in *2017 IEEE International Conference on Intelligence and Security Informatics: Security and Big Data, ISI 2017*, 2017, pp. 173–175.
9. J. Staple-Clark, "How To Quantify Qualitative Research," *Unite For Sight's Global Team*, 2019. .
10. A. Delgado and I. Romero, "Social impact assessment on a hydrocarbon project using triangular whitenization weight functions," in *2016 IEEE Congreso Argentino de Ciencias de la Informática y Desarrollos de Investigación (CACIDI)*, 2016, pp. 1–6.
11. A. Delgado, "Why do any secondary students prefer the mathematics? A response using grey systems," in *Proceedings of the 2017 International Symposium on Engineering Accreditation, ICACIT 2017*, 2018.
12. Rumbo Minero, "2.5 millones de toneladas de litio en proyecto Macusani, reporta Plateau," 2018. .
13. Plateau Uranium, "Macusani Project Uranium & Lithium in Peru Moving Towards 2020 Production," 2018.
14. G. B. Toskano Hurtado, "El Proceso De Análisis Jerárquico (AHP) como herramienta para la toma de decisiones en la selección de proveedores," *Universidad Nacional Mayor de San Marcos*, 2005.
15. A. Delgado and H. Flor, "Selection of the best air purifier system to urban houses using AHP," in *2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies, CHILECON 2017 - Proceedings*, 2017, vol. 2017-Janua.
16. J. Aznar and F. Guijarro, *Nuevos métodos de valoración. Modelos multicriterio*. 2012.
17. J. Osorio and J. Orejuela, "EL PROCESO DE ANÁLISIS JERÁRQUICO (AHP) Y LA TOMA DE DECISIONES MULTICRITERIO. EJEMPLO DE APLICACIÓN," *Sci. Tech.*, vol. XIV, no. 39, pp. 247–252, 1995.
18. A. R. Hadadian and A. Rasoulian, "Using Analytic Hierarchy Process (AHP) for Selecting the Appropriate Country for Economic Integration (Case of Iran ' s Foreign Trade with OIC Countries)," *Int. Res. J. Financ. Econ.*, no. 162, pp. 24–32, 2017.
19. A. Delgado, "Citizen criminality assessment in lima city using the grey clustering method," in *Proceedings of the 2017 IEEE 24th International Congress on Electronics, Electrical Engineering and Computing, INTERCON 2017*, 2017.
20. A. Delgado and I. Romero, "Applying grey systems and shannon entropy to social impact assessment and environmental conflict analysis," *Int. J. Appl. Eng. Res.*, vol. 12, no. 24, pp. 14327–14337, 2017.
21. P. S. Nat and S. Nupen, "Mineral Resource estimates for the Chilcuno Chico, Quebrada Blanca, Tantamaco and Isivilla deposits in the Puno District of Peru, updated to include lithium and potassium Prepared," *Bryanston*, 2016.
22. INEI, "Compendio estadístico Puno 2017," p. 464, 2017.
23. INEI CENSO, "PUBLICACIONES – Censos Nacionales 2017," 2017.
24. INEI, "PERÚ: Tasa de analfabetismo de mujeres y hombres de 15 y más años de edad, según ámbito geográfico," 2017. [Online]. Available: <https://www.inei.gob.pe/estadisticas/indice-tematico/analfabetismo-y-alfabetismo-8036/>. [Accessed: 05-Sep-2019].
25. C. Aedo, "Evaluación del Impacto Social (EIS)," 2005.
26. S. Flynn, "Desde la Minería a la Nueva Economía 1 : Principios de Diseño para el Desempeño Social," *Cent. Soc. Responsib. Min.*
27. P. A. Haslam and N. Ary Tanimoune, "The Determinants of Social Conflict in the Latin American Mining Sector: New Evidence with Quantitative Data," *World Dev.*, vol. 78, pp. 401–419, 2016.
28. D. Franks, "Evaluación del impacto social de los proyectos de recursos," *Australia*, 2012.
29. G. Vásquez, "El litio y el futuro desarrollo de Bolivia," *Puno Cultura y Desarrollo*, 2017. [Online]. Available: https://punoculturaydesarrollo.blogspot.com/2017_01_01_archive.html. [Accessed: 13-Sep-2019].
30. TeleSUR, "Noticias/América Latina: ¿Sabes cuáles son los avances tecnológicos de Bolivia?," *teleSUR- ABI- Gramma- Gestión-RT- Presidencia de Bolivia/ LP-CA*, 2014. [Online]. Available: <https://www.telesurtv.net/news/Bolivia-Desarrollo-Tecnologico-2014-0929-0051.html>.
31. Miguel Ampudia, "LÍDERES Y AUTORIDADES COMUNALES DE REGIÓN PUNO PARTICIPAN EN TALLER SOBRE MINERÍA," *Revista Proactivo Perú*, 2014. [Online]. Available: <https://proactivo.com.pe/lideres-y-autoridades-comunales-de-region-puno-participan-en-taller-sobre-mineria/>. [Accessed: 21-Nov-2018].
32. El Comercio Perú, "Elecciones 2018: Walter Aduviri es electo virtual gobernador regional de Puno," 2018. [Online]. Available: <https://elcomercio.pe/peru/puno/elecciones-2018-walter-aduviri-ganador-virtual-gobierno-regional-puno-noticia-565427>. [Accessed: 21-Nov-2018].
33. Diario Gestión, "Puno y un gobernador clandestino: Walter Aduviri," *Diario Gestión Política*, 2018. [Online]. Available: <https://gestion.pe/peru/politica/puno-gobernador-clandestino-walter-aduviri-246604>. [Accessed: 21-Nov-2018].
34. Diario Correo, "Creciente contaminación en ríos de Lampa y Melgar indignan a población local," *Diario Correo*, 2018. [Online]. Available: <https://diariocorreo.pe/edicion/puno/creciente-contaminacion-en-rios-de-lampa-y-melgar-indignan-poblacion-local-811577/>. [Accessed: 21-Nov-2018].
35. SINEACE, "Caracterización de la Region Puno," 2017.
36. CEPLAN, "Información departamental, provincial y distrital de población que requiere atención adicional y devengado per cápita," 2017.
37. 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.
38. M. Lihong, Z. Yanping, and Z. Zhiwei, "Improved VIKOR algorithm based on AHP and Shannon entropy in the selection of thermal power enterprise's coal suppliers," *Proc. Int. Conf. Inf. Manag. Innov. Manag. Ind. Eng. ICIII 2008*, vol. 2, pp. 129–133, 2008.