Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5, 843-863
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i5.1780

Using MCA methodology in the mining industry to aid in achieving sustainable management: Case study in the Peruvian mining industry

Julio Poterico Huamayalli[1*], Filomon Laurente Rosas[2]
[1]Mining Engineering Department, Faculty of Mining Engineering, Geology and Metallurgy, National University Santiago Antúnez de Mayolo, 02002, Peru; juliopoterico@unasam.edu.pe (J.P.)
[2]Universidad Nacional Santiago Antúnez de Mayolo, 02001, Perú; flaurenter@unasam.edu.pe (F.L.R.).

Abstract: Quantifying the positive and negative impacts on mining activity is precisely knowing how this activity has been operating. Indeed, in this work its central objective is to quantify the impacts evaluated from a holistic perspective. The positive and negative impacts generated by mining activity in part of the northern region of Peru have been collected, analyzed and evaluated. For the evaluation of externalities, the multiple criteria evaluation (MCA) methodology has been used as a basis, which has been improved by including adjustment factors or weights, both for the components and for the evaluation variables. The calculations of the adjustment factors have been carried out for both the assigned weights and the calculated weights. The impacts obtained through assumed adjustment factors represent 41.50% for positive impacts and 58.50% for negative impacts, while the impacts obtained through the calculated weights were 44.96% for the positive ones and 55.04% for the negative ones. Consequently, multi-criteria assessment of the impacts generated by mining activity using an enhanced multi-criteria assessment with calculated weights is more recommended. It concludes with suggestions for the Peruvian government, mining entrepreneurs and other interested actors to improve the credibility of mining and thus achieve a social license to operate.
Keywords: *Peru, Mining, Positive and negative impacts, Multi-criteria assessment (MCA), Pending agenda, Sustainability, Stakeholders.*

1. Introduction

Modern mining enhances the quality of life for individuals, because many countries, such as Peru, not only support their economy through it, but also isolated peoples can benefit through projects, which account for issues of sustainability. In fact, mining activity provides billions of dollars to Peru's national treasury because of the export of metal products and the payment of taxes, which are a percentage of net profits; hence, the per-capita income is raised [1].

Nevertheless, mining is one of the most controversial activities in many parts of the world. For instance, over the past few years Peruvian mining activity has undergone severe protests and strikes promoted by some organizations. They argue that the current mining activity also causes a variety of environmental, social, cultural, and economic negative externalities, just as mining in the past did. Even more so, they coin the phrase "¡Agricultura Sí! ¡Mina No!" [2] in spite of these activities have coexisted, developed, and cooperated with each other since ancient civilizations.

The rise of mining production in Peru generates local impacts. Mining activity has a double impact. Beneficial for the populations where the mining projects are located but unfavorable for those non-producing populations. That is, mining has a double impact on local communities in Peru: it has a positive average effect but a negative distributional effect [3].

* Correspondence: juliopoterico@unasam.edu.pe

Truly, all extractive industries including mining generate externalities. These impacts can be positive or negative. Mining activity in Peru is currently regulated by modern laws focused on environmental and social components, which seek to reach a better performance in the development of mining operations within the context of sustainability. Moreover, Peruvian mining activity uses modern technologies that are friendlier to the environment and offers safe standards for its workers, which reduces the threat of risks. In that sense, mining represents a feasible social and economical alternative in the development of towns precisely for the variety of favorable influences generated by it. For these reasons, the negative impacts are actually diminished considerably during mining operations.

However, in Peru, regarding mining activities, it is necessary to strengthen institutions that respond to the expectations not only of the population that demands better living conditions but also of mining companies that seek appropriate conditions to develop their operations. Therefore, synergy between the various actors is required to promote sustainability [4].

With this in mind, in order to gain a better perception regarding positive and negative impacts of mining activities, these impacts were analyzed in a regional context through multi-criteria assessment (MCA) methodology, which has general and specific applications.

The purpose of this paper is to show the positive and negative impacts in Peruvian mining industry relying on technological, operational, and normative components as well as socioeconomic, sociocultural, and environmental factors. Both types of externalities will be assessed using multi-criteria assessment methodology wherein the data will be quantified through an improved mathematical model linked to outcomes. In like fashion, the analysis will end with some suggestions for the key stakeholders such as the Peruvian government, mining entrepreneurs, and communities, who should join endeavors for designing and structuring better, sustainable policies resulting in benefits to people over time.

2. Literature Review

2.1. Background and Significance

There are a variety of activities developed by human beings. These activities can be either productive such as tourism, agriculture, fishing, logging trees, mining, and or a public, private, and social service. Mining activity, for example, in many countries, like Peru, has become one of the most meaningful extractive industries on account of its quantity and quality mineral resources: metallic and non-metallic. In fact, Peru's mining tradition goes back to the pre-Incan times. The Incas used many minerals, mainly gold, copper, and silver, which were found in outcrops, in huge amounts, as native metal [5].

However, decades ago, Peru had problems with terrorism and the country did not have an appropriate political climate to develop large-scale mining because of the lack of favorable conditions for developing competitive mining. Therefore, laws were implemented, which attracted international investments.

Nowadays, [6] refers that Peru is a global leader in the mining industry, which makes it a natural choice for international investors. Mining is an economically important sector in Peru, contributing around 10% of the country's total production and two thirds of the value of exports [7].

Currently, Peru maintains the second place in the production of copper and zinc worldwide and ranks first in the production of zinc, lead and tin in Latin America. Additional to this, it has the largest silver reserves in the world and ranks third in reserves of copper, lead and molybdenum worldwide. As a consequence of the bonanza economics proceeding from mining activity, mining has become Peru's main economic backbone. Thus, this income has enhanced the life quality of the Peruvian people [5].

In Peru, mining is divided into four stratums: large-scale, medium-scale, small-scale, and artisanal mining. The stratum of the large-scale mining encourages better conditions for Peru. This mining stratum extracts huge amounts of mineral resources, which are mainly traded to outside countries, such as the US, Japan, Canada, Germany, China, and so forth. Large-scale mining, consequently, contributes millions of dollars in taxes to Peru by which it has become the country's economic backbone [1].

With the establishment of a new political constitution during the 1990s, Peru incorporated environmental indicators. These indicators had as their main goal that mining operations would be worked coherently and adequately throughout their operative processes. Afterwards, there were a variety of laws that forced the mining industry to fulfill the new regulations, such as the general mining law, the general environmental law, and so on. These regulations allowed for a positive change in the Peruvian population in the way of thinking regarding mining activity. After the 1990s, when these activities were regulated in Peru, the attitudes of people rapidly changed because the people had ways to reclaim their rights, justly based on the new regulations.

One of the crucial aspects that mining activity in Peru goes through is precisely the social conflict between mining companies and the communities that are within their areas of influence. For which, as pointed out by [8] one of the essential tools is the dialogue that must be established between the company and the community involved.

Nonetheless, as mining activity causes a variety of externalities, knowing the positive and negative externalities facing the mining industry is extremely important not only for citizens, but also for local, state, and national authorities as well as mining entrepreneurs.

Certainly, there already existed some methodologies to process and quantify positive and negative externalities, such as the multiple account analysis (MAA) [9]. Nevertheless, the multi-criteria assessment (MCA) approach incorporates an integral and transversal analysis of its alternatives proceeding from its variables and factors [10].

In 2022, the Presidency of the Council of Ministers of Peru, through the Secretariat of Public Management, provides a Manual of Methodologies for the evaluation of impacts, through which it explains regarding four evaluation methodologies: 1) Multicriteria Analysis (MCA), 2) Cost Benefit Analysis (CBA), 3) Cost Effectiveness Analysis (CEA) and 4) Risk Analysis (RA) where a better emphasis is given to the methodology through multicriteria analysis [11].

In fact, this approach involves a broad context of evaluation by using a variety of criteria for its analysis and assessment, incorporating social, cultural, environmental, economic, technological, operational, and other factors according to the nature of the study. Additionally, this methodology not only combines both qualitative and quantitative data in its analysis but also is scalable for both general and specific applications. Hence, the MCA technique obtains holistic and linked outcomes, which allows for enhanced decision-making [12].

2.2. Conceptual Framework

The 2030 Agenda and its 17 sustainable development goals (SDGs) make it possible to analyze and formulate the means to achieve a new vision of sustainable development. For its implementation, the Agenda requires the participation of government representatives, civil society, academia and the private sector. The objectives of social inclusion, environmental sustainability and economic development can serve as a useful starting point for companies trying to align their operations with the SDGs (Economic and Social Research Consortium; henceforth, labeled CIES) [13].

Thus, CIES also specifies that in mining activity, sustainability indicators must be developed that allow the comprehensive measurement of the impacts generated by mining activity in all its dimensions, including the environment, society, economy, and culture. These indicators must be scientifically rigorous, socially acceptable and appropriate for each specific context [14].

The United Nations Conference on Sustainable Development, Rio+20 World Summit held in Rio de Janeiro, Brazil, 2012, raised among other aspects that the mining sector must include in its evaluations effective measures that reduce social and environmental impacts as a response to the new emerging challenges of society to promote sustained and inclusive growth, social development and environmental protection [15].

The Brundtland Commission [16] defined sustainable development in anthropocentric terms, "Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present generations without compromising the ability of future generations to meet their own needs." This means that there is implicit recognition regarding the dynamic carrying capacity of the planet as a limited resource.

In this context, according to Figure 1, three dimensions were originally comprised the sustainable development definition: social, environmental, and economic. In the last years, the sustainable development conceptualization has incorporated other dimensions, such as technology and governance. All of these multi-dimensional components must be inherently circumscribed by the ethical dimension as well as connected to each other as described in Fig. 1[17, 18]. Thereby, the satisfaction of future needs depends on how much balance is achieved for people among the social, economic, and environmental decisions, which are made now [17].

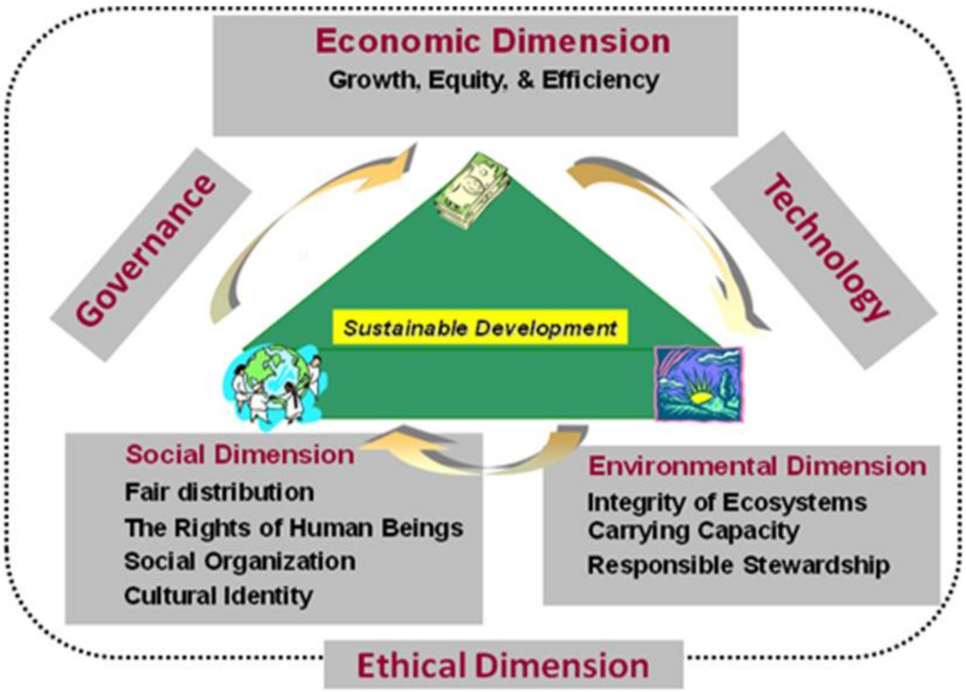

Figure 1.
Criteria of sustainable development.

Mining's contribution to sustainable development has been the subject of much debate in the last years. This is because mining has been focused on mainly economic contributions neglecting other factors, such as social, cultural, and environmental issues, which are required for the achievement of an authentic sustainable development. Owing to investment liberalization and strong demand of minerals in numerous mineral-rich countries, this activity has increased its production dramatically, which has been accompanied by conflict with local communities, among other negative externalities caused by this activity [19].

In fact, the final report of the "International Institute for Environment and Development" (IIED) and "Mining, Minerals and Sustainable Development" (MMSD) in (2002) concluded, "One of the

DOI: 10.55214/25768484.v8i5.1780

greatest challenges facing the world today is integrating economic activity with environmental integrity, social concerns, and effective governance systems." The mining and minerals industry faces some of the most difficult challenges of any other industrial sector – and people have developed mistrust with day-to-day mining operations [20].

It should be evident that quantifying positive and negative impacts coming from mining activity would result in an extremely important tool of managerial decision making. The quantification of impacts, of course, should be made through efficient methodologies, which incorporates holistic criteria to its assessment. In truth, there is a variety of methodologies to analyze alternatives.

[10] point out that it is most difficult to plan and manage any activity when there are multi-stake holders and heterogeneous expectations. Planning requires a multi-objective approach that leads to well conceived and acceptable management alternatives and expands the ability to make decisions in complex circumstances. Consequently, it also requires analytical methods that examine tradeoffs, and also consider multiple political, economic, environmental, and social dimensions in order to optimize its evaluation.

Over the last few years, a variety of MCDM (Multi-Criteria Decision Making) methods have been designed. These methods vary depending on the type of research questions, the type of problem, the theoretical background, and the type of results obtained. Since MCDM methods have been designed for particular cases, with their advantages and disadvantages, there is no specific method that can be applied to all types of problems. MCDM methods have become useful for a wide range of applications in mining and mineral processing since their introduction almost two decades ago. The role they play in the decision-making process for multi-conflict criteria under a scenario of uncertainty is of great importance [21].

The PROMETHEE-GDSS (Preference Ranking Organization Method for Enrichment Evaluations-Group Decision Support System) method belongs to the MCDA methodology family, which is a clear and efficient evaluation method since it provides an objective view of multi-actor preferences in a common scenario [22].

Another methodology based on multi-criteria evaluation called TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). TOPSIS is another ranking approach used to evaluate alternatives based on their proximity to an ideal solution and distance to a negative solution. It is applied to assess mining impacts and rank actions according to their performance on multiple criteria [23].

The MCDA technique in particular proves to be very useful in situations where decision-making is difficult due to the large amount of data that must be taken into account, as well as in situations where the decision is crucial or can generate conflict [22].

The multi-criteria decision analysis (MCDA) techniques have emerged as a major approach for solving natural resource management problems which typically defines objectives, chooses the criteria to measure the objectives of specific alternatives, assigns weight to the criteria according to its relative importance, selects and applies a mathematical algorithm for ranking alternatives, and finally chooses the best alternative.

One of the meaningful issues in this type of calculation through MCDA and MCA is the assignation of relative weights. These can be either assigned or calculated according to certain criteria of impact relevance. The results in developed formal evaluation methods, such as multi-criteria analysis, are extremely important in calculating these weights. A major advantage of the integration of evaluation methods in a decision support system are the increased opportunities for sensitivity analysis such as the discrete multiple criteria decision analysis. An important aim of discrete multiple criteria analysis is to provide a rational basis for ranking a number of alternatives on the basis of multiple criteria [24]. This criterion has also been described by [10] for integrated watershed management analysis for converting importance ranking into attribute weights.

For instance, [24] consider a decision problem with three criteria having attribute weights of λ_1, λ_2, and λ_3. All attribute weights are greater than zero (non-negativity condition) and the sum of three attribute weights equal one ($\sum_{i=1}^{n} \lambda_i = 1$) (normality condition).

[10] points out that the non-negativity condition and the normality condition define the feasible criteria weights in the space represented by the area ABC as shown in the following Fig. 2a and Fig. 2b.

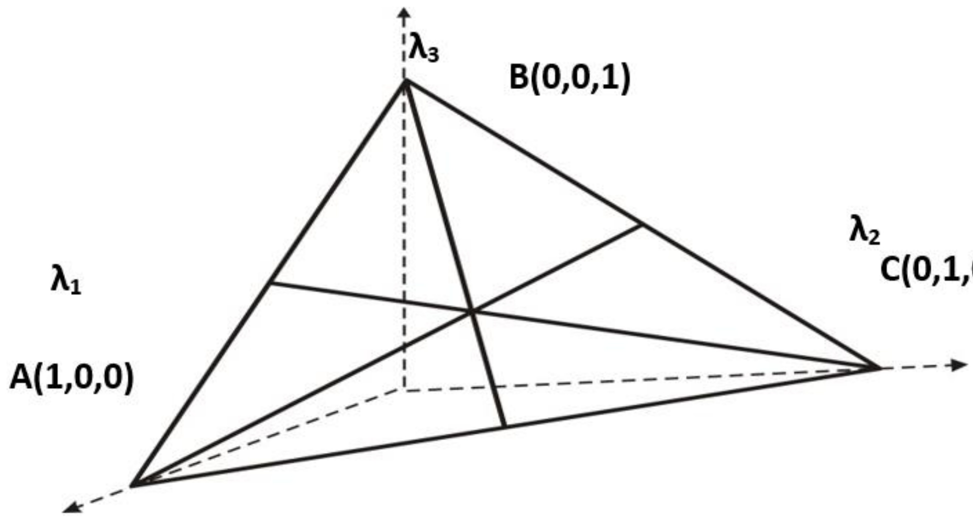

Figure 2a.
Feasible criteria weights with three criteria.

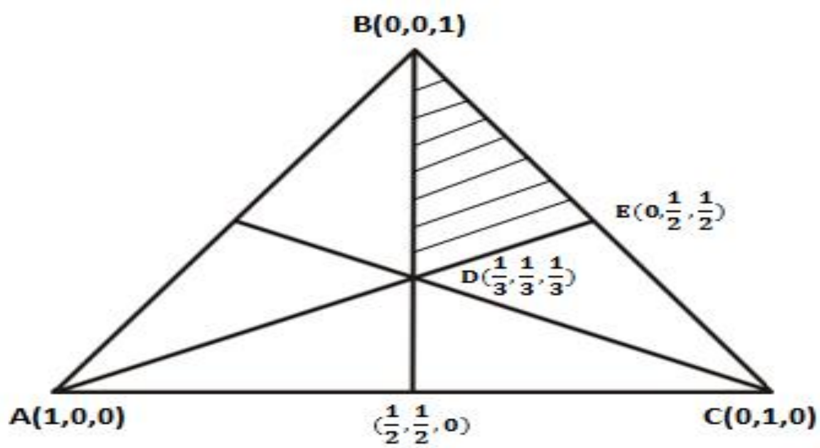

Figure 2b.
Feasible criteria weights with three criteria.

Although the values of λ_1, λ_2, and λ_3 are unknown, their relative importance may be known. In which case, values for them can be estimated by assuming a uniform probability distribution. In this regard, suppose that $\lambda_1 \leq \lambda_2 \leq \lambda_3$, then this equation refines the space of the feasible criteria weights to the area BDE in Fig. 2b, where the space ABC reproduces the space of feasible criteria, weights were obtained from Fig. 2a. The three extreme points of the feasible set are B(0,0,1), D(1/3,1/3,1/3) and E(0,1/2,1/2). In addition, the expected values of the criteria weights are defined by the centroid of the triangle set

BDE if the attribute weights are assumed to be uniformly distributed in the space. Consequently, the triangle BDE is found by computing the unweighted mean of the three extreme points, which is (2/18, 5/18, 11/18). This means that $E(\lambda_1)= 2/18$, $E(\lambda_2)= 5/18$, and $E(\lambda_3)= 11/18$. K is equal to the number of criteria and/or variables used for this analysis. Assuming discrete uniform distributions[1] for K criteria weights and in agreement to [23], we can generalize through the following mathematical algorithm:

$E (\lambda_1)= 1/K^2$

$E (\lambda_2)= 1/K^2 + 1/K(K-1)$

$E (\lambda_3)= 1/K^2 + 1/K(K-1) + 1/K(K-2)$

… … …

$E (\lambda_j)= 1/K^2 + 1/K(K-1) + 1/K(K-2) + \ldots + 1/K(K- Ki^{th}-1)$

Several distinct schools of thought appear in the MCDA literature, such as multiple attribute value theory (MAVT), multiple attribute utility theory (MAUT), analytic hierarchy process (AHP), etc., whose assessments can be qualitative, quantitative, and mixed. The practical significance of MCDA is that it improves the information basis for planning, communication, and understanding in natural resource management. This methodology has been widely used in environmental issues, energy policy analysis, farm management, food security, forest management, water management, and so forth [10].

[12] describe multi-criteria decision-making methods (MCDM) as having as central purpose to improve the quality of decisions involving multiple criteria by making choices more explicit, rational, and efficient. These approaches have six basic functions that support this overall goal: 1) to structure the decision process, 2) to display tradeoffs among criteria, 3) to help people reflect upon, articulate, and apply value judgments concerning acceptable tradeoffs, 4) to help people make more consistent and rational evaluations of risk and uncertainty, 5) to facilitate negotiation, and 6) to document how decisions are made.

[9] in their article "Use of the Multiple Accounts Analysis Process for Sustainability Optimization," state that multiple accounts analysis (MAA) is a platform for engagement of stakeholders and for the assessment of site-specific alternatives based on the qualitative and quantitative indicators success. This approach involves three steps: 1) identify the impacts (adverse and beneficial) to be included in the evaluation, 2) quantify the impacts (costs and benefits) for each of the alternatives, and 3) assess the combined or cumulative impacts for each alternative and compare these with other alternatives to develop a preference list (ranking, scaling, and weighting) of the scenarios. In addition, the list of issues on this methodology is organized in accounts, sub-accounts, and indicators of impacts from various alternatives. Precisely, an account is an issue of concern, and is typically one of the technical, economic, environmental, and socioeconomic criteria. The Figure 3 displays the accounts, which generally include an MAA [9].

[1]Discrete uniform distribution for a variable is an appropriate assumption when you have a measure of the highest and lowest values in which equal probabilities are assigned to all integer values within a lower and upper limit [25].

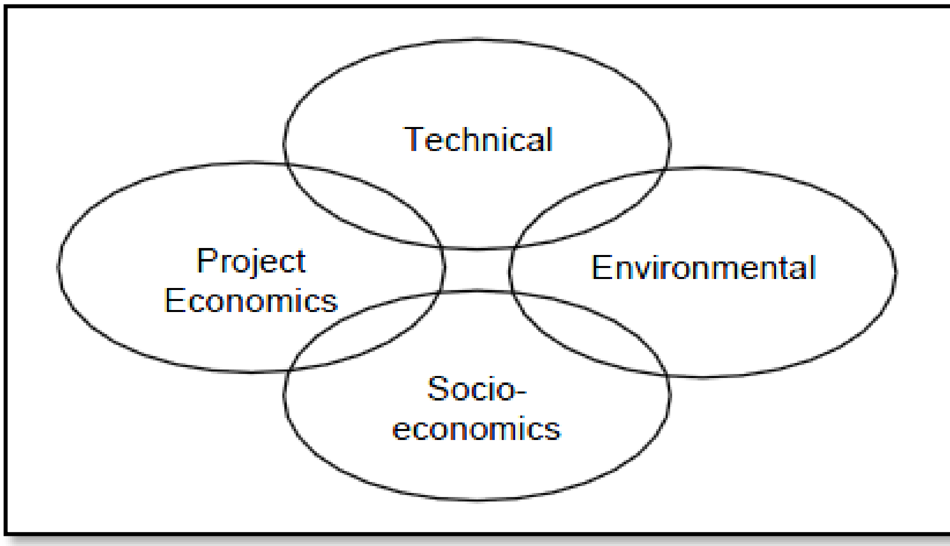

Figure 3.
Four accounts that are typically included in an MAA for a mining project.

Nevertheless, this research has used a fixed multi-criteria assessment (MCA), which is based on multi-criteria decision analysis (MCDA), in order to quantify positive and negative externalities (alternatives) proceeding from the mining activity in a regional context. Its fixed approach lies in incorporating integral components also called factors or criteria. These in turn include variables. Equally important, this theory considers relative weights for each component and its respective variables wherein each variable is assessed horizontally for each alternative through a mathematical model. Thus, the results of the current work suggest that refining "MCA" methodology for quantification of externalities analysis will continue to yield model systems, which significantly qualify outcomes of single-methodology models.

3. Material and Methods

First, the research is primarily based on descriptive and explanatory methods of: naturalistic observation, case studies, surveys, monitoring, and ex-post-facto analysis [26].

The techniques and tools for collection and tabulation of data used direct techniques such as observation and interviews, and also surveys as indirect techniques. The procedures used took place in the field, laboratory, and office.

For this purpose, the research has been carried out in a regional context. This is in the Ancash Department, considered one of the most meaningful mining regions in Peru. Above all, the analysis has been done for the four mining stratums: large-scale, medium-scale, small-scale, and artisanal mining in order to understand both impacts: positive and negative within the direct and indirect influence areas as well as the extended area of the Ancash highlands.

Second, the data was obtained from a variety of public, private, and civil organizations in Peru between 2005 and 2007. Among others was the Ministry of Energy and Mines, Ministry of Agriculture, Huascaran National Park-Huaraz, Ancash Health Regional Direction, Peruvian Institute of Mining Engineers, Ancash Regional Direction of Energy and Mines, Ombudsman Office-Huaraz, Cultural National Institute, and other regional mining companies. The following Table 1 shows some data sources and their corresponding types.

Table 1.
Some data sources and types.

Source	**Data types**
Ministry of energy and mines	Mining concessions, mines with environmental impact assessment, and sectoral regulation
Ministry of economy and finance	Regional and local GDP and taxes ('Canon Minero')
Ministry of transportation and communications	Automotive fleet size and composition
National institute of natural resources	Agricultural lands
Huascaran national park	Vulnerable species (Flora and fauna)
Glaciology unit-Huaraz	Lakes and lagoons
Health regional direction	Index of transmission for sexual illnesses-HIV/AIDS
Ombudsman office	Mining conflicts
Cultural national institute	Archaeological remains
Regional direction of environmental health-ancash and national University "Santiago Antúnez de Mayolo"	Index of environmental pollution and environmental improvement
IV **police region**	Violence index trends
Regional direction of mining and energy	Compliance of sectoral regulations, complaints, social conflicts, and environmental management plans
Other regional mining companies	Operational optimization; social programs in education, health, housing, electric energy, and communication; revegetation and reforestation etc.

Third, before collecting the data, a consistency matrix was designed in order to include criteria, variables, and indicators. For example, the sociocultural component includes, among others, social mining conflicts, generation of employment, and deterioration of archaeological remains, whose indicators are the number of conflicts, percentage of decrease, and percentage of increment, respectively. In like fashion, the environmental component takes into account, among other variables, altered agricultural land and soil, recovery and loss of flow gaps, and loss of habitat (flora and fauna), whose indicators are hectares, cubic meters, and hectares and number of species, respectively. Figure 4 describes the methodological sequence for the whole process.
The methodological sequence for the whole process is described in Figure 4.

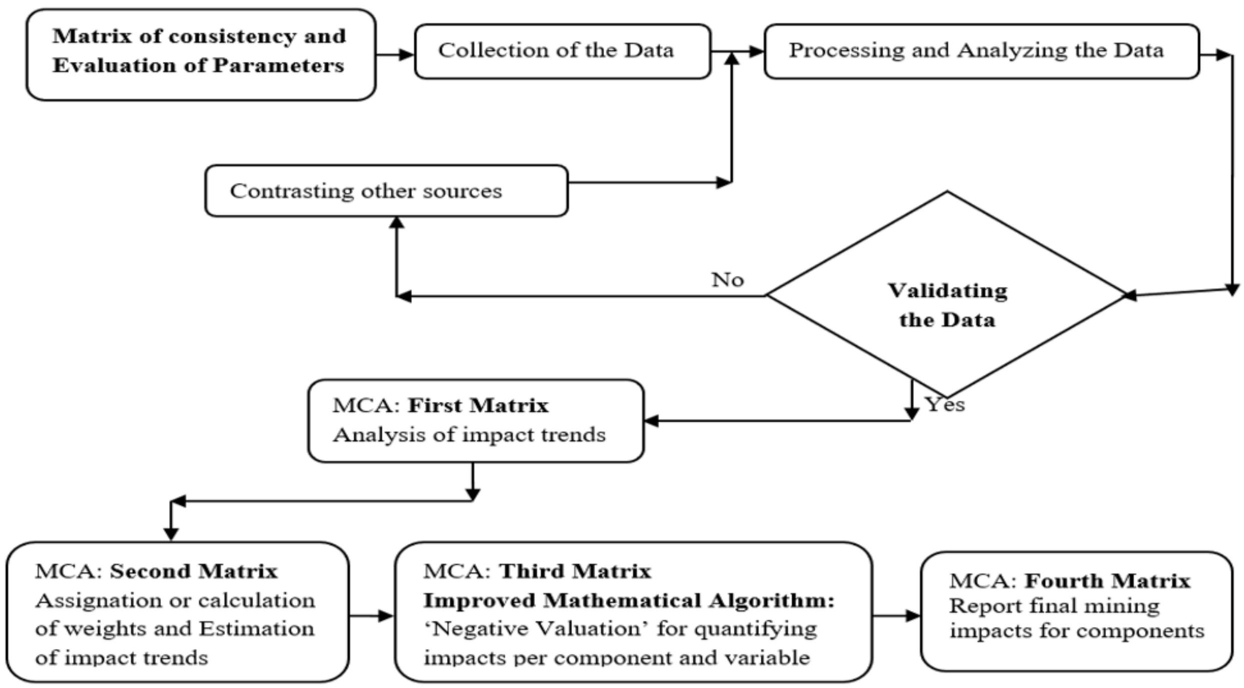

Figure 4.
Workflow using multi-criteria assessment.

Table 2 shows some results obtained regarding the trend and nature of the impacts for each of the variables in their respective components. The behavior of the impacts for certain variables was positive and in other cases negative. This table also describes the magnitude of the impact expressed as indicators.

Table 2.
Some results of the variables in the consistency matrix.

Components	Variables	Indicators	Trend of impacts	Nature
Technological, operational, & normative	Technological investments operational optimization	70% 60%	Increasing Increasing	+ +
Sociocultural	Generation of employment violence index, prostitution, etc. archaeological conservation areas social conflicts	20% 90% 40% 21 conflicts	Decreasing Increasing Decreasing Increasing	- - - -
Socioeconomic	Regional and local GDP taxes ('Canon Minero') acquisition of local products	90% 90% 60%	Increasing Increasing Decreasing	+ + -
Environmental	Recovery & land reclamation Land & soil disturbance Loss of flow gaps Loss of Habitat (flora & fauna)	90,790 Ha. 38,910 Ha. 60%127,800 Ha. & 19 species	Increasing Decreasing Increasing Increasing	+ - - -

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5: 843-863, 2024
DOI: 10.55214/25768484.v8i5.1780

Once the data was collected, it was processed, analyzed, and validated. Afterwards, the MCA approach was used, which starts with the analysis and evaluation of the importance of impacts through a scale from irrelevant to *critical i*mpacts as positive and negative for all the components and variables (First Matrix.) Table 3 depicts the scale to measure the impact trends. That is, if the impacts generated as a result of mining activity in Peru analyzed in a regional context, whether positive or negative, results have been obtained that do not exceed 20%, they will be considered irrelevant impacts and so on, for example, they are considered critical impacts if the impacts generated by mining activity have exceeded 80%, whether favorable or unfavorable for the regional environment.

Table 3.
Scale to measure the importance of impacts.

Range (%)	**1**	**2**	**3**	**4**	**5**
	$X \leq 20$	**$20 < X \leq 40$**	**$40 < X \leq 60$**	**$60 < X \leq 80$**	**$X > 80$**
Impact importance	Irrelevant	Less than moderate	Moderate	Severe	Critical

Table 4 shows the trend of impacts (positive and negative) for each of the variables of each component according to the measurement scale indicated in Table 3. That is, Table 4 indicates the behavior of the impacts generated, whether positive or negative, using a rating scale from 1(≤20%) to 5(> 80%), depending on the importance of the impact generated.

Table 4.
Example of analysis and evaluation of impact trends.

Components	**Impact trends**		**+/-**	**1**	**2**	**3**	**4**	**5**
Technological, operational, and normative								
Technological Investments	Severe		+				♦	
New technology	Critical		+					♦
Operational optimization	Moderate		+			♦		
Sociocultural								
Generation of employment	Irrelevant		-	♦				
Social programs (Education, health, housing, electric energy, and	Irrelevant		+	♦				
communication systems)	Severe		-		♦			
Automotive fleet	< Moderate		-				♦	
Immigration rate	Critical		-					♦
Violence index, prostitution, and drug addiction	Irrelevant		-	♦				
Consultation, citizen participation and dialogue with stakeholders	< Moderate		+		♦			
Archaeological conservation areas	Critical		-					♦
Complaints and social conflicts	Severe		-				♦	
Confidence level: by influence areas								
Socioeconomic	Critical		-					♦
Regional and local GDP	Critical		+					♦

Taxes ('Canon Minero')	Irrelevant		+	◆				
Availability of credits	Moderate		+			◆		
Acquisition of local products								
Environmental	Critical		-					◆
Attitude towards pollution control	Severe		-				◆	◆
Index of environmental pollution	Critical		+					◆
Protection practices, environmental improvement, and recovery	Critical		-					
Recovery and land reclamation	Severe		+				◆	
Revegetation and reforestation	Moderate		-			◆		
Land and soil disturbance	Severe		+				◆	
Air resource alteration	Moderate		+			◆		◆
Terrestrial ecosystem alteration (Flora and fauna)	Severe		-					
Compliance of environmental management plan	Irrelevant		-	◆				

Table 5 and 6 describe the estimation of impacts trends and the assignation of weights for each component and variable (Second Matrix). These relative weights are qualitatively assigned to the importance and trend of their impacts according to criteria of: extension, moment, persistence, synergy, and so forth. The consistency matrix and the evaluation of parameters, as well as the assignation of relative weights were developed in collaboration with a group of professionals and professors familiar with the issues in this case study. Certainly, it should be recognized that the evaluation of parameters in the consistency matrix along with the assignations of relative weights can be improved and will vary with the specific conditions of the study.

Indeed, Table 5 shows the relative weights both assigned and calculated of the 4 components according to their degree of importance of the impacts or externalities.

The relative weights assigned have been given according to the criteria of the author of this article and the relative weights calculated have been determined using the mathematical algorithm developed by Herath & Prato.

Both the assignment and the calculation of the relative weights have been incorporated in order to determine the difference between the two criteria used.

As for Table 6, the relative weights both assigned and calculated for each variable of each of the 4 components are described. following the same methodology determined for the results in Table 5.

Afterwards, the quantification of these externalities is generated. Table 7A shows the quantification of the externalities in which the weights for both components and variables have been analyzed through the assignation of weights. In contrast, Table 7B depicts the quantification of impacts calculated across a sensitivity analysis for the discrete multiple criteria analysis.

The results of Table 7a and Table 7b precisely indicate the results of the assessment of externalities using the mathematical algorithm based on multicriteria evaluation for both the assigned and calculated relative weights. This algorithm has been improved by the undersigned by incorporating double weighing for both each component and each variable. This is because each component and each variable have different behavior and importance in a real scenario.

Lastly, the positive and negative impacts have been quantified (Third Matrix) using an improved mathematical algorithm based on the multi-criteria assessment through one of its processes ('negative valuation') for determining criterion values. As these variables were measured in different units, they must be standardized across the analysis to avoid having the results in different measurement units [10].

$$TA_j = \left\{ \sum_{k=1}^{p} \left[\sum_{i=1}^{n(k)} \left(\frac{Value_{ij} - Min_{i\to m}}{Max_{i\to m} - Min_{i\to m}} \right) RW_i \right] RW_j^k \right\},$$

Where:

$$\sum_{i=1}^{n(k)} RW_i = \sum_{k=1}^{p} RW_j^k = 1$$

k = 1, 2,…, p (Components)
i = 1, 2,…, n(k) (Variables)
j = 1, 2,…, m (Alternatives)
TA_j = Total value of each alternative for all its components
RW_i = Relative weight of each variable
RW_j^k = Relative weight of each component
$Min_{i\to m}$ = Minimum value through the whole variable in evaluation
$Max_{i\to m}$ = Maximum value through the whole variable in evaluation

The following Tables (5, 6, 7, and 8) show the results of the analysis for the study region in the Ancash Department. Table 5 depicts the components taken into account in a regional mining context, while Table 6 shows an example of the estimation of impacts through its different components, including some variables, which rely on the analysis of impact trends. These tables also include values for assigned and calculated weights. Likewise, Table 7A and 7B describe the results through quantification of impacts using the 'Negative valuation' mathematical algorithm of the arranged multi-criteria assessment model with both assigned and calculated weights, respectively. Finally, Table 8 displays the resulting mining impacts for all the components.

Table 5.
Components of assessment and relative weights.

Component	Assigned weights (%)	Calculated weights (%)
Technological, operational, and normative	10.00	
Sociocultural	30.00	6.25
Economic	10.00	27.08
Environmental	50.00	14.58

Table 6.
Example of Estimation of impacts for some variables.

Technological, operational, and normative= 10%	**Assigned weights**	**Calculated weights**	**Impacts**	
			A (+)	**B (-)**
Technological Investments	0.20	0.16	0.70	
New technology	0.20	0.09	0.90	
Operational optimization	0.10	0.04	0.60	
Sociocultural= 30%				
Generation of employment	0.10	0.07		0.20
Social programs (education, health, housing, electric energy, and communication systems)	0.15	0.26	0.10	
Automotive fleet	0.05	0.01		0.70
Immigration rate	0.05	0.01		0.40

Technological, operational, and normative= 10%	Assigned weights	Calculated weights	Impacts	
			A (+)	B (-)
Violence index, prostitution, and drug addiction	0.10	0.11		0.90
Consultation, citizen participation, and dialogue with stakeholders	0.05	0.03	0.10	
Archaeological conservation areas	0.05	0.02		0.40
Complaints and social conflicts	0.10	0.08		0.90
Confidence level: influence areas	0.10	0.13		0.70
Socioeconomic= 10%				
Regional and local GDP	0.20	0.26	0.90	
Taxes ('Canon Minero')	0.20	0.16	0.90	
Availability of credits	0.20	0.09	0.10	
Acquisition of local products	0.10	0.04		0.60
Environmental= 50%				
Attitude towards pollution control	0.05	0.04	0.70	
Index of environmental pollution	0.10	0.17		0.80
Protection practices, environmental improvement, and recovery	0.10	0.13	0.80	
Recovery and land reclamation	0.05	0.01	0.70	
Revegetation and reforestation	0.05	0.02	0.60	
Land and soil disturbance	0.05	0.03		0.70
Air resource alteration	0.10	0.08		0.60
Terrestrial ecosystem alteration (Flora and fauna)	0.10	0.07		0.70
Compliance of environmental management plan	0.10	0.24	0.20	

4. Results and Discussion

The results shown in Figure 7a, the total negative impacts according to MCA theory with assigned weights represent 58.50% of the total impact. This means that the negative externalities are greater than the positive by 17 percentage points. The largest factors in the negative criterion are the sociocultural and environmental. In another context considering calculated weights, as shown in Fig. 7b, the negative impacts are also greater than the positive by more than 10 percentage points, but these are focused on the sociocultural, technological, operational, normative, and environmental factors as well. The components, which include a variety of variables, can be easily identified using Table 6.

According to the calculations made for both scenarios: the assigned and calculated weights have a 7 points difference between them. Moreover, the evaluation by assigned weights includes only two components as negative and two components as positive, while the calculated weights consider three components as negative and only one as positive. There is undoubtedly a marked difference in the assessment for these two weighted methodologies for making suitable decision making. This would be worse if there were more alternatives of evaluation and/or more narrow results in their calculations among them, the outlook would still be more complicated because the results would induce error in taking the alternative as well as mistaken components.

It is true that the assumed weights are only based on the expertise of the evaluator, meanwhile the calculated weights combine the mathematical sensitivity analysis and expertise of the evaluator, which gives the evaluator a better criterion. With this in mind, the calculated weights are recommended and should be incorporated into the MCA analysis.

Table 7a.
Results for the quantification of impacts through the 'Negative Valuation' mathematical algorithm (Third matrix).

Components	**Assigned weights**	**Alternatives**		**Mathematical algorithm**		**Weighted values**	
		A (+)	**B (-)**	**A (+)**	**B (-)**	**A (+)**	**B (-)**
Technological, operational, and normative	**10.00%**						
Technological Investments	0.20	0.70	0.00	1.00	0.00	0.20	0.00
New technology	0.20	0.90	0.00	1.00	0.00	0.20	0.00
Operational optimization	0.10	0.60	0.00	1.00	0.00	0.10	0.00
Sectoral regulation	0.20	0.00	0.40	0.00	1.00	0.00	0.20
Compliance of sectoral regulation	0.30	0.00	0.50	0.00	1.00	0.00	0.30
TAj=Total value alternative for the whole component=Total scenario (%)						5.00%	5.00%
Sociocultural	30.00%						
Generation of employment	0.10	0.00	0.20	0.00	1.00	0.00	0.10
Social programs (education, health, housing, electric energy, and communication systems)	0.15	0.10	0.00	1.00	0.00	0.15	0.00
New productive and service sources	0.10	0.30	0.00	1.00	0.00	0.10	0.00
Value chains	0.10	0.00	0.90	0.00	1.00	0.00	0.10
Automotive fleet	0.05	0.00	0.70	0.00	1.00	0.00	0.05
Immigration rate	0.05	0.00	0.40	0.00	1.00	0.00	0.05
Violence index, prostitution, and drug addiction	0.10	0.00	0.90	0.00	1.00	0.00	0.10
Consultation, citizen participation, and dialogue with stakeholders	0.05	0.10	0.00	1.00	0.00	0.05	0.00
Archaeological conservation areas	0.05	0.00	0.40	0.00	1.00	0.00	0.05
Development and strengthening of local capabilities	0.05	0.70	0.00	1.00	0.00	0.05	0.00
Complaints and social conflicts	0.10	0.00	0.90	0.00	1.00	0.00	0.10
Confidence level: influence areas	0.10	0.00	0.70	0.00	1.00	0.00	0.10
TAj= Total value alternative for the whole component=Total scenario (%)						10.50%	19.50%
Socioeconomic	10.00%						

ISSN: 2576-8484
Vol. 8, No. 5: 843-863, 2024
DOI: 10.55214/25768484.v8i5.1780

Regional & local GDP	0.20	0.90	0.00	1.00	0.00	0.20	0.00
Taxes ('Canon Minero')	0.20	0.90	0.00	1.00	0.00	0.20	0.00
Availability of credits	0.20	0.10	0.00	1.00	0.00	0.20	0.00
Acquisition of local products	0.10	0.00	0.60	0.00	1.00	0.00	0.10
Purchasing power	0.30	0.00	0.80	0.00	1.00	0.00	0.30
TAj=Total value alternative for the whole component = Total scenario (%)						6.00%	4.00%
Environmental	50.00%						
Attitude towards pollution control	0.05	0.70	0.00	1.00	0.00	0.05	0.00
Index of environmental pollution	0.10	0.00	0.80	0.00	1.00	0.00	0.10
Protection practices, environmental improvement, and recovery	0.10	0.80	0.00	1.00	0.00	0.10	0.00
Recovery and land reclamation	0.05	0.70	0.00	1.00	0.00	0.05	0.00
Revegetation and reforestation	0.05	0.60	0.00	1.00	0.00	0.05	0.00
Physiographic alteration	0.05	0.00	0.40	0.00	1.00	0.00	0.05
Land and soil disturbance	0.05	0.00	0.70	0.00	1.00	0.00	0.05
Aquatic resource alteration	0.10	0.00	0.60	0.00	1.00	0.00	0.10
Air resource alteration	0.10	0.00	0.60	0.00	1.00	0.00	0.10
Terrestrial ecosystem alteration (Flora and fauna)	0.10	0.00	0.70	0.00	1.00	0.00	0.10
Marine ecosystem alteration	0.10	0.00	0.50	0.00	1.00	0.00	0.10
Ecology investments	0.05	0.50	0.00	1.00	0.00	0.05	0.00
Compliance of environmental management plan	0.10	0.20	0.00	1.00	0.00	0.10	0.00
TAj=Total value alternative for the whole component=Total scenario (%)						20.00%	30.00%
Total results using multi-criteria assessment						41.50%	58.50%
Conclusion: The greatest value of the assessed alternative for the total results concludes that the impacts are more negative. This is according to the MCA considerations.							

Table 7b.
Results for the quantification of impacts through the 'negative valuation' mathematical algorithm (Third Matrix).

Components	**Calculated weights**	**Alternatives**		**Mathematical algorithm**		**Weighted values**	
		A (+)	**B (-)**	**A (+)**	**B (-)**	**A (+)**	**B (-)**
Technological, operational, and normative 6.25%	6.25%						
Technological Investments	0.16	0.70	0.00	1.00	0.00	0.16	0.00
New technology	0.09	0.90	0.00	1.00	0.00	0.09	0.00
Operational optimization	0.04	0.60	0.00	1.00	0.00	0.04	0.00
Sectoral regulation	0.26	0.00	0.40	0.00	1.00	0.00	0.26
Compliance of sectoral regulation	0.46	0.00	0.50	0.00	1.00	0.00	0.46
TAj=Total value alternative for whole the component = Total scenario (%)						1.79%	4.46%
Sociocultural 27.08%	27.08%						
Generation of employment	0.07	0.00	0.20	0.00	1.00	0.00	0.07
Social programs (education, health, housing, electric energy, and communication systems)	0.26	0.10	0.00	1.00	0.00	0.26	0.00
New productive and service sources	0.05	0.30	0.00	1.00	0.00	0.05	0.00
Value chains	0.18	0.00	0.90	0.00	1.00	0.00	0.18
Automotive fleet	0.01	0.00	0.70	0.00	1.00	0.00	0.01
Immigration rate	0.01	0.00	0.40	0.00	1.00	0.00	0.01
Violence index, prostitution, and drug addiction	0.11	0.00	0.90	0.00	1.00	0.00	0.11
Consultation, citizen participation, and dialogue with stakeholders	0.03	0.10	0.00	1.00	0.00	0.03	0.00
Archaeological conservation areas	0.02	0.00	0.40	0.00	1.00	0.00	0.02
Development and strengthening of local capabilities	0.04	0.70	0.00	1.00	0.00	0.04	0.00
Complaints and social conflicts	0.08	0.00	0.90	0.00	1.00	0.00	0.08
Confidence level: influence areas	0.13	0.00	0.70	0.00	1.00	0.00	0.13
TAj= Total value alternative for the whole component = Total scenario (%)						10.50%	16.58%
Socioeconomic 14.48%	14.58%						
Regional and local GDP	0.26	0.90	0.00	1.00	0.00	0.26	0.00

Taxes ('Canon Minero')	0.16	0.90	0.00	1.00	0.00	0.16	0.00
Availability of credits	0.09	0.10	0.00	1.00	0.00	0.09	0.00
Acquisition of local products	0.04	0.00	0.60	0.00	1.00	0.00	0.04
Purchasing power	0.46	0.00	0.80	0.00	1.00	0.00	0.46
TAj= Total value alternative for the whole component =Total scenario (%)						7.34%	7.24%
Environmental 52.08%	52.08%						
Attitude towards pollution control	0.04	0.70	0.00	1.00	0.00	0.04	0.00
Index of environmental pollution	0.17	0.00	0.80	0.00	1.00	0.00	0.17
Protection practices, environmental improvement, and recovery	0.13	0.80	0.00	1.00	0.00	0.13	0.00
Recovery and land reclamation	0.01	0.70	0.00	1.00	0.00	0.01	0.00
Revegetation and reforestation	0.02	0.60	0.00	1.00	0.00	0.02	0.00
Physiographic alteration	0.01	0.00	0.40	0.00	1.00	0.00	0.01
Land and soil disturbance	0.03	0.00	0.70	0.00	1.00	0.00	0.03
Aquatic resource alteration	0.10	0.00	0.60	0.00	1.00	0.00	0.10
Air resource alteration	0.08	0.00	0.60	0.00	1.00	0.00	0.08
Terrestrial ecosystem alteration (flora and fauna)	0.07	0.00	0.70	0.00	1.00	0.00	0.07
Marine ecosystem alteration	0.06	0.00	0.50	0.00	1.00	0.00	0.06
Ecology investments	0.05	0.50	0.00	1.00	0.00	0.05	0.00
Compliance of environmental management plan	0.24	0.20	0.00	1.00	0.00	0.24	0.00
TAj= Total value alternative for the whole component = Total scenario (%)						25.33%	26.76%
Total results using multi-criteria assessment						44.96%	55.04%

Conclusion: The greatest value of the assessed alternative for the total results concludes that the impacts are more negative. This is according to the MCA considerations

ISSN: 2576-8484
Vol. 8, No. 5: 843-863, 2024
DOI: 10.55214/25768484.v8i5.1780

The MCA methodology encompasses a wide variety of integrated and linked components. In this regard, the negative components, such as the sociocultural and environmental factors found in the present research, affect the sustainability and social license to operate. These results obviously demonstrate a powerful analytical tool for sustainable decision making. In addition to this macro-level example, further applications could include such micro-level issues as tailings impoundment location or other site-specific decisions.

Table 8.
Results for the mining impacts for components, using arranged multi-criteria assessment theory (Fourth Matrix) for both scenarios assigned and calculated weights.

Component	**Impacts with assigned weights**		**Impact with calculated weights**	
	A(+)	**B(-)**	**A(+)**	**B(-)**
Technological, operational, and normative	5.00	5.00	1.79	4.46
Sociocultural	10.50	19.50	10.50	16.58
Socioeconomic	6.00	4.00	7.34	7.24
Environmental	20.00	30.00	25.33	26.76
	41.50	58.50	44.96	55.04

8. Conclusion

The Multi-Criteria Assessment (MCA) methodology is a primary managerial tool, which has allowed identifying and analyzing criteria and variables, evaluating the trend of impacts, and quantifying both alternatives termed positive and negative externalities. Thereby, the MCA has been modified through an improved mathematical model, which integrates all processes of calculation mostly working with quantitative data. This algorithm relies on a transversal assessment considering any unit of measure as well as a double weighing as well as the improved mathematical algorithm can be used for macro and micro-level applications. The calculated results through the new mathematical algorithm could then help design and structure better sustainable policies and consequently improve the implementation of suitable decision making, which would benefit a larger segment of society. In fact, quantifying both positive and negative impacts on mining activity is precisely knowing how this activity has been operating. The purpose of impact assessment is not only to identify impacts from a comprehensive perspective but above all to correct negative impacts and improve positive impacts that contribute to sustainability. Modern mining in this regional context has incorporated a variety of positive changes during the development of its operations, which involves beneficial criteria of sustainability. Human beings and the environment are meaningful allies to modern mining. The identified negative impacts are mostly due to the past legacy of the mining industry. Nonetheless, there are still negative impacts coming from mining activity, which generate negative perception by people against the mining operations in Peru. Furthermore, with the application of said methodological proposal, it is proposed that the main stakeholders of mining activity: government, communities and companies, adopt synergies to achieve a better quality of life in population environments. For this reason, the sustainability of Peruvian mining activity is seen as both a myth and a reality, in that, mining activity requires some improvements, which should be outlined through new criteria with corporate social responsibility and thereby attaining a sustainable social license to operate.

Acknowledgment

I thank the Regional Directorate of Energy and Mines of the Regional Government of Ancash, Peru, for the opportunity provided to collect the data. Likewise, I would like to thank the University of Reno, Nevada, in the United States, for providing me with the support to strengthen the scientific foundation of this research.

References

[1] Instituto de Ingenieros de Minas del Perú, "Minería Peruana: Contribución al Desarrollo Económico y Social," *Instituto de Ingenieros de Minas del Perú*, Vol. 4, pp. 21-35, 2010. Available: https://app.ingemmet.gob.pe/biblioteca/pdf/Mine-30.pdf.

[2] Revista Educativa, "TAMBOGRANDE Vale más que Oro," *Guarango Cine y Video*. Available: https://www2.congreso.gob.pe/sicr/cendocbib/con4_uibd.nsf/ACEA3BCFA81CADCC05257E370079174D/$FILE/TambograndeValeM%C3%A1sQueOro.pdf .

[3] N. Loayza, and J. Rigolini, "The Local Impact of Mining on Poverty and Inequality: Evidence from the Commodity Boom in Peru," *World Development*. Vol. 84, pp 219–234, 2016. Available: https://doi.org/10.1016/j.worlddev.2016.03.005.

[4] A. Bebbington, and J. Bury, "Institutional challenges for mining and sustainability in Peru," *Proceedings of the National Academy of Sciences*, Vol. 106(41), pp. 17296–17301, 2009. Available: https://doi.org/10.1073/pnas.0906057106.

[5] Ministerio de Energía y Minas del Perú, "Anuario minero- Reporte estadístico 2021," *Anuario Minero 2021*, *Ministerio de Energía y Minas*, Vol. 1, pp. 7-15, 2021. Available: https://www.minem.gob.pe/minem/archivos/file/Mineria/PUBLICACIONES/ANUARIOS/2021/AM2021.pdf.

[6] M. García, "Peru´s mining & metals investment," Guide 2022/2023, 2022. Available: https://www.ey.com/es_pe/mining-metals/mining-metals-investment-guide-2022-2023

[7] BBVA Research, "Perú Situación del sector minero 2022," Available: https://www.bbvaresearch.com/wp-content/uploads/2023/02/Situacion-del-sector-minero-2022-1.pdf.

[8] C. H. Oh, J Shin, and S. S. H. Ho, "Conflicts between mining companies and communities: Institutional environments and conflict resolution approaches," *Business Ethics, the Environment & Responsibility*. Vol. 32(2), pp. 638–656, 2023. Available: https://doi.org/10.1111/beer.12522.

[9] A. Robertson, and S. Shaw, "Use of the Multiple Accounts Analysis Process for Sustainability Optimization," *SME Annual Meeting, Denver, Colorado*, 2004. Available: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=8168faee4f7e1040d3b06435898463a52b96385c.

[10] G. Herath, and T. Prato, "Using Multi-Criteria Decision Analysis in Natural Resource Management," ISBN 9781138378964. *Ashgate Publishing Limited*. 2006.

[11] Presidencia del Consejo de Ministros del Perú, "Manual de metodologías para la evaluación de impactos del AIR Ex-Ante," *Secretaría de Gestión Pública-PCM*. Vo. 1, pp. 29-86, 2022. Available: https://cdn.www.gob.pe/uploads/document/file/3160124/Manual%20de%20metodolog%C3%ADas%20para%20la%20evaluaci%C3%B3n%20de%20impactos%20del%20AIR%20Ex-Ante.pdf?v=1653925322.

[12] B. Hobbs, and P. Meier, "Energy decisions and the environment," *Kluwer Academic Publishers*. ISBN : 978-1-4613-7017-8. Vol. 28, pp. 2-67, 2000.

[13] CIES, "La minería peruana y los objetivos de desarrollo sostenible," 2018. Available: file:///C:/Users/Usuario/Downloads/folleto_mineria_cies_web%20(3).pdf.

[14] R. Eggert, "What Sustainability and Sustainable Development Mean for Mining," *J. A. Botin*. 2009.

[15] CEPAL, "Conferencia de las Naciones Unidas sobre el Desarrollo Sostenible—Rio+20," 2012. Available: https://www.cepal.org/es/eventos/conferencia-naciones-unidas-desarrollo-sostenible-rio20.

[16] World Commission on Environment and Development, "Our Common Future." 1997. Available: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

[17] J. Lescano , L. Valdéz, and L. Vilchez, "Arquitectura de la gestión del desarrollo sostenible en el Perú," *Universidad Nacional Federico Villarreal*, Primera edición, 2005.

[18] D.Van Zyl, M. Sassoon, C. Digby, A. M. Fleury, and S. Kyeyune, "Mining for the Future Main Report," *International Institute for Environment and Development (IIED) & World Business Council for Sustainable Development (WBCSD)*, Vol. 8. Pp. 11–18, 2002.
[19] J. Richards, "Mining, Society and Sustainable World," *Springer*, 2009. Available: http://dx.doi.org/10.2113/gsecongeo.105.5.1039.
[20] International Institute for Environment and Development and World Business Council for Sustainable Development, "The Report of the Mining, Minerals and Sustainable Development Project," Vol. 1, p. 476, 2002. Available: https://www.iied.org/sites/default/files/pdfs/migrate/9084IIED.pdf.
[21] F. Sitorus, J. J. Cilliers, and P. R. Brito-Parada, "Multi-criteria decision making for the choice problem in mining and mineral processing: Applications and trends," Expert Systems with Applications. ISSN 0957-4174, Vol. 121, pp. 393–417, 2019. Available: https://doi.org/10.1016/j.eswa.2018.12.001.
[22] G. Ortiz, J. A. Domínguez-Gómez, A. Aledo, and A. M. Urgeghe, "Participatory multi-criteria decision analysis for prioritizing impacts in environmental and social impact assessments," Sustainability: *Science, Practice and Policy*, Vol. 14(1), pp. 6–21, 2018. Available: https://doi.org/10.1080/15487733.2018.1510237.
[23] C. L. Hwang, and K. Yoon, "Methods for Multiple Attribute Decision Making," In M. Beckmann & H. P. Künzi (Eds.), Multiple Attribute Decision Making. *Springer Berlin Heidelberg*. Vol. 186, pp. 58–191, 2019. Available: https://doi.org/10.1007/978-3-642-48318-9_3.
[24] P. Rietveld P, and R. Janssen, "Sensitivity Analysis in Discrete Multiple Criteria Decision Problems: On the Sitting of Nuclear Power Plants," *Vrije Universiteit Faculteit der Economische Wetenschappen en Econometrie*, 1989.
[25] S. Rachev, M. Höechstöetter, F. Fabozzi, and S. Focardi, "Probability and Statistics for Finance," *John Wiley & Sons, Inc.*, 2010.
[26] H. Sánchez, and C. Reyes, "Metodología y Diseños en la Investigación Científica," *Business Support Aneth SRL*, 5th edición,

ISSN: 2576-8484
Vol. 8, No. 5: 843-863, 2024
DOI: 10.55214/25768484.v8i5.1780