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A proposal by reducing the mining social conflicts using the improved multi-criteria assessment model

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Abstract: A methodological tool for multi-criteria impact assessment has been developed for application in the productive-extractive industry, such as mining activity, with the aim of reducing social conflict. This assessment methodology is called the IMCA Model (Improved Multicriteria Assessment). It is a holistic and innovative methodology that includes the quantification of impacts evaluated from a comprehensive approach. Additionally, the IMCA Model offers other advantages; it is a participatory, inclusive, and binding tool, which allows for better and more reliable results aligned with reality due to its traceability for assessing externalities. The IMCA Model methodology encompasses technical-operational, economic, social, cultural, educational, environmental, and governance factors, among others, depending on the project's nature. This methodology also comprises five main assessment phases: 1) Participatory phase, 2) Statistical phase, 3) Application phase of the mathematical algorithm - IMCA Model, 4) Results socialization phase, and 5) Monitoring and surveillance phase. By measuring externalities in the influence areas of a productive-extractive project using the IMCA Model, it becomes a predictive evaluation tool, enabling the design of a sustainable coexistence model with local populations and environments.

Keywords: *Externalities, IMCA model, Social conflict, Stakeholders, Sustainability.*

1. Introduction

Mining in our country has become a fundamental activity for the consolidation of the economy, but apparently this same consideration is not taken in the population areas located in the vicinity of the mine; Furthermore, there is a feeling that in its environment, the context of economic growth is almost zero and that the productive system and the levels of health and education, the basis of sustained development, are in unacceptable conditions in relation to the wealth it generates. the mining company.

This perception is expressed in the absence of actions aimed at the formation of human capital in populated and communal centers located in the mining environment. The capabilities that make it possible to generate their own income are not developed in the residents; that have adequate levels of health and education, in a context of economic growth that the mine generates. It is necessary that this reality be reversed so that the population reaches an appropriate standard of living.

Also, it is known that the per capita income of the residents is distributed unequally. There are also other indicators such as malnutrition, life expectancy and infant mortality that are worrying, reflected in the unequal consumption of a series of basic services such as sanitation, housing, education and health; For this reason, it is necessary to design policies that substantially improve the indicators of fundamental services to achieve a decent standard of living.

It is urgent to change this reality, because there is no relationship between the economic boom that a mine generates for the country, with the absence of development that must be sustainable, this connotation is crucial in the social field; That is why the lack of social policies and economic policies

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nullify the dimensions that development should have, leaving the populations with their ancestral customs and making education a simple commitment of the state to children and young people.

1.1. Problem to solve

In this sense, the measures that mining companies have been developing have turned out to be insufficient, since the mining operational activities that are carried out produce a variety of negative impacts or externalities that would exceed the positive impacts in the areas of influence of a mining project. in a variety of dimensions or criteria or components or factors: technical-operational, economic, socio-cultural, environmental, governance, etc. As well as each of these factors includes a series of variables or attributes.

Thus, for example, in the technical-operational aspect of a mining project, as a result of operational activities they generate earth movement in large volumes, they generate large deposits of overburden that contain concentrations of heavy metals. Also, as a consequence of the blasting of rocks, which causes cracks in the homes of the populations neighboring the mining projects, generating discomfort in the affected population. Likewise, in underground operations there are impacts such as acid rock drainage among other externalities.

In the socio-cultural aspect, negative impacts are also generated as a result of the increase in the number of vehicles, immigration rates, land use, water use, etc. In the same way, an increase in violence, drug addiction and prostitution, a decrease in the level of trust of the residents towards the mining company, relocation of families, etc. is generated.

In the economic aspect, the negative indicators, for example, we can point out the increase in the cost of living, which mainly affects the residents who reside around the mining project, producing a decrease in purchasing power. There is also low local employability in the mining project, etc.

In the environmental aspect, the negative impacts translate into soil contamination, deterioration in air quality, alteration in the quantity and quality of water, which triggers a considerable decrease in water resources, both for human consumption and for use. used in their family subsistence agriculture. As a result of these impacts that occur, social conflict increases.

The quality of life depends on a variety of basic services, such as feeding children, access to health services, homes with drinking water and sanitation, and basic education, indicators that allow sustainable coexistence to optimize the development of people.

Given this reality, the evidence of facts that demonstrate the fragility of the correlation between economic development and poverty, it is deduced that the benefits of growth are not distributed uniformly, and it is evident that the majority do not reach the neediest classes, whose basic needs remain dissatisfied It is necessary to establish schemes to implement strategies to alleviate marginalization and poverty, within the evolution of economic development.

Therefore, one of the determining factors for sustainable coexistence is related to the responsible, timely and efficient work that companies must carry out, but above all that the decisions that are adopted are participatory, inclusive and binding.

Hence, it is necessary and a priority to change the traditional evaluation paradigms in companies by implementing management tools with prospective approaches evaluated from a holistic perspective.

Precisely one of the fundamental tools is to quantify the impacts generated by mining activity, collecting information, mainly, in the various areas of the populations surrounding the mining project, with objective, binding and measurable methodologies and, above all, that the decision makers be your main stakeholders or interest groups [1].

To this end, a multi-criteria assessment methodological tool has been developed through which it allows us to reduce social conflict.

In effect, said methodological assessment tool is based on the application of an improved multicriteria evaluation methodology for its evaluation called Improved Multicriteria Assessment (IMCA Model), which has as one of its applications that of quantifying the positive and negative impacts it generates. mining activity, evaluated from a global perspective, for which the main stakeholders are incorporated into the design as binding actors for the assessment process.

Based on these results, surely it should be suggested to include a social policy in the development strategy to play a fundamental role in the design of policies that effectively eradicate poverty. And thus, promote equal access to opportunities. Only then could we have a real idea of a concrete understanding of inclusive growth, in such a way that development has a material and human connotation.

1.2. Aim

Develop a methodological tool for multicriteria impact assessment-IMCA Model- to reduce social conflict in mining activity and design a model of sustainable coexistence in operational environments.

1.3. Scope

State, mining companies and population environments.

2. Conceptual Framework

In recent decades, concern about the viability of companies has become an important issue in many countries and industries, but with greater emphasis in the mining sector. To evaluate business sustainability, the traditional decisional paradigm must be changed for a multi-criteria approach, which is a consistent and accurate evaluation perspective [2].

One of the main management tools to help achieve sustainability is precisely to know how the productive-extractive activity is developing in terms of knowing the impacts that it is generating or is generating.

A variety of methodologies exist to evaluate decision-making processes and improve decision quality, including multi-criteria evaluations to make changes more explicit, rational, and effective [3].

Due to the heterogeneous expectations of multiple stakeholders, Herath and Prato [4] specify that it is more complicated to plan and manage any activity when there are multiple parties involved. In this case, more analytical methodologies are required that consider multiple evaluation approaches, which would optimize the results. In this sense, the technique of multi-criteria decision analysis (MCDA) and multi-criteria analysis (MCA) have advantages over other single-criteria analysis methods to solve problems mainly related to the management of natural resources.

The MCDA methodology is an approach that allows decision makers to analyze, compare, as well as evaluate alternatives using multiple criteria. By using this methodology, the relevant criteria for the problem are established and weights or importance are assigned to each of them. Then, each alternative is evaluated based on the criteria and a score or classification is obtained for each one. The MCDA technique offers a structure and an analytical framework to help decision-makers better understand the repercussions of different alternatives and adopt more consensual and fundamental decisions [5].

One of the prominent authors in the MCDA is Thomas L. Saaty, known for developing the AHP (Analytic Hierarchy Process) method and for his work in multi-criteria decision theory.

The AHP methodology is a hierarchical method that decomposes the problem into hierarchy levels, allowing the comparison and prioritization of criteria and alternatives through comparison matrices. It is a widely used methodology to make complex decisions by decomposing the problem into a hierarchy of criteria and sub-criteria. It helps to assign weights with respect to each criterion and compare alternatives in a structured way [6]. This is how the AHP can be used in a variety of fields, including business management, engineering, health and environmental decision making [7]. While Liberatore and Nydick [8] review recent advances and developments in the application of the Analytical Hierarchical Process (AHP) in medical and healthcare decision making.

There are also other methodologies based on the multicriteria approach such as the PROMETHEE method (Preference Ranking Organization Method for Enrichment Evaluations). This methodology is

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based on graph theory that compares alternatives based on qualitative and quantitative criteria, using preference and priority measures [9].

PROMETHEE-GDSS is an extension of the PROMETHEE method that allows the evaluation and ranking of alternatives in a group decision-making context, facilitating collaboration between multiple participants in the decision-making process [10]. Therefore, Gal, et al. [11] explore various practical applications of the PROMETHEE-GDSS method in fields such as business management, engineering, urban planning, and environmental decision-making.

Another method based on multi-criteria approaches is the ELECTRE (Elimination and Choice Translating Reality) method. ELECTRE is a classification method that compares alternatives based on their differences with respect to the criteria, establishing a preference relationship and classifying the alternatives based on their agreement with the established criteria [12]. Indeed, ELECTRE is a decision support technique used in multicriteria analysis. It allows you to compare alternatives based on multiple criteria and select the best alternatives based on a set of established preferences; That is, it allows decision makers to better understand the trade-offs between different criteria and make informed decisions [13]. Regarding the comparison of alternatives based on each criterion, it involves determining whether one alternative is preferable, indifferent or less preferable than another in relation to a given criterion using previously defined preference scales [14].

Figueira and Roy [15] explain clearly regarding the determination of the weights of the criteria in ELECTRE type methods, which improves the precision and reliability of the multicriteria analysis. Therefore, the model is used in a variety of fields in fields such as project management, public policy evaluation and business decision making [16].

Also, Keeney and Raiffa [17] describe another technique based on Multi-Attribute Utility Theory (MAUT) as a technique used in multi-criteria decision making that allows decision makers to evaluate and compare alternatives based on multiple attributes or criteria by choosing the alternative that maximizes its total utility. This is how [18] presents examples of how Multi-Attribute Utility Theory (MAUT) can be applied in social decision making, highlighting its usefulness in contexts where multiple criteria and objectives must be considered. However, Belton and Stewart [5] critically evaluate Multi-Attribute Utility Theory (MAUT) and other multi-criteria analysis methodologies, discussing their applications, advantages and limitations in decision making.

Another evaluation tool regarding the assessment of impacts is the Cost-Benefit Analysis (CBA). Boardman, et al. [19] detail CBA as a technique that evaluates the costs and benefits of an action or project to determine if the benefits justify the costs incurred. It is based on the quantitative comparison of costs and benefits in monetary terms or other common terms, allowing for more informed decision making. That is, the CBA considers both the monetary and non-monetary costs and benefits of mining, and allows an economic evaluation of the impacts in terms of costs and benefits for society.

Thus, Thaler and Sunstein [20] discuss how the principles of cost-benefit analysis can be applied in the design of public policies to improve individual and collective decisions in areas such as health, economy and well-being. As also Hanley, et al. [21] addresses specific techniques to assess environmental costs and benefits, as well as to evaluate environmental policies and projects. Taking into account the use of the cost-benefit analysis methodology in the context of the green economy [22] discuss its limitations and challenges, as well as propose alternative approaches to evaluate sustainable development and environmental conservation.

Even more Gillingham and Palmer [23] explore recent advances in cost-benefit analysis applied to energy efficiency policies, providing insights on how to close the energy efficiency gap and improve environmental sustainability.

Hwang, et al. [24] describe another methodology based on multi-criteria evaluation called the TOPSIS Model (Technique for Order Preference by Similarity to Ideal Solution). It is a technique used in multicriteria analysis to determine the order of preference of a set of alternatives. TOPSIS is another ranking approach used to evaluate alternatives based on how close they are to an ideal solution and how far they are to a negative solution. It is applied to assess mining impacts and classify actions based on their performance on multiple criteria. Triantaphyllou [25] explores various practical applications of the TOPSIS method in fields such as project management, strategic planning and systems engineering. While Hwang and Lin [26] critically evaluate the TOPSIS method and other multi-criteria analysis techniques, discussing their advantages, limitations and applications in group decision making.

In this context, the methodology of Multicriteria Analysis (MCA) [13] refers to as a technique used to evaluate and compare alternatives based on multiple criteria, taking into account the relative importance of each criterion and the preferences of decision makers. decisions. Thus, it is used in a variety of contexts, such as business management, engineering, urban planning and environmental decision making [27].

The assignment of relative weights to each evaluation dimension is one of the crucial elements in the type of calculation that is carried out through the methodologies: MCDA and MCA. Various criteria for the relative importance of impacts can be used to assign or calculate relative weights. Increased opportunities for sensitivity analysis, such as discrete multi-criteria decision analysis, result from the integration of evaluation methods of a decision support system. A key objective of discrete multicriteria analysis is to provide a justification for ranking a set of alternatives according to a set of criteria [28].

Indeed, the weighing of a certain set of variables tends to occur frequently, it's just that this often goes unnoticed. We clarify the word "frequent" with the following example: in the semester evaluations of a university academic subject, it is common to consider four qualified practices, say $\{P_1, P_2, P_3, P_4\}$, and from that set the average of the practices is obtained PP and the most natural thing is to take the arithmetic mean.

$$\mathrm{PP} = \frac{\mathrm{P}_1 + \mathrm{P}_2 + \mathrm{P}_3 + \mathrm{P}_4}{4}$$

That is to say, $PP = \frac{1}{4}(P_1) + \frac{1}{4}(P_2) + \frac{1}{4}(P_3) + \frac{1}{4}(P_4)$. The factor $\frac{1}{4}$ that accompanies each graded practice indicates the "value" that the practice has in relation to the total mark, i.e., 25% of PP. The factor is usually called weight and we observe that the total sum of all of them is equal to 1, that is, $1 = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4}$, which in terms of percentages means, 25% + 25% + 25% + 25% + 25% = 100%, since PP represents 100%. Moreover, the fact that the graded practices have the same weight means that all of them have the same importance.

That graded practices have the same weight, that is, that they have the same importance, is beyond the conception of what happens in reality, as there will obviously be practices that will have greater value for many and varied reasons. This type of situation is already evident, for example, in the competency-based curriculum where the purpose of assessment is to determine the achievement of competencies based on:

- Cognitive ability (partial and final assessment): 30%.
- Procedural capacity (qualified practice, research, participations): 60%.
- Attitudinal competence (values, social climate, responsibility): 10%, where all of them have different weights according to their importance.

Weights are also widely used in several other areas, for example in graph theory, specifically in the "optimal route problem" and in the "travelling agent problem". For example, in the optimal path problem, the minimization of the path cost is given over the sum of the weights of each edge traversed.

In graph theory, the weight of an edge can represent: cost or distance or time, i.e., the amount of effort required to travel from one place to another. Weight can also represent capacity, that is, the maximum amount of flow that can be transported from one place to another [29]. Thus, weights are undoubtedly given to "value" the importance of moving from one place to another.

Indeed, several methodologies use mathematical algorithms to choose different options. However, these models are inapplicable and difficult to understand for many real problems because these algorithms are often very complex, costly and time-consuming to process and interpret [4].

However, the methodology developed by the undersigned called IMCA Model (Improved Multicriteria Assessment), is a methodology also based on multi-criteria assessment but incorporates not only improved mathematical algorithms for its evaluation but also includes 5 phases for multi-criteria assessment and the key point that the main stakeholders are the decision makers in the assessment [30].

In the IMCA Model, the conception of the weights is similar to that of the graph theory and they represent the importance of an indicator and/or dimension, where the order of importance of the weights depends on the decision of the decision-making team composed of the main stakeholders and the facilitating group. It is important to emphasize that the order of importance of certain variables (e.g. indicators and/or dimensions) depends on relevance, usefulness, necessity and all other factors that highlight their value over others.

Let $\{D_1, \ldots, D_p\}$ be the set of all dimensions. If we were to fix an arbitrary dimension D_k that has a set of $n(k)$ indicators, say $\{I_1, \ldots, I_{n(k)}\}$, whose order of importance was decided by the facilitating work team, then we have the following assignment of weights:

I_1 with weight RW_1,…, I_i with weight RW_i,…, $I_{n(k)}$ with weight $RW_{n(k)}$,

with$\sum_{i=1}^{n(k)} RW_i = 1$, set according to the importance of each indicator, where $\sum_{i=1}^{n(k)} RW_i = 1$ indicates that the total sum of the weights must equal 1, as D_k has a value equal to 1 which, in percentage terms represents 100%.

Similarly, as with the indicators, we can naturally define a weighting for each dimension according to its importance, and this also has to be decided by the decision-making team. Thus, we have:

D_1 con peso RW^1,…, D_k con peso RW^k,…, D_p con peso RW^p,

with$\sum_{k=1}^{p} RW^k = 1$, where the meaning of the $\sum_{k=1}^{p} RW^k = 1$ is equal to the one we did with the total sum of the weights of the indicators.

One of the applications of the IMCA Model is precisely to quantify the positive and negative impacts of a productive-extractive project.

Quantifying the externalities allows us to strengthen and/or correct the positive and negative impacts, respectively, thus enabling us to reduce social conflict and, consequently, to design a proposal for a model of sustainable coexistence in the population surrounding a mining project.

In effect, the IMCA Model is a techno-scientific methodological innovation. The IMCA Model methodology includes an improved mathematical algorithm for the quantification of its indicators. This algorithm integrates all calculation processes and works with quantitative data generally, but also includes qualitative data in its evaluation [30].

The IMCA Model incorporates an integral and transversal analysis for the evaluation of its alternatives, both for its indicators or attributes and for its dimensions or criteria, obtaining more precise and reliable results.

The methodological innovation of the optimized model, IMCA Model, includes 5 main phases.

a) Phase: Participative, this is one of the determining phases for the efficiency in the application of the proposed model, because at this stage the main stakeholders that will participate in the quantification of impacts are identified. For which, preliminarily, there must be the initiative, leadership and commitment of the mining company and the willingness and collaborative action of the state at different levels of government as the main social actors.

The work facilitator team is composed of interdisciplinary professionals external to the mining project under evaluation, who will implement the innovative methodology in its 5 phases for the multi-criteria valuation of impacts generated by the mining project.

Thus, the technical facilitator team starts with the process of identification and validation of stakeholders. Next, they sensitize, train and socialize the 3 social actors: State-Business and Social Community. Subsequently, the representatives of the 3 social actors design the consistency matrix where the parameters, characteristics and attributes to be taken into account for both the dimensions or factors to be assessed and their corresponding variables are incorporated and prioritized, guided by the technical facilitator team. It should be noted that the parameters to be incorporated for both factors and variables are strictly the decision and responsibility of the stakeholders.

b) Phase: Statistics, includes the collection, processing, analysis and verification of the data collected. This process is also complemented by direct observation, interviews, surveys, checklists and focus groups.

c) Phase: Application of Mathematical Algorithm - IMCA MODEL, includes the mathematical calculation of weightings for each dimension and indicators. For the quantification of impacts, an improved mathematical algorithm IMCA MODEL (Improved multicriteria assessment) is used.

d) Phase: Socialization of Results, includes the report, discussion, approval and validation of the results found by the stakeholders. It is also important to specify that this phase will identify the commitments to be assumed by each participating stakeholder to strengthen the positive impacts and correct the negative impacts, mainly for each variable and respective criterion for which responsibility has been identified.

e) Phase: Monitoring and Oversight, includes the designation of a committee appointed by the 3 stakeholders participating in the impact assessment process, which will be responsible for monitoring, overseeing and reporting to the representatives of the 3 social actors on the implementation of the responsibilities of each party involved.

Precisely, one of the applications of the IMCA Model is to know the positive and negative impacts generated by the mining industry, assessed from a holistic aspect with the participation of the stakeholders of the mining project under evaluation.

The holistic perspective means including not only technical-operational and economic factors in the assessments, but also socio-cultural, environmental and political-institutional factors, among others, according to the reality of each project under study.

Thus, the mathematical calculations of the IMCA Model methodology are designed in a computational model. The measurement of impacts caused by a productive-extractive activity is an important evaluation tool, which is participatory, inclusive and binding.

Measuring impacts evaluated in a multi-criteria manner translates into measurable management indicators and results that are closer to reality. The evaluation of the impacts generated by productive-extractive activities will be beneficial at three levels.

1) For the State, it will be able to count on a reliable methodological instrument for impact evaluation, which will serve to propose more objective public policies that benefit a larger segment of society,

2) For the Communities and Popular Organizations, it will become a reliable, guiding, transparent instrument that contributes to better decision making because its results are measurable, but above all, participatory and binding.

3) For the productive-extractive company, it is a catalytic management tool to promote the development of more responsible activities with its environment, as well as to build more harmonious relationships that contribute to obtaining social acceptance.

The data must be previously collected, analyzed and verified. This algorithm also includes a double weighting as an adjustment factor for both dimensions or criteria and indicators or attributes, which makes the evaluation more reliable [1].

The positive and negative impacts are quantified 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 [4].

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2.1. Improved Mathematical Algorithm - IMCA Model

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

Source: (Poterico, J. & Taylor, D., 2011) based on [4]

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

k = 1, 2, . . ., p (Dimensions, components);
i = 1, 2, . . ., $n(k)$ (Indicators, attributes);
j = 1, 2, . . ., m (Alternatives).

TA_j= Total value of each alternative by dimensions
Phases of the multi-criteria impact assessment methodological tool
IMCA Model

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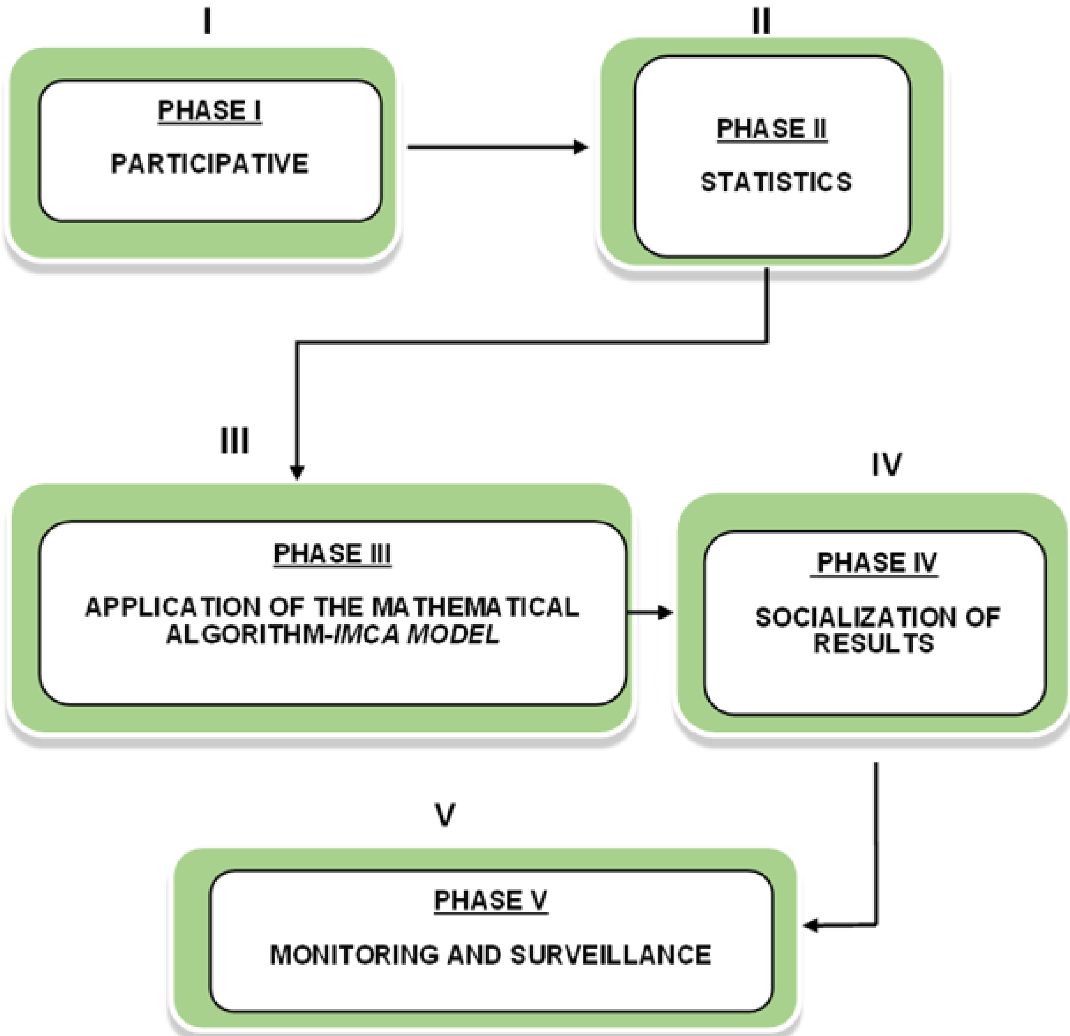

Figure 1.
General diagram.

3. Results

The information obtained through the application of the multi-criteria valuation methodological tool in the measurement of the impacts generated from a holistic perspective using the IMCA Model, allows strengthening and/or correcting the positive and negative impacts, respectively.

It also specifies that, through the traceability determined for the quantification of impacts, it allows identifying the responsibilities of each stakeholder participating in the impact assessment process, with which it is intended to design a model of sustainable coexistence in the population environments of a productive-extractive mining project.

Also, with the application of the multi-criteria methodological tool for the quantification of impacts using the IMCA Model, it focuses on the urgency of concerted actions between the state and the private company, so that the activities that materialize for the benefit of the population have deep roots, to prevent poverty from worsening in the population centers and rural communities in the area of influence of the operational project, which in some cases is a lacerating reality.

Finally, the development of the multi-criteria valuation methodological tool includes an important scientific methodology for impact assessment called IMCA Model, whose mathematical calculations are designed in a computational model. The measurement of the impacts produced by the mining activity is developed in a necessarily participatory, inclusive and binding scenario.

4. Conclusions

The methodological tool of multi-criteria valuation of impacts is a corollary of an adequate and detailed scientific research looking for the firm purpose that state organizations, mining companies and social organizations have a common vertex and more predictability for decision making.

Therefore, through the application of the methodological tool of valuation of externalities developed and quantified from a holistic perspective through the application of the IMCA Model, it is concluded that:

- It is a significant contribution, since due to the traceability for the valuation of impacts in the productive-extractive activity it contributes in a more objective way for the reduction of social conflicts in the population environments of the mining project.
- It is an important and decisive management tool and, in this way, social policies can be consolidated to improve the standard of living of the inhabitants and consequently contribute to achieve a harmonious and sustained coexistence with everyone and for everyone.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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