ECLAC Methodologies

Guide for prioritizing and evaluating environmental remediation projects

Managing mining legacies

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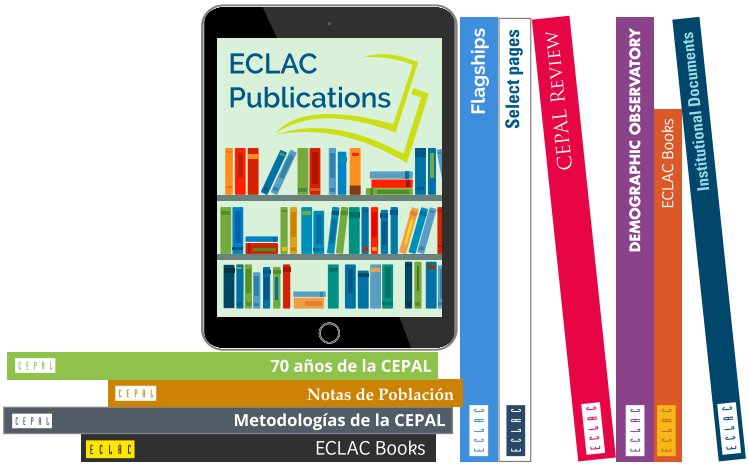

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Contents

Introduction 9

Chapter I

Purpose of this guide 13
A. Definition of an environmental legacy of mining 15
1. Types of environmental mining legacies 17
B. Concepts of environmental risk and damage 18
C. Remediation of environmental mining legacies 20
D. Road map: methodological guide for the remediation of mining environmental legacies 21

Chapter II

Guidelines for sustainable environmental mining legacy remediation projects 25
Introduction 25
A. Decision-making principles for the remediation of mining's environmental legacies 25
B. Risk management for the prioritization of environmental mining legacies 28
1. Risk-based frameworks for managing environmental mining legacies 29
2. Intervention based on risk estimation 30
3. Risk vectors 30
4. Main stages in the risk-based management of environmental mining legacies 33
5. Sustainable remediation, rehabilitation and (re)activation in Latin America and the Caribbean 36
6. Risk-based record construction 38
7. Prioritization criteria 39
C. Legal issues for the management of environmental mining legacies 39
D. Funding strategies for the remediation of environmental mining legacies 43
E. Stakeholder engagement 46
1. Stakeholder identification 47
2. Encouraging stakeholder engagement 48
3. Local community engagement 50
F. Available technologies 53
1. Reprocessing 55
2. Stabilization 56
3. Cover systems 56
4. Treatment of water affected by mining 57
5. Integrating remediation with restoration 57

Chapter III

Tools for decision-making in the management of environmental mining legacies 59
Introduction 59
A. Decision-making for the analysis of a remediation project 59
B. Main methodological approaches 61
1. Qualitative analysis 61
2. Quantitative analysis 62

3. Semi-quantitative analysis 66
4. Cost-impact analysis 68
C. Overview of cost-benefit analysis 68
D. Overview of cost-effectiveness analysis 70
E. Prioritization of projects at the national level 72
F. Applications of cost-benefit analyses and cost-effectiveness analyses in Latin America and the Caribbean 73
1. Countries and sectors using cost-benefit analysis 73
2. Countries and sectors using cost-effectiveness analyses 77
3. Characteristics of national frameworks 79

Chapter IV
Prior steps for a comprehensive and sustainability-focused assessment of a remediation project 81
Introduction 81
A. Project cycle 82
1. Pre-investment 83
2. Investment 86
3. Operation of the remediation project 86
B. Steps for conducting a sustainability-focused cost-benefit analysis 87
1. Analysis and definition of the problem posed by the mining environmental legacy 88
2. Diagnosis of the current situation (without remediation) 91
3. Risk scenario analysis 100
4. Analysis of the possible impact of inaction 105
5. Remediation alternatives 108
6. Comprehensive evaluation 116

Chapter V
Cost-benefit analysis for comparison of remediation alternatives 117
Introduction 117
A. The supply-demand approach in the cost-benefit analysis of mining environmental legacies 118
B. Identification and measurement of costs and benefits 119
1. Market-determined prices 120
2. Costs and benefits without market prices 121
C. Evaluation of costs and benefits 123
D. Project evaluation and comparison 123
1. Use of weightings for distributional considerations 124
2. Temporal comparability: the analysis horizon and the discount rate 125
3. Risk and uncertainty 126

Chapter VI
Comprehensive evaluations for sustainable remediation 127
Introduction 127
A. Dimensions of a comprehensive evaluation 128
B. Environmental evaluation 130
C. Private or financial evaluation 131
1. Financial costs of each remediation alternative 132
2. Financial revenue from remediation 134

3. Private cash flow 134
4. Financial indicators 135
D. Economic evaluation 139
1. Social costs of remediation 140
2. Social benefits of remediation 141
3. Social cash flow and indicators 144
E. Social evaluation 148
1. Characterization of the affected parties 148
2. Social analysis methods 151
3. Evaluation of equity considerations 151
F. Sensitivity analysis 155
G. Interdependence with other projects 157

Chapter VII
Feedback in the project monitoring process 159
Introduction 159
A. Types of feedback 159
B. Selecting relevant indicators 162
1. Sustainability indicators 165
C. Use of indicators in the follow-up or monitoring stage 169
D. Use of indicators in the evaluation stage 171

Chapter VIII
Final thoughts 175

Bibliography 177

Tables

Table I.1 Definitions used to classify environmental legacies and environmental mining legacies 15
Table II.1 Guiding principles for the management and sustainable remediation of environmental mining legacies 27
Table II.2 Types of physical risks associated with environmental mining legacies 31
Table II.3 Selection of possible sources of contributions for the remediation of environmental mining legacies 44
Table II.4 Principal stakeholders in environmental mining legacy remediation projects 47
Table II.5 Remediation measures by major element or material present in environmental mining legacies 53
Table III.1 Comparison of project analysis models for decision-making 60
Table III.2 Summary of main qualitative analytical tools used in cost-benefit analysis 61
Table III.3 Gains matrix 63
Table III.4 Multi-criteria decision matrix 67
Table III.5 Main differences between cost-benefit analysis and cost-effectiveness analysis 71
Table III.6 Latin America and the Caribbean (12 countries): general objective of cost-benefit analyses according to legislation, regulations or official documents, 2015 74

Table III.7 Latin America and the Caribbean (7 countries): use of cost-benefit analyses in environmental and natural resource sectors....76
Table III.8 Latin America and the Caribbean (6 countries): use of cost-effectiveness analyses in the environmental and natural resources sectors....78
Table IV.1 Classification of investment programmes and projects in cost-benefit analyses....83
Table IV.2 Categories of information about the area of influence to be collected....94
Table IV.3 Peru: qualitative risk assessment for mining environmental legacies C....101
Table IV.4 Types and levels of vulnerability from exposure to the mining environmental legacy....102
Table IV.5 Main features of tiers in multilevel assessment frameworks....104
Table IV.6 Analysis of mining environmental legacy impacts in the area of influence....108
Table IV.7 Example of a risk index matrix by exposure route and pathway, and by contaminant for soil....111
Table V.1 Chile, Paraguay and Nicaragua: social prices....120
Table V.2 Categories of value types of environmental goods....121
Table V.3 Environmental valuation methods....122
Table VI.1 Relevant financial variables for the cost-benefit analysis....132
Table VI.2 Investment, operation and maintenance costs of the alternative....133
Table VI.3 Financial cash flow for remediation project alternative A....134
Table VI.4 Comparison of project alternatives according to the net present value and cost-benefit ratio criteria....139
Table VI.5 Simplified social cash flow model....144
Table VI.6 Examples of cost-efficiency indicators for the use of a cost-effectiveness analysis....148
Table VI.7 Mechanisms for the classification of affected parties....149
Table VI.8 Allocation of social benefits and costs to identified stakeholders....150
Table VI.9 Characterization of the affected parties....151
Table VII.1 Differences between follow-up or monitoring and evaluation....161
Table VII.2 Example of an indicator selection matrix....165
Table VII.3 Relevant indicators for the management and sustainable remediation of mining environmental legacies....166
Table VII.4 Environmental legacy indicators for mining activities....167
Table VII.5 Examples of budget indicators for the sustainable management and remediation of a mining environmental legacy....168
Table VII.6 Example of an indicator evaluation matrix....171

Boxes

Box II.1 Examples of physical risks in environmental mining legacies: stability of mines and tailings deposits....33
Box II.2 Difference between closure of a mine and closure of a environmental mining legacy remediation....36
Box II.3 Extracontractual civil responsibility systems....40

Box II.4 Development of the stakeholder engagement plan 49
Box II.5 The role of women as a community and information circuit 52
Box IV.1 Absence of specific budget items for mining environmental legacies..... 85
Box IV.2 Graphic depiction of the area of influence 93
Box IV.3 Sample legal definitions of the conceptual model..... 95
Box IV.4 Relationship between sampling quantity, uncertainty and remediation costs 99
Box IV.5 Examples of the use of two-level tiered evaluations 104
Box IV.6 Component elements of the Environmental and Human Health Risk Assessment Study 106
Box IV.7 Example of scenario development.....113
Box IV.8 Hypothetical example of three common scenarios for the remediation of environmental mining legacies with costs.....115
Box V.1 Analysis by damage avoided 119
Box VI.1 Examples of costs to be avoided derived from identified impacts and valuation methods 142
Box VI.2 Reduction progression for cost reduction benefit i (expressed in the value of the fully reduced impact 143
Box VI.3 Example of the use of weightings.....149
Box VI.4 Example of the use of weightings (continued).....152
Box VI.5 Example of compensation for specific groups.....153
Box VI.6 Use of weightings in the calculation of net present value 154
Box VI.7 Examples of sensitivity analysis 155
Box VI.8 Synergistic effects between remediation projects 157
Box VII.1 Usefulness of indicators in monitoring and evaluation 162
Box VII.2 Statistical verification of remediation results.....172

Diagrams

Diagram I.1 Methodological guide for the remediation of the environmental legacies of mining: road map 14
Diagram I.2 Relationship between the concepts of environmental damage, contaminated site and environmental legacy.....19
Diagram I.3 Preliminary considerations in the design and implementation of a remediation plan 22
Diagram I.4 Recommendations for designing, implementing and monitoring a remediation project..... 23
Diagram II.1 Stages in the management of environmental mining legacies..... 34
Diagram II.2 Glossary of basic remediation terms 37
Diagram II.3 Flow chart of the steps to be followed in identifying, registering and prioritizing environmental mining legacies..... 38
Diagram II.4 Stages in the development of a financing strategy 46
Diagram II.5 Components of the community participation plan 51
Diagram III.1 Example of a decision tree with estimated values 64
Diagram III.2 Overview of life-cycle assessments for environmental mining legacies..... 65
Diagram IV.1 Stages in problem solving 82
Diagram IV.2 Stages in the life cycle of a project 83

Diagram IV.3 Pre-investment stage in the life cycle of a project and its relationship with the management of mining environmental legacies 84
Diagram IV.4 Documentation for the remediation management plan 86
Diagram IV.5 Constituent parts of the cost-benefit analysis 87
Diagram IV.6 Steps in the cost-benefit analysis for remediating a mining environmental legacy 88
Diagram IV.7 Example of a problem tree of a mining environmental legacy remediation project with facilities and waste from mining operations 89
Diagram IV.8 Example of a means-ends tree for a mining environmental legacy remediation project 90
Diagram IV.9 Preparatory activities 91
Diagram IV.10 Types of information collected after the field visit 92
Diagram IV.11 Iterative process for designing a conceptual model for a mining environmental legacy 96
Diagram IV.12 Factors affecting dispersion of contaminants 97
Diagram IV.13 Relevant data for the cost-benefit analysis obtained from the conceptual model 97
Diagram IV.14 Component elements of the diagnosis of the current situation 98
Diagram IV.15 Cost items for studies associated with a potentially affected ecosystem 100
Diagram IV.16 Risk assessment activities for potential receptors of exposure to contaminants present at the study site 101
Diagram IV.17 Actions according to risk index 103
Diagram IV.18 Areas typically affected by mining environmental legacies 107
Diagram V.1 Objectives of presenting the interaction between supply and demand 118
Diagram V.2 Importance of supply and demand analysis in the remediation of mining environmental legacies 119
Diagram VI.1 Sequence of stages in evaluating remediation alternatives 128
Diagram VI.2 Organization and products of the comprehensive evaluation 129
Diagram VI.3 Main categories covered by a comprehensive evaluation with sustainability aspects 130
Diagram VI.4 Intertemporal financial equivalents 136
Diagram VI.5 Flow equivalence for an environmental capital project 146
Diagram VII.1 Steps in implementing a data-based evaluation 160
Diagram VII.2 Dimensions of elements to be evaluated, with some examples within sustainable remediation indicators 164
Diagram VII.3 Stages in the implementation of an indicator monitoring system 170

Introduction

Mining environmental legacies —that is, mining and metallurgical sites (mines, pits, infrastructure and so on) that have not been technically and formally closed and that pose risks to people and the environment— can harm local communities, disrupt ecosystems and represent a burden for current and future generations. By eliminating or minimizing the risks associated with mining environmental legacies through remediation, social well-being increases and economic opportunities arise and give the remediated site a new life. However, given the scarcity of public resources and the socioeconomic challenges facing governments in Latin America and the Caribbean, it is necessary that the most effective projects be chosen and implemented.

Within the management of mining environmental legacies, a core issue is determining which party was responsible for creating them and, consequently, who should be tasked with funding and carrying out the remediation actions. Many mining legacies represent situations inherited from the past, having originated prior to the entry into force of environmental regulations. Although the "polluter pays" principle should be applied, when the polluter cannot be found, the responsibility falls on the current landowner or the State. Frequently, responsibility for the management and remediation of mining legacies falls on States, which increases the pressure on their generally limited budgetary resources.

In this context, the aim of this methodological handbook in relation to the selection of remediation options for mining legacies is to interconnect the issues of human rights, environmental protection, liability for damage remediation, and economic and financial analysis. To achieve that goal, it provides basic guidelines to help assess needs, prioritize funding for the remediation of mining legacies and guide the work of public policymakers.

The handbook is designed to facilitate the comparison of remediation alternatives for a mining legacy. In particular, it offers common definitions and guiding frameworks to standardize the economic and financial analysis involved in the management of

mining legacies, based on risk analysis. As a starting point, this handbook aligns with the principle that any remediation project must be evaluated from the perspective of environmental sustainability. Financial, economic and social analyses help determine the most appropriate projects according to prevailing conditions. The concepts presented in this document are applied and understood within the framework of public sector economics, environmental economics, the economics of well-being and the sphere of financial economics.

The first chapter explains, analyses and sets out the purpose of the handbook and definitions of its key concepts. It establishes the main methodological guidelines for evaluating and prioritizing the financing of various mining legacy remediation projects. It emphasizes the safeguarding of human rights, environmental protection, and the responsibility for carrying out remediation and the related economic and financial analyses. The handbook also includes information, methodologies and guidelines for formulating or implementing public policies to prioritize investments focused on the remediation of mining legacies.

It also explores the concepts and most important aspects of mining environmental legacies and remediation, taking into account the wide range of definitions used in different countries within Latin America and the Caribbean. At the end of the first chapter, a road map is included to help decision makers determine the main steps and their recommended timeline when exploring the subsequent chapters.

The second chapter sets out essential guidelines for consistent decision-making and good governance in the sustainable remediation of a mining legacy. It presents reference principles to promote efficient and effective decision-making, along with the characteristics of the main remediation approaches, with an emphasis on the concept of risk. It also highlights the most important aspects of national legal frameworks, outlines select strategies for remediation funding and stresses the importance of early and meaningful engagement with stakeholders, including local communities. Finally, it describes some of the state-of-the-art technologies that can be considered in a remediation project.

Chapter III provides a summary of the main analytical tools. First, it introduces qualitative, quantitative and semiquantitative methods. It then describes in detail the characteristics of cost-benefit and cost-effectiveness analyses, with a focus on Latin America and the Caribbean, and explains the circumstances under which the use of one or the other is preferred.

The fourth chapter sets out the methodological steps to be followed, taking into account the pre-investment, investment and execution stages of a remediation project, with a risk management approach.

Chapter V sets out in detail the theoretical bases of quantitative analysis. It discusses notions of social welfare, measurement, and supply and demand in the context of cost-benefit analyses applied to remediation, as well as analyses with intertemporal and equity elements. It also discusses the role played by risk and uncertainty.

The sixth chapter describes the steps to be taken in carrying out a comprehensive analysis. It explains the roles and relationships between environmental, financial, economic and social sustainability analyses and presents a practical perspective on cost-benefit analysis through a review of the concepts set out in chapter V.

Chapter VII deals with issues related to monitoring and evaluation processes for remediation investments These processes are carried out using performance indicators. The final part of the chapter stresses the importance of choosing appropriate and relevant indicators that allow adjustments to be made during the closure and post-closure stages of a project. Finally, chapter VIII contains a series of final thoughts.

This handbook does not exhaustively analyse the more technical aspects of characterizing mining legacies or assessing risks to human health and the environment. This topic is widely explained in international literature and national regulations via various technical guides, many of which are referenced in the present work.

This handbook is part of the work of the Sustainable Development and Human Settlements Division of the Economic Commission for Latin America and the Caribbean (ECLAC), the purpose of which is to develop regionally relevant methodologies that include environmental management. In this context, it acknowledges its continuity with the methodological guides published by the organization in similar areas, such as *Guía de evaluación ambiental estratégica* (Jiliberto Herrera and Bonilla Madriñán, 2009), *Guía metodológica: diseño de indicadores compuestos de desarrollo sostenible* (Schuschny and Soto, 2009), *Guía metodológica: medición del gasto en protección ambiental del gobierno general* (Collinao and others, 2015), *Guía metodológica: instrumentos económicos para la gestión ambiental* (Pantaleón, Pereira and De Miguel, 2015), and the *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean: implementation guide* (ECLAC, 2023). Another noteworthy publication is *Guía metodológica de cierre de minas* (Morales and Hantke, 2020), published by ECLAC, which proposes guidelines for the correct closure of mining sites and for preventing the emergence of new mining environmental legacies. A supplement to that guide was also published, in 2023 (Morales, 2023).

Chapter I
Purpose of this guide

This document sets out the main guidelines for evaluating mining environmental legacy remediation projects. It emphasizes the safeguarding of human rights, environmental protection, responsibility for damage remediation and the related economic and financial analyses. It also proposes a methodology for evaluating and prioritizing funding for the remediation of a mining environmental legacy.

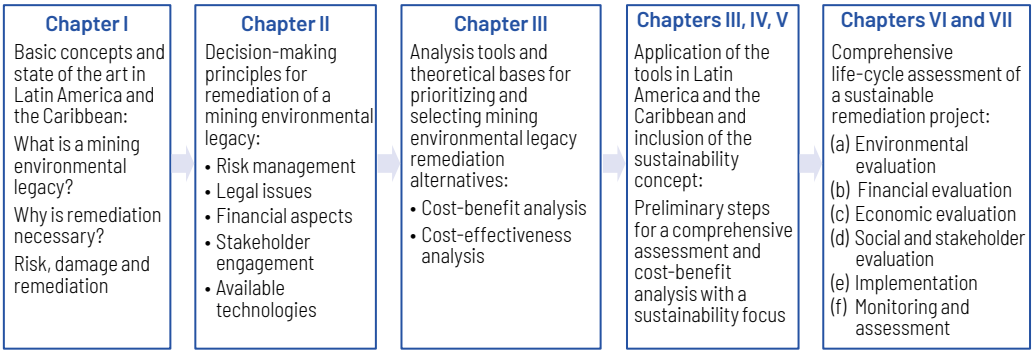
The guide is intended primarily for those responsible for formulating and implementing public policies that prioritize sustainable investments for the remediation of environmental mining legacies. The document sets out the main concepts associated with the definition of environmental mining legacies, remediation and risk. It also illustrates its objectives and approach by means of a road map in order to facilitate the reading of the document.

Throughout the guide, common definitions and guiding frameworks are provided to standardize economic and financial analyses related to the management of mining environmental legacies for sustainable remediation. The document emphasizes the following principles: (i) the protection of human health and the environment, (ii) coherent decision-making, and (iii) good governance and stakeholder engagement.

This is linked to the traditional guidelines of a cost-benefit analysis, but with the inclusion of sustainability considerations. Note that the guidelines can also be applied to other economic activities that generate environmental legacies.

Diagram I.1 shows the road map for this guide, which is intended to help readers navigate it and to gain familiarity with its concepts and with the decision-making and analysis tools for selecting mining environmental legacy remediation options.

■ Diagram I.1
Methodological guide for the remediation of the environmental legacies of mining: road map



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The first box (from left to right) identifies the notions discussed in chapter I, where the definitions, classifications and origins of environmental mining legacies are discussed in more detail. It presents the concepts of environmental damage and risk associated with the legacy, together with the definition of remediation and the reasons why remediation actions are necessary.

The second box covers chapter II, which identifies several decision-making principles for the management and remediation of environmental mining legacies. It also discusses in depth the steps to be followed in conducting a risk analysis to prioritize legacy remediation. In addition, it highlights the importance of the legal and financial aspects of management and remediation, as well as the key role to be played by all stakeholders in the closure of a mining operation, particularly the surrounding communities, and it describes the remediation technologies that are currently available.

The road map's third box corresponds to chapter III of the guide, which sets out the analysis tools that exist and the methodological approaches that can be used to assess funding alternatives for remediation. In particular, it discusses cost-benefit analyses and cost-effectiveness analyses.

The fourth box indicates the contents of chapters III, IV and V. Reference is made to the application of cost-benefit and cost-effectiveness analyses in Latin America and the Caribbean (chapter III), the concept of sustainable remediation is discussed in greater depth, and the preliminary steps for conducting a comprehensive assessment and cost-benefit analysis with a focus on sustainability are listed (chapter IV). Chapter V explains the theoretical bases that can be used to identify and evaluate the various remediation alternatives.

Finally, the fifth box indicates the information included in chapters VI and VII. Particular emphasis is placed on the importance of conducting a comprehensive assessment process throughout the life cycle of a mining environmental legacy remediation project. A comprehensive assessment must address socioenvironmental, economic and financial

issues (chapter VI). The importance of continuous project monitoring and of an evaluation of its success is emphasized, along with the selection of suitable and relevant analysis indicators (chapter VII).

A. Definition of an environmental legacy of mining

Environmental mining legacies, in general, originate from a historical absence of regulations for a management model to address and internalize environmental issues in productive and extractive activities, including their technical closure. They are also associated with the abandoning of projects, poor environmental practices and the lack of responsible owners who can be held accountable for their timely remediation.

Despite the existence of common elements such as risk, potential impact and damage, Latin American and Caribbean countries still lack a single definition of environmental mining legacies (Oblasser, 2016), and the debate on the most appropriate terminology for their definition remains open. A single definition would enable the regional coordination of different policies for managing environmental mining legacies and would, in addition, improve the coordination of international funds for remediation activities (De Miguel and Pereira, 2019).

Typically, environmental mining legacies are associated with abandoned (or inactive) mining operations or activities, or their components, that pose a potential risk to people and the environment. In light of that, several concepts must be brought together to establish a definition of environmental mining legacies (see table I.1).[1]

■ Table I.1
Definitions used to classify environmental legacies and environmental mining legacies

Country	Definition	Regulations
Bolivia (Plur. State of)	The series of negative impacts detrimental to health and/or the environment caused by certain works and activities existing in a certain period of time and the general environmental problems not resolved by certain works or activities.	Supreme Decree No. 24176 of 8 December 1995. Article 46 of the General Environmental Management Regulations.
Chile	An abandoned or idle mining operation, including its tailings, that poses a significant risk to human life or health or the environment. Site or land environmentally impacted by a past economic activity that has ended and over which no control is currently exercised.	2005 bill on the remediation of environmental mining legacies. National Policy for the Management of Sites with Contaminants.

[1] Mining operations are defined as "all the facilities and workplaces of the extractive mining industry", including "the totality of the workings, facilities and support services and infrastructure that exist in respect of a mine or extraction establishment to ensure the functioning of mining operations" (National Congress of Chile, 2011).

Country	Definition	Regulations
Colombia	Environmental impacts caused by anthropic activities directly or indirectly by human action, authorized or not, cumulative or not, that can be measured, located and geographically delimited, that generate an unacceptable level of risk to life, human health or the environment, as established by the Ministry of Environment and Sustainable Development and the Ministry of Health and Social Protection, and for the control of which there is no environmental or sectoral instrument.	Act No. 2327 of 2023.
Ecuador	The environmental damage and/or negative environmental impacts not respectively repaired or restored, or those that have been previously but inadequately or incompletely addressed and continue to be present in the environment, constituting a risk for any of its components, generated by a mining activity.	Mining Act, No. 45 of 2009, as amended in 2016, and Environmental Regulations for Mining Activities, Ministerial Agreement No. 37-2014, as amended in 2016.
Mexico	Sites contaminated by the release of hazardous materials or wastes that have not been remediated in a timely manner to prevent the dispersion of contaminants and that imply the obligation of remediation.	Regulations to the General Act for the Prevention and Comprehensive Management of Waste.
Peru	Facilities, effluents, emissions, remains or waste deposits produced by mining operations that are currently abandoned or inactive and that pose a permanent and potential risk to the health of the population, the surrounding ecosystem and property.	Act No. 28271 to regulate the environmental legacies of mining activities, published in 2004.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Among the countries of Latin America and the Caribbean, Colombia, Ecuador, Mexico and Peru have regulatory frameworks for the corrective management of environmental legacies (Congress of the Republic of Colombia, 2023; OLACEFS, 2021) (see table I.1).

Based on the definitions shown on the table above, a large number of inventoried environmental mining legacies in the Andean countries can be identified (for example, Colombia with 781 (2015), Ecuador with 3,710 (2020), Peru with 6,128 (2023) and so on). Thus, a large number of environmental mining legacies or abandoned or idle sites and facilities exist that pose an imminent risk to society and the environment (Congress of the Republic of Colombia, 2023; Ministry of Environment, Water and Ecological Transition of Ecuador, 2024; MINEM, 2023).

More broadly, and for the purposes of this guide, environmental mining legacies are understood as the potential negative socioenvironmental impacts associated with abandoned mining operations (and the waste deposited therein), whether with or without an identifiable owner or operator, and where no regulated closure has been carried out and certified by the competent authority (Yupari, 2004). In addition, physical risks exist, such as abandoned infrastructure and its possible collapse, as do chemical risks, such as the generation of acid drainage that can drain through open pits.

The physical risks of a mining environmental legacy can be triggered, aggravated and converted into damage through natural phenomena or the poor conditions of the facility. Those natural phenomena include seismic activity, water erosion, wind, floods, landslides

and extreme rainfall. Facility conditions can be related to the compaction of the tailings dam wall,[2] the way the facility was operated and maintained while functioning, and the correct (or otherwise) follow-up of closure measures (Morales and Hantke, 2020). For example, a failure in the tailings disposal system may result in the collapse of a tailings impoundment (see box II.1).

Environmental mining legacies can also pose chemical risks at sites where the contamination primarily involves waste or materials containing potentially toxic elements. The potentially toxic elements found at mining legacies that are of the greatest environmental concern because of their high toxicity include arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), molybdenum (Mo), nickel (Ni), antimony (Sb), selenium (Se), lead (Pb), vanadium (V) and zinc (Zn) (Alberruche and others, 2014; Arranz-González and others, 2022; European Union, 2009). These elements can be directly related to mining activities, either on a primary basis (the mineral that is extracted) or on a secondary basis (remaining residues, such as those produced by the extraction of precious metals).

Finally, the impacts on people's safety and health, the environment and economic activities can be classified into the following categories: (i) seismic risk, (ii) hydrogeological risk, (iii) dust generation, (iv) soil contamination, (v) water consumption, and (vi) failures in the disposal system (BGR/SERNAGEOMIN, 2008; SERNAGEOMIN, 2014; López and others, 2003). (See examples in chapters II and IV.)

1. Types of environmental mining legacies

Several types of environmental mining legacies can be identified in terms of: (i) their component elements, (ii) the circumstances from which they arise, and (iii) the applicable legal regime. These factors will ultimately have an impact on the risks the sites pose (Oblasser, 2016):

- **Environmental mining legacies from extractive mining activities that include or may include:** subterranean or open pit mines, facilities and workplaces, leach heaps, massive mining waste dumps, tailings and waste rock dumps, leach debris and, in general, the totality of workings, facilities, support services and infrastructure that exist in connection with a mine. This class of environmental mining legacies also includes those generated by the oil industry, such as exploitation sites (wells), sites used to deposit waste (e.g. drilling muds), derivative production and storage sites, and sites used exclusively for storage and distribution.
- **Environmental mining legacies from mining and metallurgical activities that include or may include:** smelting plants, slag deposits, treatment plants, batteries, equipment, workshops, powerhouses, warehouses, storage facilities, support and service facilities, and related infrastructure necessary for the functioning of mining and metallurgical operations.

[2] According to Arranz-González and others (2020a), the term "tailings dam" is synonymous with "tailings impoundment". The terminology used for those deposit facilities varies from country to country: the term *tranque de relaves* is used in Chile, *presa de relaves (colas)* in Colombia and Peru, and *presa de relaves* in Mexico.

- **Environmental mining legacies arising from major accidents caused by extractive mining activities that include or may include:** waste dispersed by the accident (such as massive wastes, tailings, leach debris and acid solutions used in processes) that contain potentially toxic elements or acid solutions and are dispersed throughout a watershed in different environmental aspects, such as soil, sediments, water and air.

B. Concepts of environmental risk and damage

A mining environmental legacy represents a potential risk to the community and the environment, where a risk is understood as "the combination of the probability of an event occurring and its consequences" (BGR/SERNAGEOMIN, 2008). Additionally, it can be defined as an "aggregate estimate of the probability and severity of an adverse event on life, health, property or the environment" (Arranz-González and others, 2020a, p. 19). The risks arising from environmental mining legacies generally relate to the people's physical safety and to pollution, and they can have negative repercussions on economic activities. In turn, all this can trigger social and environmental conflicts with neighbouring communities. For this reason, managing the risks associated with a mining environmental legacy is a fundamental tool for analysing and calculating its potential impact. It is important that the management of legacies be planned with a view to their remediation.

According to the Association of Iberoamerican Geological and Mining Surveys (ASGMI), environmental damage entails a "measurable adverse loss, change, deterioration, impairment, affectation or modification of habitats, ecosystems, natural elements and resources, their chemical, physical or biological conditions, the interactions and relationships between them, and the environmental services they provide" (Arranz-González and others, 2020a, p. 7).

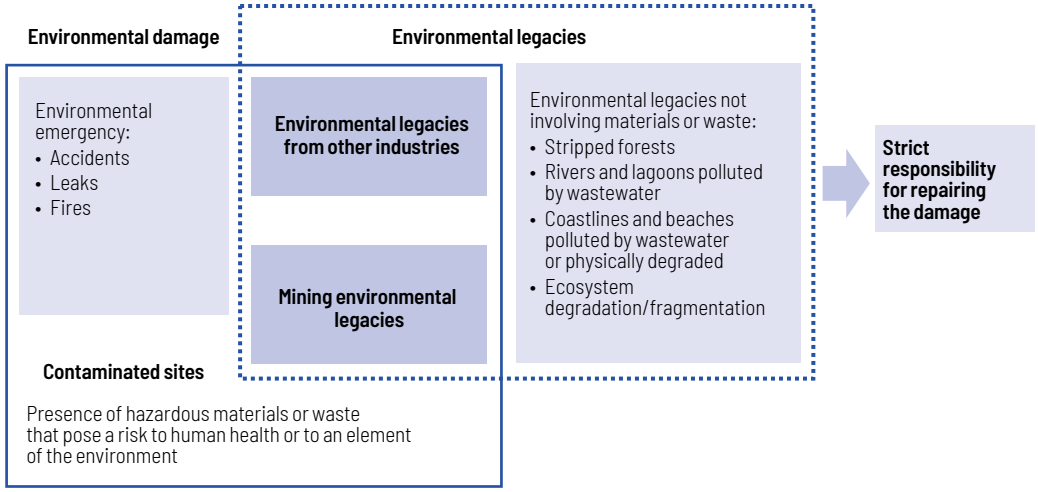
The concept also covers "any loss, reduction, detriment or significant impairment of pre-existing conditions in the environment or one of its components. It affects the functioning of the ecosystem or the renewability of its resources" (Ministry of Environment, Water and Ecological Transition of Ecuador, 2004, p. 12). In short, damage is a risk that has materialized.

Although environmental damage can in some circumstances be equated to environmental legacy (for example, when waste from industrial or mining activity seriously contaminates the environment), the two concepts should not be confused. Environmental legacy is, or should be, the step prior to environmental damage. Given that distinction, it can be said that environmental legacies entail an *ex ante* stage, since they have the potential to become environmental damage. Likewise, environmental damage entails an *ex post* stage, in which legal consequences arise for the party responsible for repairing and redressing something that has already occurred.

In particular, environmental damage —which could originate in an unremediated environmental legacy— is more closely linked to the event that generates the damage. Those events may include the collapse of a tailings dam, a spill of hazardous substances onto the ground or into watercourses, a concentrated release of pollutants into the atmosphere, the accumulation of contaminated waste at a specific site and so on. To be considered environmental damage, the event must produce a significant modification or impairment of pre-existing conditions in the environment or one of its components (Arranz-González and others, 2020a).

In view of the above, in addition to the concepts of risk and potential damage included in the definition of environmental mining legacies, some countries include the accumulation of uncompensated environmental damage produced by a company over the course of its history, both in its normal activities and as the result of accidents (see diagram I.2).

■ Diagram I.2
Relationship between the concepts of environmental damage, contaminated site and environmental legacy



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

From an economic point of view, environmental mining legacies may be related to an externality. The risk associated with environmental mining legacies may also entail social harm in terms of human health and safety, for both workers and the communities adjacent to sites contaminated by mining activity. This implies that the party responsible for the damage is not the only one who should be concerned about the remediation of the mining environmental legacy or about providing compensation: instead, the duty falls on society as a whole (Martínez-Alier and O'Connor, 1996). Therefore, state subsidiarity does not always apply when negative externalities or information asymmetries exist. On occasions, debts owed to local communities are not recognized as such by the relevant jurisdiction and, in other cases, the laws that set limits and restrictions are not respected.

C. Remediation of environmental mining legacies

Two elements must be taken into consideration during the post-closure phase: (i) how to maintain facilities in perpetuity, and (ii) how the land where the mining environmental legacy was located will be used in the future. Both of these points highlight the need to ensure the physical and chemical stability of the site over time, as well as to safeguard the life, health and safety of the population (Morales and Hantke, 2020).

The remediation of a mining environmental legacy is key to controlling its negative impact on society and the environment. The management of a mining environmental legacy should focus primarily on reducing the risks associated with its presence, establishing rules of responsibility and enabling the improvement of the living conditions of the communities affected —either directly or indirectly— by the existence of the mining environmental legacy. Failure to properly manage a legacy could result in high costs that, in many cases, would exceed those of preventive work (Oblasser, 2016; Sánchez, 2019).

The competent authorities should rank and prioritize mining environmental legacies according to their different levels of risk in order to avoid the most immediate potential repercussions for society. Thus, a risk management plan must be devised and a community resilience analysis must be conducted as a complement to the risk-based approach. The risk management plan is essential to manage the technical, economic and social conditions that will increase the communities' degree of adaptation to the possible impacts of mining environmental legacies. In turn, the community resilience analysis helps generate the conditions and knowledge necessary to implement community engagement measures, in order to bolster their capacities and execute sustainable risk management strategies (De Miguel and Pereira, 2019).

According to the National Geology and Mining Service of Chile, (BGR/SERNAGEOMIN, 2008), remediation means the "set of actions and measures needed for the control, reduction or elimination of the risk to human life or health or to the environment posed by a mining environmental legacy, to such a degree that the risk is reduced to an acceptable (non-significant) level".[3] According to the definition proposed by the Office of the Comptroller General of the State of Ecuador, the concept covers "the set of measures and actions aimed at restoring environmental affectations produced by negative environmental impacts or environmental damage as a consequence of the pursuit of economic or productive activities, works or projects" (Arranz-González and others, 2020a, p. 18).[4]

The main purpose of remediation is to ensure that a site is left in conditions that are acceptable and safe for people and the environment. This entails addressing the current and planned use of the site, maximizing its future uses while trying to minimize the negative impact of the mining environmental legacy. Given its positive potential but also its potential for conflict, preventive or corrective management of mining environmental legacies must involve all stakeholders throughout the life cycle of a mining project, including the post-closure phase (Oblasser, 2016; Sánchez, 2019).

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3 The definition is based on the concepts set out in the *Risk Assessment Manual for Abandoned or Paralysed Mine Sites FMA/P* (BGR/SERNAGEOMIN, 2008).

4 The definition is extrapolated from the *Environmental Auditing Guide* of the Office of the Comptroller General of the State of Ecuador. (For additional definitions, see diagram 6).

At the international level, remediation rules are scarce. Normally, the responsibility for remediating a legacy falls on the party that generated it: for example, a public or private company. However, there are cases in which the party responsible for creating the legacy cannot be identified, or they are not in a position to remediate the contaminated site. When legacy cannot be attributed to the polluter, responsibility should lie with the current landowner or with the State, in accordance with each country's laws (WHO, 2021b; see section II.C). Since environmental legacies are situations inherited from the past —that is, prior to the entry into force of environmental regulations deliberately formulated to prevent them from arising— States do not prioritize investing their generally limited budgetary resources in remediation actions.

According to Oblasser (2016), remediation should not only be understood as an action aimed at reducing contamination or controlling risk, but also as an opportunity. From a positive perspective, remediation involves both the reactivation of mining (secondary mining) and the identification of alternative uses. Thus, remediation becomes a source of investment for the local economy, and this is in alignment with the principles of the circular economy, as it could generate job opportunities and enable the reuse of existing infrastructure.

This guide addresses the concept of sustainable remediation, i.e. in terms of the three pillars of sustainability: economic, environmental and social. For a remediation to be considered sustainable, it must: (i) reintegrate the site with its surroundings (ideally returning it to its condition prior to the creation of the mining environmental legacy), (ii) reintegrate the economic value of the site (e.g. through productive reuse), and (iii) provide a benefit to society, such as recreational reuse for the community (EPA, 2008 and 2012).[5] The use of suitable and environmentally friendly technologies is a necessary condition. Sustainable remediation, among other benefits, involves the execution of interventions that allow: (i) society to recover the investment made by the State, (ii) risks to be managed effectively, (iii) the impact of remediation works on the environment and adjacent communities to be minimized, (iv) socioenvironmental responsibility to be fostered within companies, thereby maximizing their relationship with stakeholders, and (v) the net environmental benefit of clean-up actions to be maximized (r3 Environmental Technology, 2014; EPA, 2008).

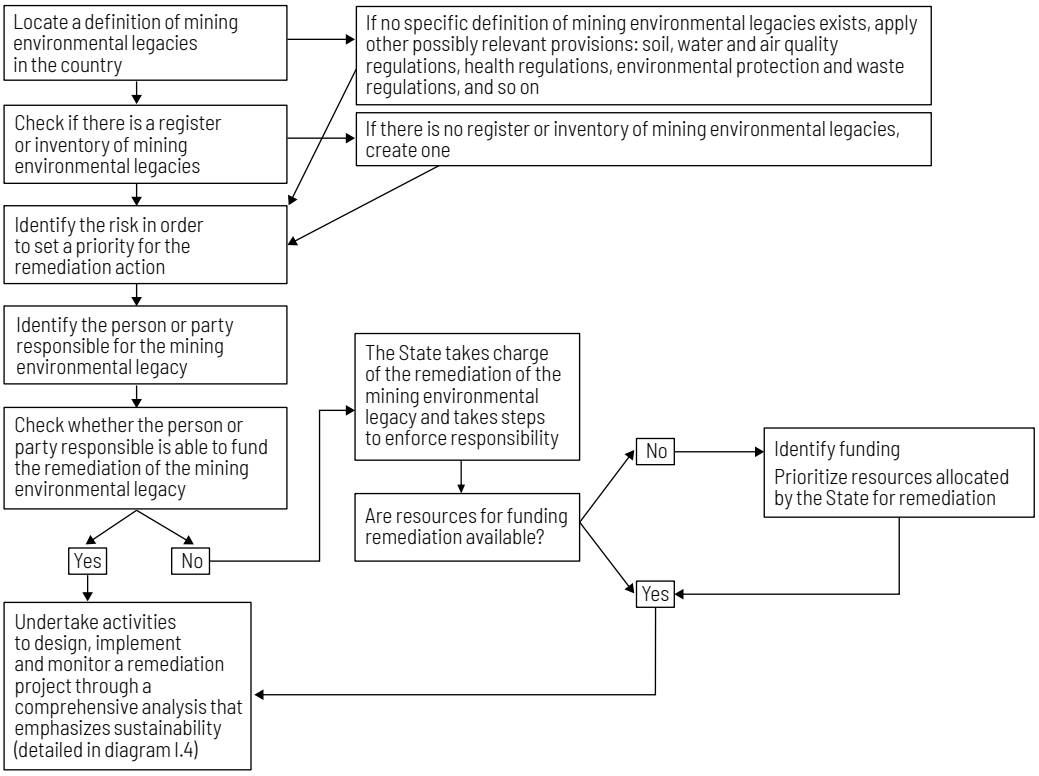
D. Road map: methodological guide for the remediation of mining environmental legacies

This section provides a graphic representation of the process to be followed by policy-makers in formulating remediation policies for mining environmental legacies. Diagrams I.3 and I.4 show a flow of actions and decisions for analysing remediation alternatives, designing and launching implementation and, finally, project monitoring.

As explained by diagram I.3, the following preliminary questions must be answered: Does the country have a definition of mining environmental legacies? Is the mining environmental legacy inventoried? Does a register exist?

[5] The concept of sustainable remediation includes what is often referred to as soil "remediation" (for more details on key concepts, see chapter II).

■ Diagram I.3
Preliminary considerations in the design and implementation of a remediation plan



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

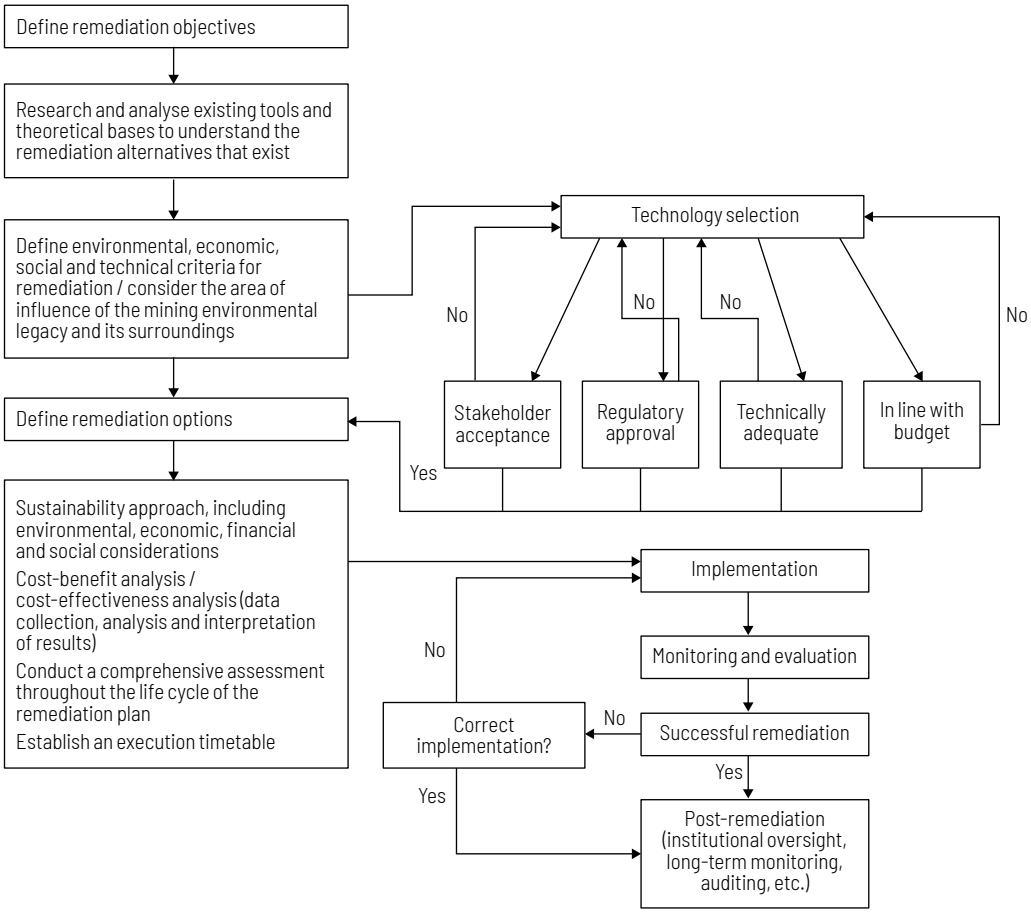
If the answer to those questions is affirmative, the decision-maker should: (i) examine the risk related to the mining environmental legacy in order to identify and prioritize the remediation actions, and (ii) determine whether the owner of the mining environmental legacy can be identified in order to involve them and hold them responsible for the remediation process. Once the person responsible for the remediation has been identified or determined, their financial solvency is investigated and, if necessary, government funding for the remediation of the mining environmental legacy is secured.

According to diagram I.4, and taking the previous considerations into account, remediation policy-makers can define the objectives of the remediation and further explore the theoretical bases and existing analysis tools that would be used to remediate the mining environmental legacy. With that information they will be able to: (i) define the remediation action's environmental, economic, social and technical criteria, and (ii) identify one or more remediation options.

At this stage of the process, the feasibility of the remediation options identified is determined. If they are feasible, the technologies to be used to remediate the mining environmental legacies are defined, identifying whether or not: (i) they are appropriate,

(ii) they enjoy the support of all the stakeholders, (iii) they are within the established remediation budget, and (iv) they comply with the country's regulations. If all these conditions are met, implementation of the remediation plan can begin. Before implementation, however, it must be ensured that it was prepared with a sustainable and participatory approach and covers the environmental, social and economic aspects necessary to guarantee the sustainability of the project. Execution must also be sequential and logical.

■ Diagram I.4
Recommendations for designing, implementing and monitoring a remediation project



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (crcCARE), Remediation Action Plan Development: Guideline on Performing Cost-benefit and Sustainability Analysis, Newcastle, 2019.

Once the project has been implemented, continued monitoring of the situation by means of a comprehensive evaluation is essential to determine whether the remediation has been successful or if there is still room for improvement. If the remediation is deemed successful, the project moves to the post-remediation phase; if it is not, the aspects that have posed problems or have prevented its correct implementation are evaluated.

Chapter II
Guidelines for sustainable environmental mining legacy remediation projects

Introduction

This chapter presents a series of guidelines for framing and standardizing the evaluation of investment projects for managing the sustainable remediation of environmental mining legacies. In particular, it details the characteristics of the main approaches to environmental mining legacy remediation, with an emphasis on the concept of risk. Likewise, the main issues associated with international legal frameworks are analysed and funding strategies are explored. It also highlights the importance of meaningful public participation of stakeholders, including local communities. Finally, it identifies some of the technologies that can be considered in a remediation project.

A. Decision-making principles for the remediation of mining's environmental legacies

According to the international standard for the management of environmental mining legacies developed by the International Organization for Standardization (ISO, 2023a), all environmental mining legacy remediation projects should be aligned with the Sustainable Development

Goals set out in the 2030 Agenda for Sustainable Development (United Nations, 2015).[1] In addition, several guidelines and principles exist for framing and guiding remediation processes to ensure sustainable management of legacies.

In general terms, decision-making regarding contaminated site remediation should abide by the following principles (IAEA, 2009; CL:AIRE, 2010 and 2020; ISO, 2023a):[2]

- Protection of human health and the environment.
- Safe work practices.
- Logical coherence.
- Consistent, clear and reproducible evidence-based decision-making.
- Transparent record-keeping and reporting.
- Good governance and stakeholder empowerment and engagement, taking into account the opinion of all stakeholders (see the section "Local community engagement" in this chapter).
- Application of science and technology.
- Analysis of all factors affecting the decision-making process.
- Balanced consideration of all possible courses of action.
- Circular economy and maximum use of waste.

In particular, project implementers and authorities involved in reviewing remediation plans and future-use projects should consider guiding principles to achieve sustainable, cost-effective and transparent results.

Table II.1 suggests the following guiding principles: the execution of standardized studies, risk identification, selection of remediation alternatives, community engagement and adaptive remediation implementation techniques. It also connects each guiding principle with its potential contribution to greater transparency in information access, broader participation, reduced remediation execution costs and time, and so on.

1 The ISO handbook on mining legacies explores issues related to the internal management of the agencies responsible for remediation. Its consultation is recommended to ensure compliance with international best practices (see ISO, 2023b).

2 Colombia, among other countries, has incorporated these principles into its remediation strategies for contaminated mining sites (r3 Environmental Technology, 2017).

■ Table II.1
Guiding principles for the management and sustainable remediation of environmental mining legacies

Guiding principles:	Contributes to:
The execution of studies to determine whether the extent of damage meets the minimum standards in force and also to secure the most complete information possible for all the exposure pathways considered.	- Improved information quality. - Increased public confidence in the process. - Improved quality of risk communication.
The identification of the current risks to human health and the environment, carried out in a transparent and traceable manner (with accessible records of calculations) covering the data, sources, methodology and assumptions used.	- Minimized likelihood of objections from the technical and scientific side during legal proceedings. - Provision of a reliable basis for placing a value on the damage (costs).
The selection of remediation alternatives, carried out by taking the following into account: - Acceptable risks for the most vulnerable potentially exposed human population groups. - Acceptable risks to environmental assets (e.g. water and soil) and to ecosystems and their components. - Efficient disruption of exposure routes and pathways. - Minimum movement of materials during the remediation process to achieve the lowest possible level of greenhouse gas (GHG) emissions. - Increased potential for the future economic and environmental sustainability of the site (and its use). Consideration should be given to balanced operation and maintenance costs. - Highest possible capture of greenhouse gases in future use.	- Increased public confidence in the process. - Improved quality of risk communication. - Minimized likelihood of objections from the technical and scientific side during legal proceedings. - Increased health and environmental benefits. - Provision of a reliable basis for identifying and, where appropriate, placing a value on benefits. - Lower carbon footprint of remediation.
The evaluation process provides the affected population the opportunity to express their concerns and expectations (see the section "Local community engagement" in this chapter). The remediation plan evaluation process should address health, economic and sustainability issues with respect to: - The carbon footprint of remediation actions, civil engineering works to be carried out and future use. - Post-remediation exposure monitoring. - The mechanisms for concluding responsibility in relation to the different stages of the remediation project: remediation actions (e.g. construction work) and post-remediation monitoring.	- Minimized likelihood of objections to the procedural aspect of the evaluation from the technical and scientific side during legal proceedings. - Increased confidence in the evaluation process and in the role of the participating authorities.

Guiding principles:	Contributes to:
In remediation execution, the following issues are prioritized: - Flexible decision-making to adapt the remediation plans to possible unforeseen circumstances, including the obligation to document the decisions adopted. - Modularization or phasing of the remediation plans to adapt them to annual budget cycles, public bidding cycles, seasonal climatic changes and operational capacity. - The completion of remediation stages or modules, which must be preserved as of the approval of the remediation plans, in order to comply with legal provisions and, at the same time, to provide the project with the necessary flexibility. - Public access to the site and information both at the beginning of remediation activities and during execution.	- Reduced remediation costs. - Prevention of accidents. - Avoidance of operational losses due to weather conditions, such as rainy seasons, when equipment and machinery are kept on standby. - Avoidance of hasty and time-pressured public bidding processes and proposal and work evaluations, as well as price overruns (for example, due to the priority execution of sample analysis). - Improved quality of communication and trust between the executing agency and the affected community.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Presidency of the Republic of Mexico, *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City, 2006; Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008; Congress of the Republic of Peru, *Ley N° 28271, Ley que regula los pasivos ambientales de la actividad minera*, Lima, 2004; "Ley Nº 28611: Ley General del Ambiente", *El Peruano*, Lima, 15 October 2005; Sustainable Remediation Forum (SURF), "Sustainable remediation white paper—integrating sustainable principles, practices, and metrics into remediation projects", *Remediation*, vol. 19, No. 3, Hoboken, Wiley, 2009; B. Limón and M. Herrejón, "Remediación y revitalización del predio de Peñoles, Compañía Minera, Fundidora y Afinadora Monterrey, S. A. y su conversión en el Paseo de Santa Lucía, 2ª etapa, en Monterrey, Nuevo León", *Remediación y revitalización de sitios contaminados: casos exitosos en México*, W. Schmidt, R. Flores and U. Ruiz (eds.), Eschborn, Deutsche Gesellschaft für Internationale Zusammenarbeit/Secretariat of the Environment and Natural Resources (GIZ/SEMARNAT), 2013; Office of Solid Waste and Emergency Response (OSWER), "Green remediation best management practices: mining sites", 2012 [online] https://clu-in.org/greenremediation/docs/GR_factsheet_miningsites.pdf; "Guía comunitaria sobre la cobertura", 2012 [online] https://clu-in.org/download/citizens/EPA-542-F-12-004S_guia_del_ciudadano_sobre_el_recubrimiento.pdf.

B. Risk management for the prioritization of environmental mining legacies

The identification, estimation and management of socioenvironmental risks support strategic decision-making for the remediation of environmental mining legacies. Decision-making also depends on the availability of financial resources and technological inputs, as well as the prevailing economic and social conditions. This section covers, among other topics, risk management schemes, intervention mechanisms, risk vectors, an analysis of the different stages in managing environmental mining legacies, remediation alternatives and intervention prioritization criteria.

1. Risk-based frameworks for managing environmental mining legacies

Risk assessment begins with a simple conservative approach (level I) that consists of, for example, comparing soil contaminant concentrations with reference values (see, for example: EPA, 2023; Congress of the Republic of Peru, 2014; CCME, 2024; Federal Ministry of the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of Germany, 2002). If the values found at the site are below the reference value, significant risk is ruled out. Otherwise, a risk is found to exist.

If a risk is present, a site-specific risk assessment (level II) is performed and the particularities of the site are examined to determine whether an unacceptable risk actually exists and, consequently, whether remediation of the site is necessary. These risk assessments require a great deal of information on site conditions, the presence of contaminants, assessment methodologies and so on (MINEM, 2015; EPA, 2022).

Generally, the risk-based management of environmental mining legacies can take one of two forms: a tiered model, and a two-stage model. Both options are explained below.

(a) Tiered or gradual management of risk estimation

This type of management is derived from models whereby the level of responsibility can be tiered according to the degree of contamination at the site:

- Level I: The obligation or responsibility to recognize and register a site where contaminants may be present, i.e. a suspected contamination site. This occurs when certain contaminants present at the site are presumed to have exceeded specific concentrations on account of the activities carried out there. The concentrations may be identified in lists of contaminants set out in laws, regulations or lower-level regulatory instruments. This stage is commonly associated with preliminary technical and risk assessments of the suspect site that may or may not include basic orientation sampling.
- Level II: The party responsible may have an additional obligation to investigate the site. If a second level of contaminant concentration is exceeded or certain risk criteria are exceeded (in this case, the risk assessment is focused on identifying all risks), third level obligations may arise. The area is identified as a contaminated site under assessment or investigation.
- Level III: The responsible party takes charge of pursuing the investigations, which include specific detailed sampling and studies and human health and environmental risk assessments (which take site-specific conditions into account). At this level, the area is classified as a contaminated site under a process of intervention.

(b) Binary management of risk estimation

In some countries, such as Costa Rica and Mexico, there are two management options:

- When reference concentrations are exceeded in an environmental matrix (soil, water or both), a remediation obligation arises. That responsibility falls on the user, licensee, owner or user of the site. The responsible party can remediate the site (the contaminated matrices) until the contaminants reach the reference concentration levels. Once remediation is achieved, the responsibility is terminated.
- When responsibility arises, instead of remediating baseline concentrations, the responsible party may choose to perform a risk assessment. The way to carry it out can be associated with the third level of the previously described model (see chapter IV).

2. Intervention based on risk estimation

Regardless of the risk management model (i.e. level III of the tiered model or exceeding baseline values under the binary model), the intervention process follows the same path:

- The specific risks for potentially vulnerable groups, ecosystems and public or third-party assets are established, taking into consideration socioeconomic, demographic and environmental conditions, as well as a specific future scenario.
- Based on the results of that assessment, an intervention is planned (see chapter IV).
- The intervention is carried out to reduce those risks, which entails a review and authorization process by the competent authorities.

3. Risk vectors

As noted in chapter I, different types of risks are associated with environmental mining legacies depending on their location, the surrounding population, the resources exposed and the threats posed. Table II.2 discusses in further detail the physical risks related to seismology, hydrogeology, dust generation and so on.

■ Table II.2
Types of physical risks associated with environmental mining legacies

Risk	Explanation
Seismic risk	The impact of this risk is directly related to the size, design and construction of the tailings dam, whether the site is abandoned or idle, and the characteristics of where the deposit is located, in addition to the magnitude of the earthquake. The risk is assessed by slope stability and liquefaction risk.[a] A seismic event can cause contamination of watercourses, negatively affect land and agricultural areas and, in more serious cases, cause death.
Hydrogeological risk	The impact of this risk is associated with the dragging of debris and waste by rainfall, river floods and avalanches, the risk of flooding, water acidification, metal solubilization, sediment dragging and groundwater contamination. Impacts can affect both water and soils.
Dust generation[b]	This phenomenon has, first, an impact on people's health, since particles can be inhaled and pass into the respiratory system, and, second, an impact on the environment, since it impedes (either partially or totally) photosynthesis within plants and reduces the fertilization capacity of flowers and the yield and quality of fruit trees and crops (Farmer, 1993). At the same time, the latter aspect can also have detrimental economic effects (such as loss of crop area and risks for agriculture and livestock), with negative repercussions for local food security.
Soil contamination	When salts and metals from tailings begin to emerge, particularly when land is revegetated, they may come into contact with plant roots and kill them. If the plants survive, the absorption of toxic metals can lead to bioaccumulation processes, which could cause intoxication and diseases in the animals that consume them (risks for livestock), and these toxic metals could even enter the trophic chain.
Water consumption	The disposal of tailings generates significant water loss (due to seepage, retained moisture or evaporation). This loss is even more serious when it occurs in hot areas with high rainfall. Abandoned or idle tailings can become environmental mining legacies, especially on account of their level of risk.
Failures in the disposal system	This covers failures of design, construction and operation; safety risks, such as direct contact with corrosive products and spills; and chemical risks, including the generation of acid drainage. The impact of these faults can lead to, first, the contamination of watersheds and coastlines and, second, implications for people's safety (for example, due to the presence of faults in tailings dam walls or open pits, shafts or slopes that can cause accidents).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008; National Geology and Mining Service of Chile (SERNAGEOMIN), *Guía Metodológica de Evaluación de Riesgos para el Cierre de Faenas Mineras*, Santiago, 2014; P. López and others, "La minería y su pasivo ambiental", *Análisis de Políticas Públicas*, No. 24, Santiago, Terram Foundation, 2003; M. Silva and G. Suazo, "Metodologías para el uso de factores de emisión: material particulado en depósitos de relaves abandonados", *Environment and Development series*, No. 170 (LC/TS.2020/92), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020; A. Farmer, "The effects of dust on vegetation – a review", *Environmental Pollution*, vol. 79, No. 1, Amsterdam, Elsevier, 1993.

[a] Liquefaction is the sudden loss of soil consistency that occurs when the pore pressure of water equals the cohesive strength.

[b] The phenomenon occurs with greater intensity in abandoned tailings deposits or during the drying process.

The risk-based management of environmental mining legacies should incorporate the evaluation of soil and water samples, risk assessment studies for human and environmental health, and the following elements (Office of the President of Mexico, 2006; MINEM, 2015):

- The mechanical stability of the mine and the waste, tailings and waste rock dumps (see box II.1).
- Waste (slag, tailings, tailings and other hazardous waste such as ash) and the leaching of potentially toxic compounds.
- Concentrations of contaminants present in soils and subsoils, groundwater and unsaturated and saturated areas (where legal limits are exceeded), and in walls, floors and building structures.
- Buildings and facilities, their structures and the mass of building materials (possible demolition waste).
- Pathways through which contaminants spread:
  - Effluents, ground and surface waters, leachates and liquid infiltrations.
  - Particulate emissions (dust) and their possible dispersion.
  - Absorption and adsorption of contaminants in plant roots.
  - Bioaccumulation processes.
  - Vapours.
  - Soil.
- Physicochemical and mechanical properties of slags and tailings.
- Edaphological, geological and geohydrological characteristics of the site.
- Condition of bodies of water and runoffs in the legacy's immediate watershed (probability that the legacy will affect part or all of a watershed).
- Concentrations or background values occurring naturally in the watershed where the site or environmental legacy is located.
- Productive activities: quality of food, crops and livestock in the area where the environmental mining legacy is located.
- The influence of the environmental mining legacy and exposure of homes and people.

■ Box II.1
Examples of physical risks in environmental mining legacies: stability of mines and tailings deposits

The danger associated with the physical stability of a tailings dam is closely related to the possible occurrence of a liquefaction event. Escaping tailings can travel great distances at high speeds, sweeping away everything in their path. The behaviour of tailings in their containment structure, be it a tailings dam or a reservoir, differs according to where they are located.

Thus, tailings in dry areas are relatively stable and remain so after closure. Over time, the tailings deposits dry out and a compacted powder with characteristics of a solid block forms from the original slurry.

Tailings stored in rainy and humid areas pose a grave danger to nearby populations and ecosystems due to the constant humidity from rain, which generates instability (liquefaction) in the tailings and the deposit's structure. These storage sites maintain internal humidity even when the mining site is closed or idle. The worst mine tailings deposit disasters have occurred during heavy rainfall events or strong seismic activity and have claimed the lives of large numbers of people (National Congress of Chile, 2012).

The most likely scenarios related to the final disposal of mine tailings that endanger people, the environment or economic activities include (BGR/SERNAGEOMIN, 2008):

- Violent release of tailings from containment dams, which could affect people, the environment or economic activities. In countries prone to earthquakes, such as Chile and Ecuador, infrastructure oversight is of particular importance.
- Violent release of tailings stored in reservoirs.
- Slope failure in tailings deposited in cake or other stockpile systems, which can produce material displacement and cover surrounding land. Failure may be caused by seismic activity or water erosion.

According to Rico and others (2008), the most frequent causes of tailings failures, in order of importance, are unusually heavy rainfall, seismic liquefaction, tailings management failures, structural failure, overfill spillage, slope instability, foundation failures, seepage and cavity formation, and subsidence.

Source: National Congress of Chile, "Proyecto de ley de la remediación de pasivos ambientales mineros", Santiago, 2012; M. Rico and others, "Reported tailings dam failures: a review of the European incidents in the worldwide context", *Journal of Hazardous Materials*, vol. 152, No. 2, Amsterdam, Elsevier, 2008; Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008; J. Arranz-González and others, *Glosario técnico en materia de gestión de pasivos ambientales mineros*, Madrid, Association of Iberoamerican Geological and Mining Surveys (ASGMI), 2020.
Note: According to Arranz-González and others (2020a), the term *relavera* refers to tailings deposits.

4. Main stages in the risk-based management of environmental mining legacies

There are nine main stages in managing environmental mining legacies, from the identification to the closure and post-closure phases (see diagram II.1 and ISO, 2023a: sections 7 and 8).[3]

[3] For detailed mine closure overviews and methodologies, see Morales and Hantke (2020).

■ Diagram II.1
Stages in the management of environmental mining legacies

Source: Economic Commission for Latin America and the Caribbean (ECLAC), United Nations Educational, Scientific and Cultural Organization (UNESCO), "Agua y minería en cuencas áridas y semiáridas: guía para la gestión integral", *Documento Técnico del PHI-LAC*, No. 17, Montevideo, 2009; Presidency of the Republic of Mexico, *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City, 2006; Congress of the Republic of Peru, "Aprueban criterios para la gestión de sitios contaminados: decreto supremo N° 012-2017-MINAM", *El Peruano*, Lima, 2 December 2017.

(i) **Identification of the environmental mining legacy.** The site's identification is derived from a regulatory instrument such as (i) an environmental impact assessment, (ii) the sale or transfer of a site, or (iii) a complaint or social conflict that ends with the involvement of the competent authorities (environmental or health officials).

At this stage of the process, it should be noted that according to the Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (Escazú Agreement), "each Party shall have in place one or more up-to-date environmental information systems, which may include, inter alia: (...) a list of polluted areas, by type of pollutant and location" (ECLAC, 2022a and 2022b).[4]

(ii) **Registration, inventory, classification and prioritization of information.** These tasks are usually under the responsibility of the competent authorities. For registration and inventorization, the authority includes the site in a list and, in accordance with the inventory processes, is responsible for modifications to its status. These activities may be subject to auditing mechanisms, as they are governmental responsibilities and must ensure compliance with general obligations to guarantee citizens' rights (e.g. a healthy environment free of pollutants; see Constituent Assembly of Ecuador, 2008; Office of the President of Mexico, 2024; Arranz-González and others, 2020a).

[4] In December 2024, the Escazú Agreement had been ratified by 17 countries: Antigua and Barbuda, Argentina, Belize, Chile, Colombia, Dominica, Ecuador, Grenada, Guyana, Mexico, Nicaragua, Panama, Plurinational State of Bolivia, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines and Uruguay. For more information, see [online] https://www.cepal.org/en/escazuagreement.

Registration and inventorization can be accompanied by ranking and prioritization according to preliminary risk schemes. At the same time, the data included should allow the risks of the registered sites to be assessed in order to prioritize those in need of remediation (see specific requirements in ISO, 2023a).

Once the list of environmental mining legacies has been defined and prioritized, the information must be made public in accordance with article 6.3 of the Escazú Agreement (ECLAC, 2022a and 2022b). Making the register transparent and publishing its data on an online platform can also facilitate the raising of funds for remediation projects (e.g. companies can identify sites with the potential to be reactivated; see the section "Financing strategies for the remediation of environmental mining legacies" in this chapter). The involvement of an independent organization —such as a university or research centre— in inventory management can provide stakeholders or the general public with access to relevant, up-to-date and systematized data (ISO, 2023a).

(iii) Identification of the responsible party (from a legal and management point of view). The responsible party may be a private or public company or, in the case of orphaned environmental legacies, it may be the State (see the section "Legal issues for the management of environmental mining legacies" in this chapter).

(iv) **Deployment of remediation tools and provisions.** The competent authority requires the responsible party to undertake their deployment for those actions already established in environmental instruments, such as environmental impact assessment resolutions (for example, mine closure plans as derivative instruments).

(v) **Investigations to identify and determine the extent of damage and risks.** The authority conducts an assessment before defining the scope of the intervention in view of its implications for the remediation's sustainability (see chapter V). These investigations include:

- Determining the extent of contamination.
- Determining the site conditions.
- Determining the area of influence of the environmental mining legacy.
- Assessing the risks for human health and the environment.

(vi) **Report by the authorities.** The authority evaluates the above elements before defining the scope of the intervention.

(vii) **Decision-making/reclassification of the environmental mining legacy.** The outcome of the investigations and of the intervention's economic consequences is reviewed. If there is a responsible party, it covers the costs of investigations and remediation, and the decision-making process is focused on overseeing the intervention carried out by the private party. For orphaned environmental legacies, the State assumes responsibility and decision-making focuses on two issues:

- The current risks (the unaddressed situation) and, depending on the acceptable risk, the intervention that would benefit society (the remediated situation).
- Obtaining sufficient resources to carry out the remediation or intervention in the public interest (which requires a cost-benefit analysis).

(viii) **Intervention and monitoring.** This relates to risk control or the execution of the remediation project.

(ix) **Conclusion and termination of responsibility.** The measures adopted in the previous stages are implemented and the case is closed (see box II.2).

■ Box II.2

Difference between closure of a mine and closure of a environmental mining legacy remediation

The cessation of responsibility is linked to the closure and post-closure of a mine after it has gone through the environmental assessment process, in accordance with the regulations in force in each country. At the same time, when a environmental mining legacy was created before the environmental legislation came into force or when those laws have not been complied with, responsibility for remediation must be assigned. Once the environmental mining legacy has been remediated, either by a private entity or by the State, the remediation and post-remediation closure stages begin.

Mine closure: The actions taken at the end of mining operations, based on the environmental instruments that made them possible.

Closure of the remediation and monitoring of a environmental mining legacy: The post-remediation stage, which is defined by those activities that denote the end of the responsibility. Civil works related to the remediation of a environmental mining legacy must have a work plan to guide monitoring and maintenance and, if liquid emissions still exist, the continuous management of those effluents even after the remediation is completed. The work plan will be carried out by the responsible party and must be included in the legal instrument that allows the environmental authorities to conclude the remediation of the environmental mining legacy. The operation, maintenance and monitoring plan may have a specific time frame (five or ten years, depending on the situation of the environmental mining legacy); therefore, the final release from responsibility will depend on how the environmental mining legacy evolves during the post-closure phase.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of National Congress of Chile, *Ley núm. 20.551. Regula el Cierre de Faenas e Instalaciones Mineras*, Santiago, 2011; G. Doroni, "Responsabilidad por pasivos ambientales mineros y cierre de minas: breve análisis de los marcos normativos de Bolivia, Chile y Perú", *Anuario del Centro de Investigaciones Jurídicas y Sociales*, No. 12, Cordoba, National University of Cordoba, 2015.

To save time and resources, it is recommended that the technical studies and risk assessment (which allows exploring different remediation scenarios) be offered for tender and executed together with the cost and unit price analyses. Both are fundamental to the cost-benefit analysis. In addition, they should be accompanied by an analysis of demand (see chapter V) and a quantification (in monetary terms) of the benefits (see chapter VI).

5. Sustainable remediation, rehabilitation and (re)activation in Latin America and the Caribbean

Interventions in environmental mining legacies, generally when contaminants are present, encompass various definitions depending on their scope. This ranges from risk control and the process of site rehabilitation for new productive activities to forms of remediation that seek to maximize the social, environmental and economic dynamics achieved through sustainable remediation (see diagram II.2).

■ Diagram II.2
Glossary of basic remediation terms

Remediation

- A set of actions and measures suitable for the control, reduction or elimination of the risk to human life and health or to the environment from a environmental mining legacy, until the risk is reduced to an acceptable (non-significant) level (Arranz-González and others, 2020a).
- A set of measures and actions aimed at restoring environmental affectations produced by negative environmental impacts or environmental damage as a consequence of the pursuit of activities, works or economic or productive projects (Arranz-González and others, 2020a).
- Measures taken to eliminate or reduce contaminants to a safe level for health and the environment and to prevent their dispersion (see Ministry of Health of Costa Rica/Ministry of Environment and Energy of Costa Rica, 2018 [for Costa Rica]; Office of the President of Mexico, 2006 [for Mexico]).
- In Peru, the term also "includes actions to achieve the subsequent use of the site or its reestablishment to a state similar to that which existed before the negative environmental impacts occurred" (Congress of the Republic of Peru, 2017).
- In some of the region's countries, the terms "decontamination" or "rehabilitation" are also used to refer to remediation (see the terms below).

Decontamination

- Elimination of contaminants or their reduction to acceptable levels.
- Generally, it involves "habilitating" site conditions for a particular use.

Rehabilitation

- In addition to eliminating the contaminants, all or part of the land's functions are restored.
- A set of actions to restore to degraded land the possibility of supporting one or more land uses, while becoming ecologically stable, so that it does not contribute substantially to environmental deterioration and is integrated into the surrounding landscape (Arranz-González and others, 2020a).

Revitalization (reuse)

- Restoration of land quality and functional urban structures (buildings and services) that allow a productive use (in a broad sense) in a place that was previously degraded and without productive use.
- The aim is to incorporate revitalized sites into their surroundings so they function in an integrated way with their adjacent areas, in order to improve living and working conditions (Lindell, 2009; (see chapters V and VI).

Renovation

- Repairs to buildings in order to restore their functionality and value (Lindell, 2009).

Sustainable remediation

- Elimination of contaminants or their reduction to a safe level for health and the environment, or the prevention of their unmodified dispersion in the environment. At the same time, the benefits obtained in a remediation process, in terms of the three pillars of sustainability (economic, environmental and social), outweigh any other type of remediation (see the section "Incorporation of the sustainability concept" in chapter IV).

Green remediation considers all the environmental effects of implementing remediation and includes options to maximize the net environmental benefit of cleanup actions (EPA, 2008; r3 Environmental Technology, 2014).

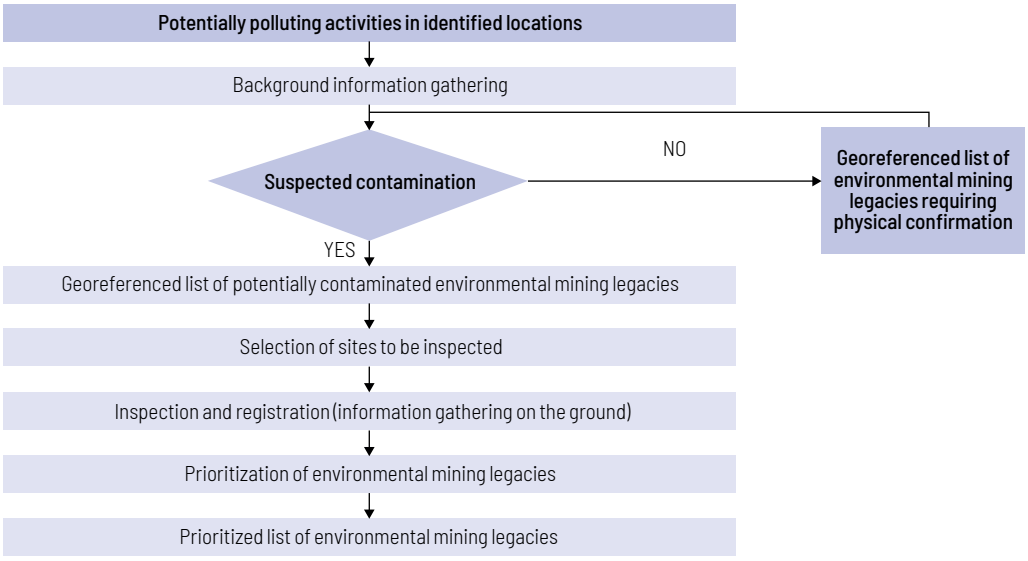
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of J. Arranz-González and others, *Glosario técnico en materia de gestión de pasivos ambientales mineros*, Madrid, Association of Iberoamerican Geological and Mining Surveys (ASGMI), 2020; Congress of the Republic of Peru, "Aprueban criterios para la gestión de sitios contaminados: decreto supremo N° 012-2017-MINAM", *El Peruano*, Lima, 2 December 2017; United States Environmental Protection Agency (EPA), *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*, Cincinnati, 2008; r3 Environmental Technology, "Remediación sostenible", Bogota, 2014 [online] http://www.r3environmental.com.co/es/servicios/remedacion-sostenible.html; A. Lindell, *Revitalización urbana de sitios contaminados a través de ejemplos en México*, Mexico City, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2009; Ministry of Health of Costa Rica/Ministry of Environment and Energy of Costa Rica, *Reglamento General para la Clasificación y Manejo de Residuos Peligrosos*, San Jose, 2018; Presidency of the Republic of Mexico, *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City, 2006.

6. Risk-based record construction

Site prioritization is carried out by constructing registers of environmental mining legacies in several countries in the region, such as Chile, Brazil, Chile, Colombia and Peru (SERNAGEOMIN, 2019), the State of São Paulo in Brazil (CETESB, 2023), the Plurinational State of Bolivia (Terán, 2017), and Mexico and Peru (MINEM, 2023). In general, risk-focused criteria are used (in this case, potential or preliminary risk; see the section "Risk-based environmental mining legacy management frameworks").

Although the process of identifying, registering and prioritizing contaminated sites is subject to each country's specific regulations, it generally follows the same steps (see diagram II.3).

■ Diagram II.3
Flow chart of the steps to be followed in identifying, registering and prioritizing environmental mining legacies



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Ministry of Energy and Mining of Peru (MINEM), *Remediación de pasivos ambientales mineros en el Perú*, Lima, 2015; J. Arranz-González and others, *Glosario técnico en materia de gestión de pasivos ambientales mineros*, Madrid, Association of Iberoamerican Geological and Mining Surveys (ASGMI), 2020; Presidency of the Republic of Mexico, *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City, 2006; G. Petek, *Improving California's Response to the Environmental and Safety Hazards Caused by Abandoned Mines*, Sacramento, Legislative Analyst's Office (LAO), 2020; Secretariat of the Environment and Natural Resources (SEMARNAT), "Procedimiento de identificación y caracterización de sitios contaminados", Mexico City, 2017 [online] https://www.gob.mx/cms/uploads/attachment/file/249157/4._Procedimiento_de_caracterizacio_n_de_sitios_contaminados.pdf.

Note: Physical confirmation requires that the professionals are aware of the physicochemical conditions and characteristics of the environment where the risk source is located. Field visits include the on-site observation of indicators and preliminary description of field samples.

7. Prioritization criteria

Based on the information gathered in the field, a preliminary risk assessment is conducted (see chapter IV), in which a score is assigned according to the probability, informed by professional judgment, of a situation occurring or being present (see SERNAGEOMIN, 2007; SEMARNAT, 2008; Arancibia, 2017; MINEM, 2023).

The main risk criteria for environmental mining legacies (MINEM, 2015) include:

- Risk to human safety.
- Risk to human health and the physical environment.
- Risk to wildlife and conservation.

Because of its physical and geochemical characteristics, a environmental mining legacy can become a source of contamination affecting different aspects of the environment (water, quality of water resources, soils and sediments, air, landscapes, flora, fauna and socioeconomic features). The evaluation criteria are related to the characteristics of the legacy and its area of influence, and so other criteria may also be considered (Arancibia, 2017):

- Biotic vulnerability.
- Vulnerability for the zoning component.
- Socioeconomic vulnerability.

In accordance withthe information obtained, evaluation matrices are constructed for each aspect of the environmental mining legacy. The matrices examine the data and the risk assessment for each reporting element and criterion, which ultimately produces to an overall risk assessment of the environmental mining legacy. This preliminary overall risk assessment allows the authorities to prioritize remediation projects, which is especially important when resources are subject to constraints. It also increases the transparency of information on legacies' locations and risks and encourages the participation of affected communities.

C. Legal issues for the management of environmental mining legacies

The structures adopted for the risk-based management of environmental mining legacies depend on the legal framework and the resultant institutional design. In Latin America and the Caribbean, there are two main environmental management designs:[5]

[5] The term "management" refers to the administrative formalities and procedures through which the various environmental instruments are authorized, such as the approval of official studies and plans for the remediation of mining environmental liabilities.

(i) **Sectoral:** As in Colombia and Peru, the national or federal environmental authority formulates policies and standards, while the national or federal ministry for each sector is responsible for the environmental management of mining legacies (e.g. procedures related to the evaluation of technical studies) only in the industrial and commercial areas under their responsibility.

(ii) **Centralized:** Legacy management is centralized, at either the federal (Mexico) or state (Brazil) level, in an environmental agency that deals with environmental management in all industrial and commercial areas or sectors where environmental legacies are present.

Determining who should assume environmental legacy remediation obligations is a key issue and a sensitive one. The most common traditional practice is related to the system of responsibility by reason of fault or negligence, i.e. subjective responsibility. In addition, the options of strict responsibility, risk-based responsibility and objective responsibility also exist. In this case, proving the wilful misconduct of the party that created the environmental legacy is not necessary, but only that party's ownership of the activity that caused the risk and, consequently, the damage produced (see box II.3).

Special regulations include other alternatives that require the owners of risk-generating properties to take the steps necessary to avoid that risk. Internationally, the risk-based option is preferred for assigning responsibilities in the remediation of environmental legacies.

■ Box II.3
Extracontractual civil responsibility systems

Under **subjective responsibility**, also known as responsibility by reason of fault or negligence, the person who causes the damage is considered liable, provided that they acted with fault or wilful misconduct.

Based on the moral conceptualization of fault according to medieval doctrine and jurisprudence, the obligation of reparation is justified by the reproachable actions of the person who caused the damage. In the nineteenth century, however, the first European civil codes, influenced by liberal and economic philosophy, established what would become a general principle: "there should be no legacy without fault". Thus, the French Civil Code of 1804 established the principle of fault for imputing responsibility, and that principle that was followed by other civil codes enacted during the nineteenth century: by the Italian Code in 1865, the Spanish Code in 1889 and, in Latin America, by the Peruvian Code in 1852, the Chilean Code in 1855 and the Argentine Code in 1869.

At the end of that same century, French jurisprudence on extracontractual responsibility took a notable turn by introducing a variant of subjective or fault-based legacy. This new perspective focused on responsibility based on the risk of the use of dangerous devices, which established, under that criterion, the obligation of indemnification based on the objective fact of the damage caused. Along the same lines, the German Civil Code attenuated the fault criterion, emphasized the notion of damage and adopted a set of general provisions for compensation, which led to the development of the objective criterion of responsibility based on the damage from a causal nexus.

Strict responsibility, also known responsibility by reason of risk, establishes the obligation of repairing all damage that arises in the exercise of an activity, regardless of the diligence applied: in other words, regardless of the care taken by the person who carried out the activity, because responsibility for it is based on the exercise of that activity.

This type of responsibility differs technically from subjective responsibility in that it does not require negligence on the part of the person who caused the damage. In addition, this new approach to responsibility is shaped by the causal relationship between the act committed by the one party and the damage suffered by the other, and its basis is the risk created by a person pursuing a certain activity, not the omission of the duties of care. Therefore, attributing responsibility does not require a value judgment with respect to the conduct of the person who caused the harm; it is sufficient for the damage to occur as a consequence of an activity whose risk is regulated by law, subject to a statute of responsibility without negligence.

The basic idea behind this variant of civil responsibility is that any activity that generates a risk for a third party makes its author liable for the damage that they activity may cause, without the need to establish fault as the origin of the damage. As an expression of an elementary principle of justice, it is expected that after a person obtains a benefit for themself, they should also repair the damage they cause.

It is well known that unlike fault-based responsibility, which can be formulated as a general principle, strict or objective responsibility is restricted to those cases expressly authorized by law, which invariable cover situations of abnormality or of exposure to great risks or dangers.

Strict responsibility does not apply absolutely and definitively to the strict objectification of responsibility of any right, but is limited to certain aspects of damage. One of those aspects is related to industrial manufacturing activity, as is the case with workplace accidents, which must be governed by objective rules, and to damage caused to third parties during the operation of the company's productive apparatus (explosions, electric shocks and so on). Likewise, within the company, productive activities themselves are a source of strict responsibility in the event of damage caused by product defects. Another aspect of damage in which this type of responsibility applies is activities related to particularly dangerous —or typically dangerous— elements, such as firearms or automobiles.

In any case, civil law experts agree that although strict responsibility has assumed a broader field of application, particularly thanks to the emergence of jurisprudence relating to the fact of things, the general regime for responsibility is still based on negligence. Even decades after the beginning of a revolution that was considered inevitable, negligence-based responsibility is still the general and supplementary legacy regime in a wide range of legal systems.

Source: E. Barros, *Tratado de responsabilidad extracontractual*, Santiago, Editorial Jurídica de Chile, 2010; H. Corral, *Lecciones de responsabilidad civil extracontractual*, Santiago, Editorial Jurídica de Chile, 2011; A. Cabanillas, *La reparación de los daños al medio ambiente*, Pamplona, Editorial Aranzadi, 1996; P. Le Tourneau, *La responsabilidad civil*, Bogotá, Legis Editores, 2004; F. Vidal, *"La responsabilidad civil"*, *Derecho PUCP*, No. 54, Lima, Pontifical Catholic University of Peru (PUCP), 2001.

To avoid triggering that responsibility, the party responsible for an environmental legacy can make use of the alternatives offered by the procedural legal framework. In legal frameworks where strict responsibility prevails, responsibility for remediation arises from contamination, and the competent authority is responsible for overseeing sectors with a high likelihood of contamination to ensure compliance with environmental regulations. Companies carry out this process implicitly with the authority, in accordance with the provisions of environmental instruments.

With the development of national legal frameworks, environmental responsibility regulations and schemes that complement the civil rules on damage to third parties (non-contractual or extra-contractual damage) can be found in the countries of Latin America and the Caribbean. In environmental matters, the doctrine of strict responsibility (or risk-based responsibility) is usually applied, according to which the damage must be assumed by those who benefited from the activity that caused the damage.[6] La gestión de ciertos componentes de la faena minera, como los residuos o las instalacionThe management of certain components of mine sites, such as tailings or facilities (buildings), which in some cases are also contaminated, can be complemented by other environmental regulations (for example, regulations governing hazardous or industrial waste). This is irrespective of whether such elements meet the definitions and, if they exist, give rise to an obligation (strict responsibility) of redress.

In practice, the ability of States to seek redress for environmental damage is limited by several factors:

- **Determination of (mining) environmental legacies:** Environmental legislation covering environmental damage is relatively recent and, in some countries, the regulatory frameworks are incomplete; as a result, it is difficult to understand what is meant by environmental mining legacies in specific situations.
- **Allocation of responsibility:** Almost everywhere in the region, the burden of proving environmental damage falls either on the affected parties or on the State. However, information asymmetries create situations in which it is relatively easier for defendants to prove the harmlessness of their activities than for plaintiffs to prove a causal link between those activities and the environmental damage. In ordinary proceedings the general rule applies, which entails imposing on the party alleging a fact or act the burden of proving it. When the burden of proof is reversed, the task of proving the existence or non-existence of environmental damage shifts from the plaintiff to the defendant. Similarly, when the dynamic burden is used, the onus is on the party that is best positioned to prove or disprove it, taking into account its situation, knowledge or special capabilities in the case in question. In Ecuador, for example, the burden of proof has been reversed and it is the parties responsible for the activities that cause environmental damage who must prove that their activity has not caused the damage (see article 397 of the Constitution of the Republic of Ecuador; Constituent Assembly of Ecuador, 2008). As time passes after site closure, it becomes increasingly unlikely that polluters will be held legally responsible for the contamination and the associated remediation costs (WHO, 2021b). In some cases, it may not even be clear who was responsible for creating the environmental mining legacy (see the point below).

6 In the provision of public services, a number of lawsuits have determined the existence of strict responsibility of States for damages derived from its activities (for example, electrical service failures; Crespo, 2008; National Assembly of the Republic of Ecuador, 2017).

- **Responsibility for orphaned sites:** If a private company created the environmental mining legacy before the relevant laws came into force, if that company no longer legally exists or if the site has become the property of third parties, the State may, in some cases, settle or litigate with the companies that caused the legacy. If the procedural instances required to determine that a site is indeed abandoned or orphaned are exhausted and not even joint or several responsibility can be established,[7] the State has to assume responsibility as matter of public interest. A "good Samaritan" law that limits voluntarily assumed responsibility may encourage third parties to undertake site remediation (ISO, 2023a).
- **Illegal mining:** The prevention of illegal mining activities, with all the environmental and social consequences they entail, has not yet been fully addressed. The State must also assume responsibility for abandoned sites.

D. Funding strategies for the remediation of environmental mining legacies

Few financial mechanisms are available for remediation programmes (De Las Casas, 2019; see table II.3). The different points of view on the issue and the lack of conceptual frameworks prevent the problem from being defined and measured and, consequently, the resources needed to carry out remediation activities cannot be quantified. In some of the region's countries, factors such as insecurity, institutional inefficiency, limited fiscal space and unwillingness to commit financial resources also discourage foreign donors and investors. There is still not enough international funding available to cover the closure and post-closure phases (OHCHR, 2022), and more international interest needs to be generated (World Bank, 2005).

The region's governments traditionally provide most of the funding for the remediation of environmental mining legacies. The scarcity of investment incentives for the private sector means that remediation costs fall on public budgets as the only alternative for site remediation (WHO, 2021b).[8]

In that context, the financial concept of implicit contingent legacies arises, referring to government disbursements that are not officially recognized until the existing risk materializes. For the reasons set out above, if remediation is not undertaken, an uncertainty component is added to the amount that the government will have to pay for the damage caused by the environmental mining legacy. This could result in financial support that far exceeds the government's legal obligation (see Polackova, 2000).

7 In accordance with the provisions of joint and several liability, an entity that shares responsibility for the existence of a mining environmental liability will assume full responsibility in the absence of the other co-responsible entities.

8 It is even more difficult to raise funds to remediate contaminated areas located in areas of low economic value.

Private sector participation offers several advantages: (i) reduced costs, (ii) fostering innovation, and (iii) increased effectiveness. At the same time, it entails risks of incomplete or unfulfilled contracts. Nevertheless, increasing numbers of mining companies in the region are making environmental commitments that cover the closure and post-closure phases (Working Group "Access to Mining Certification Information", 2022; Dufey and Zamorano, 2023). The development of national remediation strategies depends primarily on the regulatory frameworks that exist (see diagram II.4). States need to promote transparency and provide the relevant data. Projects backed by sound data and projections, and supported by cost-benefit analyses and by financing mechanisms chosen in accordance with the nature of the project, are more likely to attract private capital. In addition, they can encourage in-kind contributions from investors (such as labour, equipment and transport services) and convince international donors.

■ Table II.3
Selection of possible sources of contributions for the remediation of environmental mining legacies

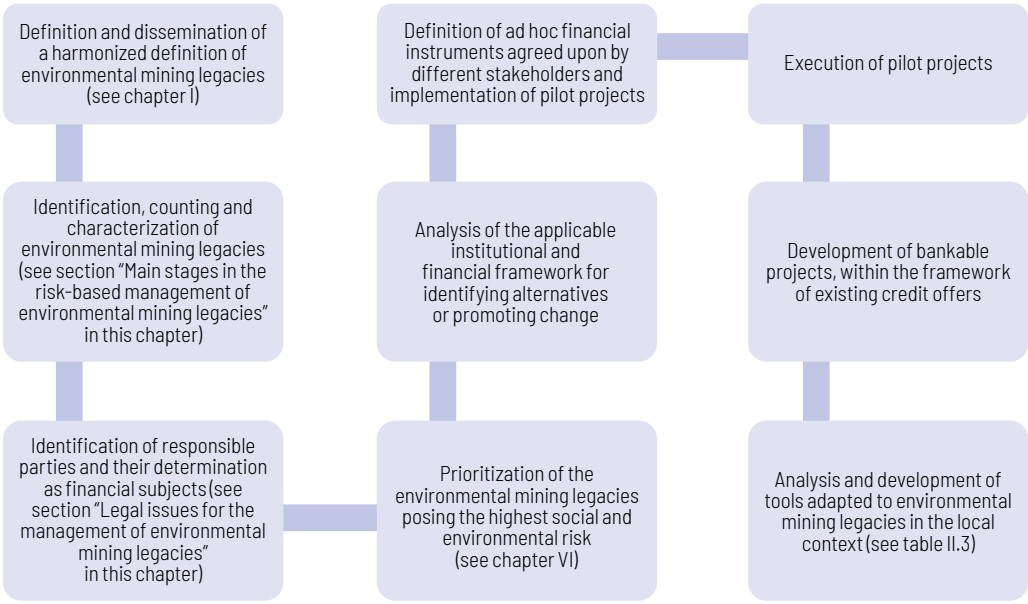
Form of financing	Instrument	Comment
Public	General budget	The central administration funds remediation works when the regional or local authorities do not have sufficient resources. The resources allocated to remediation depend on current political priorities and prevailing macroeconomic conditions. The costs of remediation are passed on to society as a whole.
	Funds allocated to the remediation of environmental mining legacies	Resource allocations based on multi-year frameworks provide more short-term security against political and economic circumstances. Funds can be managed at the federal level (e.g. the United States Comprehensive Environmental Response, Compensation, and Legacy Act or the Federal Contaminated Sites Action Plan (FCSAP) in Canada) or at the state or provincial level (e.g. the Mining Rehabilitation Fund (MRF) in Western Australia). Levies imposed on industry (as in Western Australia) take the form of mining royalties, taxes on future sales and fines collected by regulatory bodies, and they provide an alternative or complementary revenue stream to public funds.
Mixed or private	International funding	National governments can apply for reimbursable and non-reimbursable loans and technical cooperation from international institutions and foreign development agencies (for example, the Nordic Development Fund). The objectives and designs of the programmes run by external agents determine the availability of resources. Funding lines can be sought for remediation projects (for example, the Inter-American Development Bank loan to Argentina in 2015, or the World Bank loan to Zambia in 2017) and for the training of authorities (for example, the World Bank loan to Peru in 2010 or the contribution made by the Government of the Republic of Korea to Peru for the years 2021–2025). International financing remains scarce and tends to be oriented toward low-income countries. Establishing a link between environmental mining legacies and climate change adaptation and mitigation would free up more resources (for example, the Green Climate Fund or the Adaptation Fund).
	Investment funds	Fund earnings can cover remediation expenses. However, good long-term fund management is required. Financial risk must be taken into consideration.

Form of financing	Instrument	Comment
	Financial markets	Sovereign green bonds can be channelled as soft loans, grants and financing for remediation projects (World Bank, 2015). Recognized owners and outside investors can also issue them directly for those purposes, but they may be constrained by their creditworthiness.
Mixed or private	Own capital	Private capital can fund initiatives that offer business opportunities (e.g. adding value to real estate), remediation plans that open up areas for secondary mining (for example, copper leaching at Lo Aguirre; Bongaerts, Casals and Domsch, 2018), sports and cultural activities and so on. These projects can be considered bankable and can be developed in conjunction with potential investors (see the section "Stakeholder identification" later in this chapter). Guarantees for closure and post-closure (such as those applied in Chile, Ecuador or even through guarantee pools that bring together companies of different sizes, State-underwritten or not, in Peru) share project implementation risks (for example, in the Plurinational State of Bolivia and the United States). In addition, accounting provisions may arouse investor interest (for example, the Brownfields Expensing Tax Incentive in the United States). Environmental mining legacies that are particularly complex or located in certain geographic areas are not of interest to private investors.
	Voluntary contributions	Companies can provide not only financial resources, but also services, labour, equipment, lodging, and transport by air and sea (such as the Restor-Action Nunavik Fund in Canada, created to assist the restoration of abandoned mining exploration sites).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of *Minería Chilena*, "PAM: ideando mecanismos de financiamiento", Santiago, 2013; C. De Miguel and M. Pereira, "Pasivos ambientales mineros: retos para la sostenibilidad", *La bonanza de los recursos naturales para el desarrollo: dilemas de gobernanza*, ECLAC Books, No. 157 (LC/PUB.2019/13-P), R. Sánchez (ed.), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2019; Government of Peru, "Corea apoyará a Perú en proyecto de remediación de pasivos ambientales mineros", Lima, 2 July 2021 [online] https://www.gob.pe/institucion/apci/noticias/503960-corea-apoyara-a-peru-en-proyecto-de-remediacion-de-pasivos-ambientales-mineros; J. Clerc, "Mecanismos de financiamiento para la remediación de PAMs", Santiago, E2BIZ/Economic Commission for Latin America and the Caribbean (ECLAC), 2022 [online] https://www.cepal.org/sites/default/files/news/files/jacques_clerc.pdf; International Organization for Standardization (ISO), *Mine closure and reclamation – Managing mining legacies — Part 1: requirements and recommendations*, Geneva, 2023.

It is imperative for countries to avoid creating new environmental mining legacies and, to achieve this, specific laws and regulations governing the closure of mining sites must be enacted. In line with international best practices, operating companies can be held responsible for the closure and post-closure phases by granting them the environmental licence or authorization before production begins on the condition that they have an approved closure plan. Companies can deposit surety in a trust fund (established by the State or by the mining sector itself) to keep remediation funds separate from the rest of their financial resources. They can also provide the State with a bond, which will then cover the necessary expenditure. Cost estimates should be updated periodically to ensure they remain realistic.

■ Diagram II.4
Stages in the development of a financing strategy



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

E. Stakeholder engagement

Stakeholder identification and analysis is extremely important because stakeholders will greatly influence the objectives included in the remediation project. Benefits of community participation include, from the viewpoint of remediation project management, improved access to local and historical information, which can lead to a more accurate characterization of pathways for exposure caused by human behaviour. Stakeholders also provide valuable data on the populations and interest groups that will be directly affected by the project.

In addition, acceptance of the remediation project and participation in it indicates consideration of community members' needs and concerns, thereby creating opportunities for increased community involvement in the future use of the site and minimizing potential conflicts, saving time and financial resources (Velásquez, 2012; Chappuis, 2020; see the section "Local community engagement", below). Finally, in determining the impact that remediation project alternatives could have on the community, account should be taken of the fact that some population sectors may face different exposure burdens, as well as different environmental health effects caused by the actual or potential release of hazardous substances (EPA, 2020; see chapter VI).

1. Stakeholder identification

In the context of environmental mining legacy remediation projects, stakeholders are the distinguishable economic agents who are in some way related to those projects: either through the problems created by the environmental mining legacies originated by the project or through the project alternatives that are designed for remediation. In other words, stakeholders include all those actors who affect or are affected by environmental mining legacies or their remediation alternatives, and who can influence the success or failure of the associated activities (see table II.4 and Bourne, 2016).

■ Table II.4
Principal stakeholders in environmental mining legacy remediation projects

Stakeholder group	Relationship or importance of inclusion
State (government)	Defines and promotes its national economic and ecological interests. Sets objectives for site remediation and groundwater protection, and adopts measures to ensure order and reduce the impact on green areas.
Site owner	Seeks to market the land in optimal conditions and, therefore, does so at the highest possible price. Interests are not necessarily linked to the site's sustainable reuse.
State mining sector agency (ministry of mines or oversight agency)	Provides background information on the environmental mining legacy, its creation, the studies conducted and the applicable regulations.
State agency for sectors with activity in the area (e.g. ministry of agriculture)	Provides information on damage and risks for the relevant productive sector.
Regulatory entities	Ensure compliance with applicable regulations.
Company responsible for creating the environmental mining legacy (if known and in existence)	Provides background information on the environmental mining legacy and information that might not have been recorded.
Companies with mining concessions in the area	May assume the role of potential voluntary remediators.
Investors	Seek to increase the profitability (productivity) of the site, but in general, do not wish to assume any unforeseen additional risk related to previous use.
Municipalities	Want projects for the reuse or restoration of areas with priority economic interests that can encourage the creation of operational human settlements, create jobs and potentially increase municipal revenues.
Ministry of health	Provides information on damage and risks to public health.
Local communities	Provide information on damage and risks for the relevant productive sector. Also suffer the negative economic, social and environmental effects of environmental mining legacies and are directly affected by remediation.
At-risk population	Constitute (differentiated) affected and vulnerable groups.
Environmental organizations	Provide information on remediation alternatives and collect specific data in the area.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of A. Bezama and others, "Application of a balanced scorecard system for supporting decision-making in contaminated sites remediation", *Water, Air, and Soil Pollution*, vol. 181, Berlin, Springer, 2007.

2. Encouraging stakeholder engagement

Once identified, stakeholders are encouraged to communicate and get to know each other to share and better understand their interests, in order to determine the objectives sought and the timelines for their attainment, their level of commitment, and the plans and actions that will impact the objectives. They can also rethink their strategies and activities, which would generate long-term benefits for them (Taylor and others, 2019). The stakeholder engagement process includes the development of a series of tools to manage their participation:

- A **stakeholder engagement plan** is a formal strategy for communicating with project actors and stakeholders that seeks to win their support for the project and specifies the frequency and type of communications, media used, contact persons and locations of communication events (see box II.4). The plan is drawn up at project commencement and is frequently updated as stakeholder communication requirements change (Roseke, 2019). The document enables the remediation execution agency and the authorities to remain aware of the activities to be carried out (or not), the risks to be addressed and how to interact with other parties.
- A **concept of ownership or usufruct of the site** for use by the community. The concept includes:
  - The identification of the site owner.
  - A list of the properties that comprise the entire site affected by the environmental mining legacy.
  - The formalities and conditions for transferring the site to the end users or local authorities.
  - Terms of use of the site.
  - The obligations to which the user will be subject in relation to the site (for example, the legal solution to the problem of ownership or usufruct of the land comprising the environmental mining legacy). The concept covers the future ownership of the site, the entity that will make use of it and in what way, and the obligations that the community could assume when it acquires ownership or usufruct rights.

  This concept is materialized by identifying the data of the properties and their owners in the public land registry and thereby determining the most appropriate method for transferring the site's ownership or use. This requires the involvement of legal and civil experts. It may also be necessary to check with local authorities to verify the status of tax payments to the municipality or to the government with jurisdiction over the site location. Whether the site is current with the payment of other federal or national obligations should also be checked.

■ Box II.4
Development of the stakeholder engagement plan

Stakeholder engagement plans may contain the following:

List of stakeholders or actors: The first step is to classify the stakeholders into project supporters or opponents, or to divide them according to the following criteria:

- Upwards (e.g. the parties responsible for the environmental mining legacy).
- Sideways (e.g. regulators and communities).
- Outwards (e.g. other projects competing for limited resources).
- Downwards (e.g. project team, suppliers and contractors).

It is essential that no actors be overlooked. Any of them can slow down the project if they are not included or if a poor communication strategy is followed.

Project phase: Some stakeholders will be involved only in certain phases of the project.

Contact names of stakeholders: It is important that contact be maintained with the right people. For a community, these could be the representatives or the most influential members. For government offices, they are the main decision-makers.

Areas of influence: Stakeholders' motivations and interests are analysed, and an assessment is made of how those interests affect or interfere with the project. The needs and wishes of the stakeholders must be described clearly.

Power: An analysis of the stakeholders' power complements the earlier assessment of their areas of influence. Each stakeholder has a unique ability to halt or alter the project. The plan must describe the extent and source of the stakeholders' influence and, on occasions, how a stakeholder's power can be checked or modified. The success of the project largely depends on keeping them informed on an ongoing basis.

Commitment approach: The stakeholder engagement strategy must be described in detail. This entails recording the type and frequency of communications (e.g. weekly emails, monthly phone calls, or weekly face-to-face meetings) and publicizing their content (e.g. through weekly reports covering project progress, design information and open-door plans).

Stakeholder engagement: Stakeholder communication needs are detailed in light of the analysis of their power and influence, and the types of communication and their frequency are specified.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of A. Taylor and others, "Five-step approach to stakeholder engagement", *Reports*, San Francisco, Business for Social Responsibility (BSR), 29 April 2019; Youmatter, "Stakeholder engagement – meaning, definition & strategies", Paris, 1 October 2018 [online] https://youmatter.world/en/definition/stakeholder-engagement-meaning-definition-and-strategies/.

- A **concept for managing the future use of the site** that describes the rights and obligations of the stakeholders who will operate the site (for example, small-scale solar power plant, agricultural or livestock use). A clear definition of the community's obligations (such as minor maintenance of embankments, slopes, decks and roads) in exchange for the usufruct of the site provides a reduced cost scheme and contributes to improving the project's rate of return and increasing its long-term sustainability.

  Having the site owner (for example, the government) and the beneficiaries (such as the community) sign a contract is a good way to define the maintenance obligations of the beneficiaries and the owner. Such a contract could also cover consideration for services provided by the future use project (SENER/FSUE/FIDE, 2017; for example, the community will become the user of the site, with the corresponding rights and obligations, and will benefit from an economic contribution from the State to cover maintenance costs).

3. Local community engagement

The participation of local communities in decision-making on environmental issues that may affect them is increasing, although it is not yet occurring either consistently or in sufficient amounts. At the international level, the Escazú Agreement establishes provisions to govern access to environmental information and the process of public participation in environmental decision-making in the countries that have ratified it (see ECLAC, 2022a; in particular, articles 5.2, 6.3 and 7.2). In turn, the Agreement's implementation guide sets out the background to its adoption and highlights the cross-cutting issues that shaped it (connection with human rights, attention to vulnerable persons and groups, link with the right of access in environmental matters and so on) (ECLAC, 2022b). The agreement helps attain social legitimacy. Likewise, the Indigenous and Tribal Peoples Convention, 1989 (No. 169) of the International Labour Organization (ILO) seeks to ensure that free, prior and informed consent is obtained.

At the same time, and related to the above, legal frameworks and court rulings in Latin America increasingly emphasize the rights of affected communities and the authorities' obligation to address them. Peru, for example, has regulations for the development of public investment projects focused on the remediation of environmental mining legacies that seek to empower communities in the decision-making process and in mitigation and long-term monitoring, foster transparency in communications and promote participation by the public in the environmental mining legacy's area of influence (article 13 of Supreme Decree No. 059-2005-EM) (Chappuis, 2020). Finally, participation provides a legal safeguard for the human rights of an affected community's members.[9] [10]

The participation process is governed by the community involvement plan, which should use an approach that is "tailored to the specific, unique needs of the particular community where activities are being implemented" (EPA, 2020, p. 16; see diagram II.5). The community involvement plan is developed by means of interviews with the community. They identify the needs, concerns and expectations of the members and groups that make up the site's local community, together with the channels through which the community obtains information about the site and how they prefer to receive it. In these interviews, the

[9] En la sentencia del *amparo* en revisión 640/2019 de la Segunda Sala de la Suprema Corte de Justicia de la Nación en México (SCJN, 2020, págs. 48 y 49), se señala en el numeral 103 que: "si bien es cierto que, conforme a la normativa aplicable, en el desarrollo del procedimiento administrativo de inspección y vigilancia no se da intervención a las personas físicas habitantes de la comunidad adyacente al daño ocasionado al ambiente o a aquellas directamente afectadas, también lo es que de conformidad con lo dispuesto en los artículos 1, 4, quinto párrafo, 6 y 35, fracción III, de la Constitución Política de los Estados Unidos Mexicanos; 11 del Protocolo Adicional a la Convención Americana sobre Derechos Humanos en Materia de Derechos Económicos, Sociales y Culturales "Protocolo de San Salvador"; 25, inciso a), del Pacto Internacional de Derechos Civiles y Políticos; 13, numeral 1 y 23, numeral 1, inciso a), de la Convención Americana Sobre Derechos Humanos, debió consultarse y darse participación a los quejosos no solo en los convenios administrativos previstos en el artículo 168 de la Ley General del Equilibrio Ecológico y la Protección al Ambiente, sino también en aquellos actos emitidos por la autoridad administrativa que tuvieran por objeto la reparación y compensación de los daños ocasionados al ambiente, específicamente los relacionados con el cumplimiento de las medidas correctivas impuestas en la resolución con que concluyó el mencionado procedimiento administrativo".

[10] Se destacan el curso "Minería con las personas" elaborado por la Federación Iberoamericana del Ombudsman (FIO), la CEPAL y la Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) y el documento titulado "Recomendaciones para la incorporación del enfoque de derechos humanos en la evaluación de impacto ambiental de proyectos mineros" (FIO/CEPAL/GIZ, 2020). Véase Comisión Económica para América Latina y el Caribe (CEPAL), "Curso 'Minería con las personas'" [en línea] https://observatoriop10.cepal.org/es/capacitacion/curso-mineria-personas.

community can help determine past uses, practices or other aspects of the site's history, which are necessary inputs for the site investigation and risk assessment. Special attention should be paid to improving relations with indigenous groups (ILO, 1989; ISO, 2023a).

Geographic, socioeconomic and sociocultural reasons may give rise to barriers that prevent the effective participation of some local community groups. Typical barriers include: (i) lack of availability and access to resources (specifically, funding and staff) to conduct the required activities over the long term, (ii) poor or little coordination between government agencies at various levels and institutions representing the communities (indigenous or otherwise), (iii) language and cultural differences, (iv) identification of and coalition-building among local leaders, (v) failure of communities and individuals to recognize their stakeholder status, and (vi) lack of trust between community members, regulatory agencies and the regulated industries (EPA, 2020).

■ Diagram II.5
Components of the community participation plan

Site description
Summarizes the relevant history, type and extent of contamination, human health risks, exposures and environmental concerns.
Community description
Gathers information on the population and local government structure, on subgroups with environmental justice concerns, and on ethnic and cultural practices and characteristics.
Communications strategy
Defines communications objectives and goals, the stakeholders and their concerns, the messages to be conveyed and information to be collected, and possible communications channels (traditional and new media) and feedback methods. Maintaining coordination with other governmental actors is recommended. The strategy should foster trust and constructive dialogue, and deploy exceptional teamwork.
Community needs, questions and concerns
Details key community-specific expectations and needs (such as translation and disability services) and unique cultural behaviours, customs and values. The risk must be communicated effectively and intelligibly. The collection and possible disclosure of personally identifiable information is explained to community members.
Technical assistance
Programmes and services that provide communities with technical assistance in order to build the capabilities needed to be part of the participation process.
Plan of action
Describes the objective and intent of each activity and the expected sequence of project milestones (with estimated timelines, if possible) in a road map with outreach activities and participation mechanisms. The available resources, knowledge of the site and the affected community's needs are taken into account.
Special services and approaches to address unique needs
Additional tools are identified and implemented according to local needs, such as a community advisory group (a working group comprising community members and other stakeholders affected by the site), facilitation mechanisms and information documents.
Mechanisms for processing comments
Suggestions or comments are received at formal or informal public forums and community meetings, and are taken on board before the final remediation plan is issued. Environmental justice concerns are evaluated and addressed, and views are expressed on reasonably likely future land use possibilities.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), *Superfund Community Involvement Handbook*, Washington, D.C., 2020.

When the time has come, the community participation plan should recognize that reality and provide solutions. With the participation of the affected community, the following milestones must be achieved:

- **Consultation and participation of the affected community.** These tasks need to be conducted from the beginning of the project to identify community concerns regarding health and potential harm to property and public services (drinking water or restrictions on use of the contaminated site; see box II.4). Communities can demand the complete elimination of contaminants, but this is not always an economically viable solution. Communication must be maintained during the project preparation phase, as it enables an association to be established between the solutions and the expected benefits in the community and the identification of the solutions that correspond most closely to those benefits, taking into account technical and economic constraints.
- **The community accepts the project.** Community members fully understand the benefits of the project and its implications for their quality of life. This means that the project background has been correctly communicated and that the authority is managing the project transparently and minimizing risks to the community.
- **The community takes ownership of the project.** They see how the remediated site will be integrated into their daily lives, the functions and services it will provide, and how the community will be able to use it (or not).
- **The community agrees to manage the site.** Once remediation is completed, the community contributes to the maintenance of the site and, if appropriate, its operation, especially if the site provides them with services. By means of a contract, the executing agency (either the government or a responsible private party) can agree with the community on the use of the remediated site, together with the reuse project, through a management committee (composed of community representatives). In addition, community promoters take charge of minor maintenance and report major problems to the executing agency.

■ Box II.5

The role of women as a community and information circuit

Encouraging the intentional participation of women from the earliest stages of a project improves the prospect of future sustainability. This is because they generally better understand the background and health status of family members, have broader social networks and assume greater responsibility in the obligations arising from productive activities undertaken as a result of a project. Women provide more accurate information about the fears, expectations, illnesses and economic difficulties that environmental mining legacies cause or will cause after remediation. They also provide better information on how family conditions have changed. Consequently, a better organized community will emerge in relation to future site use and the maintenance and operation obligations.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Global Environment Facility (GEF), "Celebrating women's contribution to global environmental sustainability", Washington, D.C., 8 March 2019 [online] https://www.thegef.org/blog/celebrating-womens-contribution-global-environmental-sustainability.

F. Available technologies

The remediation of environmental mining legacies represents a considerable challenge because of (i) the large areas of land that mining operations generally occupy, (ii) the high volume of materials and wastes that may contain potentially toxic elements, (iii) the combination of different types of sites, and (iv) the various aspects of the ecosystem that may suffer damage. Given their nature, there are several alternatives for the remediation of environmental mining legacies. These are linked to multiple materials and elements that make up environmental mining legacies and their associated risks (see table II.5).[11]

■ Table II.5
Remediation measures by major element or material present in environmental mining legacies

Element or material of the environmental mining legacy	Measure		Type
Land and tailings	Mechanical stabilization and systems for:	Low-security coverage	On-site
		Revegetation or phytoremediation	
		Coverage with biosolids and revegetation	
		Coverage with loan materials from the site	
		Reprocessing, relocation to new tailings dam and cover systems (tailings only)	Off-site
Surface soils with low to medium contamination	Excavation, piling, application of mechanical stabilization and systems for:	Low-security coverage	On-site
		Revegetation	
		Coverage with biosolids and revegetation	
		Coverage with loan materials from the site	
		Soil treatment by stabilization with Portland cement (depending on the contaminant)	
Surface soils with high to very high contamination	Treatment with phosphates or stabilizers (such as Portland cement) and:	Security coverage	
		Revegetation	
		Coverage with biosolids and revegetation	
		Coverage with loan materials from the site	
		Security cells	
		Relocation to secure containment off-site	Off-site

[11] Documents addressing remediation technologies in Latin America and the Caribbean include MINEM (2006), Palma and others (2007), Fundación Chile (2015) and Arranz-González and others (2019).

Element or material of the environmental mining legacy	Measure		Type
Buildings and facilities with low to medium contamination	Demolition, separation of materials and application of mechanical stabilization and systems for:	Low-security coverage	On-site
		Revegetation	
		Coverage with biosolids and revegetation	
		Coverage with loan materials from the site	
Buildings and facilities with high and very high contamination		Security cells	
		Relocation to secure containment off-site	Off-site
Acid drainage	Mechanical stabilization of materials, construction of surface storm drainage and catchment systems, and passive treatment with limestone[a]		On-site
Contaminated shallow groundwater	If the treated water is to be used subsequently:	Installation of a network of extraction wells of a calibre suitable for the water body's productivity, water treatment plant, application of inputs to separate pollutants, final disposal of treatment sludge as hazardous waste[a b]	
	If the treated water is not to be used subsequently:	Installation of cross-flow permeable barriers for passive groundwater treatment[a]	
Contaminated deep groundwater	If the treated water is to be used subsequently:	Installation of a network of extraction wells of a calibre suitable for the water body's productivity, water treatment plant, application of inputs to separate pollutants, final disposal of treatment sludge as hazardous waste[a b]	
Surface water body	If the treated water is to be used subsequently for agriculture or livestock (non-human use):	Installation of cross-flow permeable treatment systems for passive water treatment	
Slag	Mechanical stabilization and systems for:	Low-security coverage	
		Coverage with biosolids and revegetation	
		Coverage with loan materials from the site	
		Storm drainage and capture of water-borne sludge[c]	

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Office of Solid Waste and Emergency Response (OSWER), "Green remediation best management practices: mining sites", 2012 [online] https://clu-in.org/greenremediation/docs/GR_factsheet_miningsites.pdf; "Guía comunitaria sobre la cobertura", 2012 [online] https://clu-in.org/download/citizens/EPA-542-F-12-004S_guia_del_ciudadano_sobre_el_recubrimiento.pdf.

Note: Remediation technologies are classified as "on-site" when implemented within the contaminated site and "off-site" when the material must be transported beyond the confines of the contaminated site. In addition, they can be classified as *in situ*, when no excavation of the soil or material is needed to implement the technology, and *ex situ*, when excavation is required.

[a] Regular monitoring and replacement of supplies is required.

[b] Waste removal is required.

[c] Additional measure if finer slag (unglazed or massive) is present.

Remedial actions, the purpose of which is to reduce the toxicity of a contaminant in a specific medium (for example, soil or water), are implemented through technologies that can be grouped according to their operational characteristics or purpose in line with the following criteria: (i) remediation objective, (ii) location where the remediation process is applied, and (iii) type of treatment used. In terms of the remediation objective, a distinction is drawn between containment, confinement and decontamination techniques. Regarding the location where the remediation process applied, both *in situ* and *ex situ* treatments exist. Finally, the treatments used may be chemical, physical or biological (Oblasser, 2016).

It is recommendable to choose technologies that minimize the use of water and energy (and promote the use of renewable energies), reduce negative impacts on water resources, reduce atmospheric pollutants and greenhouse gas (GHG) emissions, promote materials management and waste reduction, and favour the protection of ecosystem services (EPA, 2012). To prioritize the reduction of the ecological footprint of waste remediation and affected zones, the following are particularly important among the technological approaches currently available:

1. Reprocessing

Reprocessing (also called reuse or secondary mining) involves the extraction or recovery of minerals or elements with economic value found in abandoned mine tailings. It relates to the mechanical, physical, biological, thermal and chemical processes applied to mining waste to extract valuable materials (Arranz-González and others, 2020a; DEQ, 2020). Unlike treatment, the reduction of the toxicity, mobility or volume of a contaminated material is considered a secondary objective (ITRC, 2010).

When gravity, flotation or leaching separation methods are employed, the waste material is suitable for another use or for environmentally safe disposal at the mine site (EPA, 2000). Reuse is the direct use of problematic mining waste after reprocessing or other treatment to convert it into environmentally safe products (ITRC, 2010).

Ideally, the implementation of secondary mining technologies should generate revenue. Before selecting suitable mine site remediation technologies, consideration must be given to market conditions, the effectiveness and safety of the technology and the relegacy of the supplier; perceptions of risk among community members must also be assessed, since they may not agree with the reopening of the site even if the toxicity of the tailings is reduced during the process.

It is possible for the technologies used in the new installations to be superior to the original ones (EPA, 2000). Even so, small amounts of polluting waste can be generated, which must be managed and controlled. Often, remediation does not remove all the contaminants and remediation or long-term management may be required, which also entails a cost (ITRC, 2010).

2. Stabilization

Stabilization improves soils to meet the requirements set, prevents the dispersion of fine particles and the risk of tailings collapse and enables the modification of the material itself. The main stabilization methods are described below (EPA, 2012; Palma and others, 2007; Fundación Chile, 2015):[12]

- **Chemical stabilization:** Certain chemicals (asphalt emulsions, cement, sodium chloride and others) are used to replace metal ions and change the constitution of the processed soils. Because chemicals are used, this technology is not considered a green solution.
- **Physicochemical stabilization (solidification):** This technique does not destroy the contaminants; instead, it traps or immobilizes them within the medium. Portland cement is typically used, which prevents land restoration and has a high carbon footprint. Organic agents also exist (Jouini and others, 2020), as do agglutinating agents with a lower carbon footprint (Wang and others, 2019).
- **Mechanical stabilization:** Mechanical stabilization is used in piling and gives a specific shape to slopes, which minimizes the possibility of landslides caused by hydrometeorological or seismic events or other factors. It may include the construction of drainage, the placement of barriers on slopes and terraces and the deployment of protective coatings.
- **Bioremediation stabilization:**
  - **Microbial stabilization:** Living organisms (plants, algae, fungi and microorganisms) are used to absorb, degrade or transform contaminants and eliminate, inactivate or attenuate their effect on soil, water and air (see Niroshika and others, 2020).
  - **Phytostabilization:** This technique seeks to cover and protect land surfaces threatened or affected by wind action using plants, seeds or other vegetation (see, for example, Karaca, Cameselle and Reddy, 2018). It can be accompanied by phytoextraction (in which, by translocation, contaminants move from the soil to the root, and from there to the aerial parts of the plant, after which they are harvested and the accumulated contaminants are recovered). This is a simpler and less costly solution than traditional methods. It also reduces the ecological impact of machinery and the transport —and storage— of hazardous substances.

3. Cover systems

Cover systems are used to cover contaminated areas or waste cells to prevent infiltration of rainfall, leachate, erosion of contaminated material or contact between contaminated materials and humans or wildlife. The technology is on occasions classified as "restoration" because it can restore the site's ecosystemic functionality. There are four basic types of cover systems:

[12] For a detailed discussion, see Garbarino and others, (2018).

(i) **Surface sealing:** Materials are used to reduce permeability (asphalt agglomerates, concrete or synthetic sheets).

(ii) **Coverage with soil and clay:** Multiple layers of compacted soil and clay are applied.

(iii) **Revegetation:** Considered the greenest of the coverage techniques.

(iv) **Technosols:** These are created from waste, pavements with their underlying unconsolidated materials, soils with geomembranes and soils constructed with man-made materials. They reduce the use of productive land, the amount of waste taken to landfills and, if they come from the same environmental mining legacy, the carbon footprint caused by haulage.

4. Treatment of water affected by mining

Two types of treatment exist for water affected by mining, including drainage. Traditionally, use was made of engineering solutions that required artificial energy sources or (bio)chemical reagents (Younger, Banwart and Hedin, 2002; UNESCO, 2009). At present, preference is given to passive treatments that use only energy sources derived from natural processes (e.g. gravitational forces, microbial metabolic energy, photosynthesis and sunlight) and that require sporadic maintenance (Younger, Banwart and Hedin, 2002; PIRAMID Consortium, 2003; UNESCO, 2009). The main treatment technologies for water affected by mining include:

- **Wetlands:** Engineered systems that take advantage of natural resources to clean waste from water. They entail placing an impermeable material on the affected land to prevent the liquid from seeping into the subsoil. A substrate mixture consisting of sand, gravel, stone and other components is applied on top. Finally, aquatic plants that float on the water are put in place. Both the substrate and the flora absorb the contaminating particles, which they use as nutrients.
- **Passive inorganic media systems:** Remove contaminants by precipitation or dissolution of dissolved metals or metalloids (most commonly limestone).
- **Anoxic limestone drains (ALDs):** Anoxic channels filled with limestone fragments through which the solution to be treated passes (PIRAMID Consortium, 2003; Watzlaf and others, 2004).
- **Dispersed alkaline substrates:** Based on the dissolution of limestone sand (DAS-limestone) to remove trivalent metals (Fe and Al) and on the dissolution of powder-sized magnesium oxide (DAS-magnesium) to retain divalent metals (Zn, Mn, Cd, Co and Ni) (Liñán and Rötting, 2013).

5. Integrating remediation with restoration

According to EPA (2012), green remediation can contribute to the ecological restoration of environmental mining legacies. The following are therefore recommended:

- Planting trees, preferably native varieties, to complement reforestation plans on adjacent government-owned land.

- Installing surface water corridors that replicate original waterway conditions and complement regional watershed plans.
- Incorporating the land reuse preferences of neighbourhood organizations in order to expand recreational and environmental education services for the community (see the section "Stakeholder engagement", earlier in this chapter).
- Coordinating with renewable energy developers to produce energy from on-site renewable resources.

Chapter III
Tools for decision-making in the management of environmental mining legacies

Introduction

This chapter covers the tools available for evaluating investments made to remediate environmental mining legacies. In particular, it identifies various qualitative and quantitative methodological approaches found in the global literature. Chapter II presented the main considerations for developing remediation strategies based on a risk analysis, taking into account the prevailing legal aspects, the funding available and stakeholder participation. It also described a number of remediation technologies.

This chapter introduces the bases for beginning the economic evaluation of different remediation alternatives. To that end, it further explores cost-benefit analyses and cost-effectiveness analyses from the perspective of sustainability and taking account of environmental regulations. It outlines their main characteristics and provides examples of how they have been applied in the region.

A. Decision-making for the analysis of a remediation project

The role of project analysis in decision-making varies according to the decision makers' preferences. Multiple approaches to project analysis exist but, in general, two main ones can be identified: (i) those that seek a definitive classification from the point of view of social desirability and (ii) those that produce relevant information for decision-making. Regarding the latter point, it should be borne in mind that economic considerations are not the only relevant factors in selecting an alternative (see table III.1).

The cost-benefit analysis, unlike other approaches, enables projects to be ranked in monetary terms according to the criterion of efficiency or in combination with the criterion of equity. This is achieved through simplifications, normative assumptions and conceptual and methodological decisions (Brent, 2008; Stiglitz and Rosengard, 2015; Boardman and others, 2018; see section "Overview of cost-benefit analysis" below).

■ Table III.1
Comparison of project analysis models for decision-making

	Project classification	Collection of background information for democratic and informed decision-making
Identification	All costs and benefits	
Measurement of costs and benefits	All costs and benefits are measured in monetary terms.	Some costs and benefits are measured in non-monetary terms (such as air quality or public health improvements).
Comparison of results	All costs and benefits are compared in monetary terms using the appropriate social discount rate.	Some costs and benefits are measured according to other metrics, but a uniform methodology must be used for all alternatives.
Selection of the appropriate alternative	A ranking is created and the option with the greatest social well-being benefits is identified.	Through a democratic and participatory debate, the cost-benefit analysis provides decision makers with information for choosing an option according to their own value judgments (well-being function).
Presentation of information	The expected change in social well-being is presented.	The expected change in social well-being is presented, with the addition of other indicators.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of K. Nyborg and I. Spangen (2000), "Cost-benefit analysis and the democratic ideal", *Nordic Journal of Political Economy*, vol. 26, Cambridge, Cambridge University Press, 2000; K. Nyborg, *The Ethics and Politics of Environmental Cost-Benefit Analysis*, New York, Routledge, 2012; T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016.

Given its multiple simplifications, cost-benefit analysis does not encourage decision-making reflective of a broad set of views, experiences and capabilities (Sen, 2000). Unless decision makers share the assumptions underlying the analysis (for example, monetization of relevant aspects, ways of measuring social well-being, anthropocentric value of nature, absence or use of social group weighting), cost-benefit analysis is of limited usefulness (Nyborg, 2012). It should be noted that regional systems are increasingly incorporating variables and criteria based on equity in conjunction with the efficiency-based approach (see chapters II and VI).

Explicit and implicit normative assumptions and constraints must be taken into account in each project evaluation. A national evaluation system that empowers stakeholders and enables the effects for society as a whole to be measured should be established. If possible, the assumptions on which the analysis is based should be made explicit and standardized at the national level (for example, the way a project's effects are expressed in monetary terms, the weightings applied for socioeconomic groups or conditions of vulnerability). Likewise, assumptions that deviate from the standard methodology must be indicated, explained and justified.

B. Main methodological approaches

This section sets out the main methodological approaches used for applied research and analysis and for the selection of remediation alternatives; it therefore covers with qualitative, quantitative and semi-quantitative analyses. Qualitative analysis is based primarily on an inductive method, while quantitative analysis uses a strictly deductive method. In turn, semi-quantitative analysis represents a combination of the other two approaches.

1. Qualitative analysis

Qualitative analysis is based on an empirical approach that builds its premises from inductive reasoning and is primarily based on observations and inferences. This method is deployed to conduct analyses using data and information available in text or narrative form.

Unlike the quantitative method (described below), the qualitative method has a strong correlation between the observer and the information to be analysed. This method is preferred when the analysis aims to explain phenomena relevant to the social sciences (Williams, 2007) and seeks to understand the way things are experienced or perceived (Biddix, 2018).

Methodologies based on qualitative assessments can complement the development phases of alternatives when cost-benefit analyses are used (see table III.2).

■ Table III.2
Summary of main qualitative analytical tools used in cost-benefit analysis

Tool/technique	Example/explanation
Brainstorming	A group technique used to generate new ideas quickly or to identify and consider different solutions to a specific problem through teamwork.
SWOT Analysis	The identification of a SWOT list (Strengths, Weaknesses, Opportunities, Threats) facilitates exchanges of ideas. The benefits of brainstorming should be combined with an approach that defines the relationships among the SWOT factors identified. Those relationships should then be used to guide decisions regarding the steps to come.
Fishbowl	In medium-sized and large groups, this technique facilitates the effective and orderly discussion of a topic. In this model, some of the participants form a discussion circle while the rest stay outside, forming a circle around them, and listening to them and taking notes to provide feedback. It is also used to develop communication and debating skills, as well as respect and tolerance.
Nominal group technique (decision by consensus and ranking)	Used in groups with multiple opinions to prioritize ideas and rank them in an inclusive and consensual format. The aim is to prioritize and classify the issues or problems.
World Café methodology	In groups comprising participants with different perspectives, this method allows a specific topic to be discussed in small groups that rotate during the meeting or conversation. In this way, different perspectives help to enrich the discussion on the topic of interest while fostering networking among the stakeholders and their different proposals or solutions.

Tool/technique	Example/explanation
Delphi method	Used to request information from experts in a structured manner. It comprises four steps: (1) planning, (2) creation of the expert panel, (3) administration of questionnaires and (4) interpretation of final data for decision-making. This technique aims to reach consensus among experts to define scenarios, identify desired outcomes, prioritize causes or recommend solutions.
ZOPP methodology (*Zielorientierte Projektplanung*)	This method involves a set of tools and procedures that guide planning in the process of managing a development project over the course of its life cycle. It covers both project analysis and planning and consists of a series of workshops, facilitated by a moderator and attended by representatives from all stakeholder groups and links in the hierarchy.
Fishbone	This is a diagram of potential (or actual) causes and effects that visually displays the relationships between an issue and a problem. In group discussions, it is useful for in-depth analysis of the causes of a performance problem.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "Interactive community planning. ZOPP: Goal Oriented Project Planning", Washington, D.C., 2001 [online] http://web.mit.edu/urbanupgrading/upgrading/issues-tools/tools/ZOPP.html; T. Kendrick, *Project Management Tool Kit: 100 Tips and Techniques for Getting the Job Done Right*, Nashville, AMACOM, 2010; R. Watkins, M. Meiers and Y. Visser, *A Guide to Assessing Needs: Essential Tools for Collecting Information, Making Decisions, and Achieving Development Results*, Washington, D.C., World Bank, 2012.

2. Quantitative analysis

This method uses a numerical or statistical approach to design the research, and its objective is to quantify the data. Reasoning is deductive and based on mathematical models. It is useful for directly quantifying results through accurate measurements. In theory, the research itself is independent of the observer or researcher and, by that token, the information gathered is used to measure reality in an objective manner (Williams, 2007).

The **gains matrix** combines the possible actions that decision makers can adopt with regard to external factors —i.e. those beyond their control— and reveals the expected gains. The gains expected from each strategy are obtained as follows (adapted from Schuyler, 1994; Stefanovic and Stefanovic, 2005):

$$EMV_i = \sum PV_x * p_x$$

Where:

EMV_i = expected monetary value of scenario i

x = possible outcome

PV_x = present value of outcome x

p_x = probability of outcome x

The sum of the probabilities of the individual outcomes must be 100%.

The gains matrix helps rank alternatives according to objective criteria (see table III.3). Note that the associated probabilities, all feasible outcomes and the monetary value of all variables are not always known for each scenario. The importance of probabilities should be taken into account, as they indicate decision makers' level of risk aversion.

■ Table III.3
Gains matrix

		Scenario 1 (20%)	Scenario 2 (40%)	Scenario 3 (25%)	Scenario 4 (15%)	Expected monetary value	Ranking
Strategy	A	165	40	120	140	100	2
	B	80	80	80	80	80	4
	C	-30	15	210	250	90	3
	D	105	110	20	0	70	5
	E	10	160	200	-40	110	1

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "Interactive community planning. ZOPP: Goal Oriented Project Planning", Washington, D.C., 2001 [online] http://web.mit.edu/urbanupgrading/upgrading/issues-tools/tools/ZOPP.html; T. Kendrick, *Project Management Tool Kit: 100 Tips and Techniques for Getting the Job Done Right*, Nashville, AMACOM, 2010; R. Watkins, M. Meiers and Y. Visser, *A Guide to Assessing Needs: Essential Tools for Collecting Information, Making Decisions, and Achieving Development Results*, Washington, D.C., World Bank, 2012.

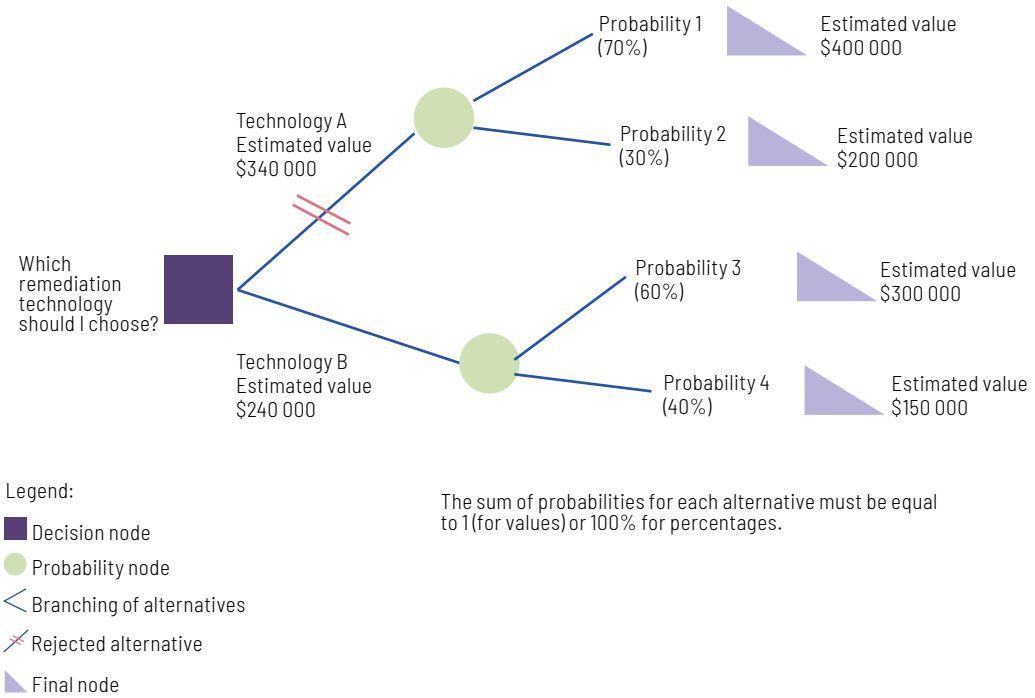
In turn, **decision trees** provide a schematic representation of the available alternatives and help improve decision-making by revealing the risks, costs and benefits of multiple options. This method uses logical consequential functions related to the decision taken (Zuniga and Abgar, 2011). Each decision depends on one or more probabilities, and a potential cost must be estimated for each decision. Once each alternative's costs have been estimated, the best option can be chosen using the expected value criterion, revealed by the weighted sum of the estimated values multiplied by the probability of the decision alternative (Berger, 2007). Decision trees facilitate more informed decision-making based on the available information and best assumptions by helping to reveal, analyse and quantify the cost and probability of each outcome (Castellanos, 2015).

Diagram III.1 shows how a decision tree is used to decide between two remediation technologies. Each technology has a probability related to its use. The sum of the alternatives' probabilities must be 100%. For each option, an estimated value is established by weighting the value of the final node by the probability of its occurring. Once each alternative's estimated values have been calculated, the decision maker will be able to identify the alternative that offers the greatest benefits. In this diagram, the choice would be technology A, since its estimated value is higher than that of technology B.

Decision trees can be difficult to construct accurately, and their use is recommended when a limited number of possible actions exists. Decision trees are based on expectations that are not necessarily met, the allocation rules are sensitive to small shifts in the data, and those data are sometimes not available. Finally, representation is lost due to the absence of a global function of the variables.

The **life-cycle assessment (LCA)** is a comprehensive method for the orderly identification, quantification, interpretation and evaluation of the direct or indirect environmental impacts of a product, function or service over the course of its life and for comparing alternatives (Brusseau, 2019). In this case, what is analysed is the remediation activity over its entire life cycle.

■ Diagram III.1
Example of a decision tree with estimated values



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of A. Berger, "Árboles de decisión", Buenos Aires, CEMA University (UCEMA), 2007 [online] https://ucema.edu.ar/~aberger/Arboles/Arboles.pdf; R. Sánchez-Pedraza, O. Gamboa and J. Díaz, "Modelos empleados para la toma de decisiones en el cuidado de la salud", *Revista de Salud Pública*, vol. 10, No. 1, Bogotá, National University of Colombia, 2008.

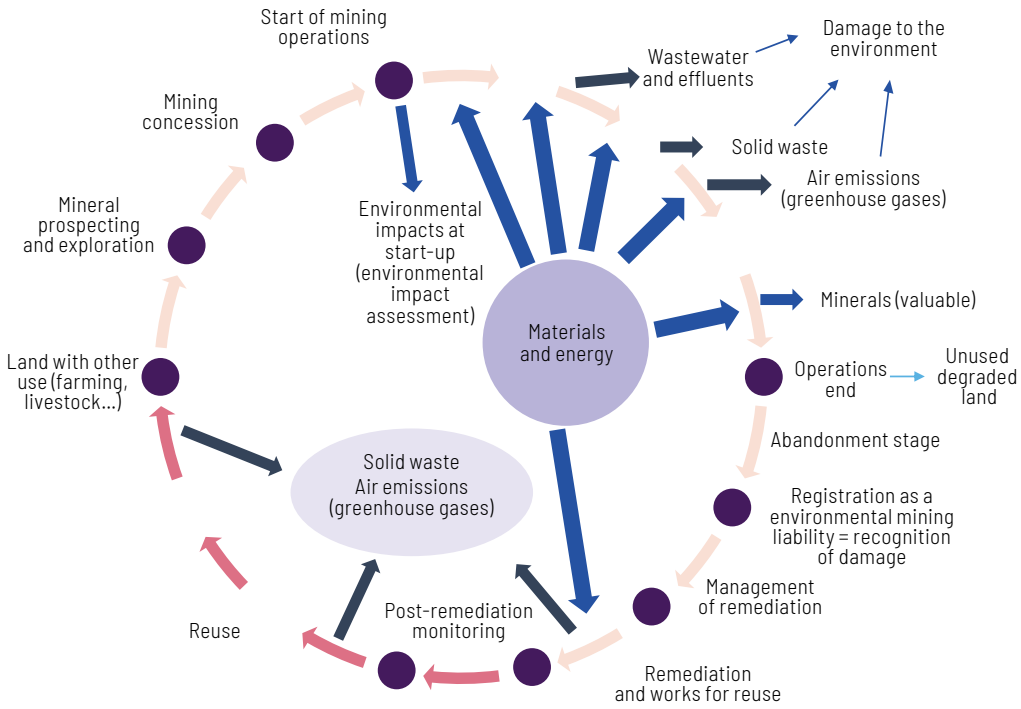
The method is based on the identification and description of all stages in a product's life cycle, from extraction and pretreatment of raw materials, production, distribution and use of the final product to the possible reuse, recycling or disposal of the product (cradle to grave).

Diagram III.2 shows how this method applies to mining, which starts with prospecting and exploration, followed by extraction, the abandonment of the site and its becoming a disused mine site and, consequently, a environmental mining liability. Remediation or reuse is finally achieved through remediation efforts and actions (European Commission, 2006).

The following are the main steps in conducting a life-cycle assessment:

- Definition of the study's objective and scope.
- Life-cycle inventory: the life-cycle assessment model is prepared, including inputs and outputs, and the environmental impacts are quantified.
- Life-cycle impact assessment: estimation of environmental impacts through inputs and outputs.
- Interpretation of the findings.

■ Diagram III.2
Overview of life-cycle assessments for environmental mining legacies



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of European Commission, "Life Cycle Assessment (LCA) as a decision support tool (DST) for the eco-production of olive oil", Brussels, 2006 [online] https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=2743&docType=pdf.

In life-cycle assessments, a functional unit must be defined. This represents the measurement of the function of the system under study, which provides a reference point with respect to the inputs and outputs, enabling different systems to be compared. The functional unit must be precise and comparable, and it must be determined through data collection and studies. However, note that there may be restrictions on the depth of the study, as well as on the sources and quality of the data (European Commission, 2006).

The main quantitative approaches with economic applications are cost-benefit analyses and cost-effectiveness analyses. Cost-benefit analysis is used when the costs and benefits of a project can be quantified. This method is useful for assessing whether, at any given time, the cost of a specific measure is greater or less than its benefits. In other words, it is used to organize and analyse information related to social advantages (benefits) and disadvantages (costs) expressed in a common monetary unit (Gómez, 1994).

While cost-effectiveness analysis shares several similarities with cost-benefit analysis, it focuses on the relationship between the costs and outcomes of measurable interventions. Cost-effectiveness analysis is the most common method for conducting economic evaluations of health interventions, the aim of which is to determine which

interventions are a priority in order to maximize benefits with the available economic resources. In other words, it describes an intervention in terms of the relationship between the incremental costs per unit and the positive effects on people's health (Garber and Phelps, 1997; Prieto and others, 2004).

3. Semi-quantitative analysis

This mixed-method approach incorporates data collection and analysis techniques from both the quantitative and qualitative techniques. It highlights the complementarity between the two methods and is based on both numerical and narrative data. With this method, approximate rather than exact measures are assigned to the data, which allows researchers to employ both deductive and inductive analysis in the same study (Williams, 2007).

Semi-quantitative analysis is based on a holistic interpretation of the data through the integration of different methods. This enables more robust and complete inferences to be obtained than through data collection and analysis carried out using a single method (Biddix, 2018).

Multi-criteria analysis facilitates informed and defensible decision-making by structuring complex problems and analysing multiple sets of criteria (Watkins, Meiers and Visser, 2012). In multi-criteria analysis, preferences are established among options related to an explicit set of objectives. Those objectives are identified, measurable criteria are established and the degree of compliance is assessed. The criteria are weighted to reflect their relative importance. The decision is made based on the results once all the analysis criteria have been aggregated.

This method involves the participation of different stakeholders, which may imply a certain degree of subjectivity. However, the involvement of experts in the evaluation process can help minimize biases (Galindo and others, 2017).

Multi-criteria analysis is characterized by the inclusion of non-monetary values in its analysis. It can therefore be adapted to various contexts, generating a range of variants (Galindo and others, 2017). Multi-criteria analysis has been used in environmental studies since the 1990s on account of its ability to incorporate and standardize environmental, economic, political and social factors in policy evaluation (Santé and Crecente, 2005; Galindo and others, 2017; Dean, 2022).

The steps to carry out a multi-criteria analysis are as follows (Pacheco and Contreras, 2008; European Commission, 2015):

- Select the field of application and determine the justification for the intervention.
- Choose the negotiation group.
- Select the technical team responsible for supporting the negotiation team.
- Establish the list of competing activities to be included in the analysis.

- Determine judgment criteria.
- Determine the relative weight of each criterion.
- Formulate a judgment for each criterion.
- Calculate the aggregate judgments.

As shown in table III.4, and in keeping with Barba-Romero (1996), multi-criteria analysis considers alternatives (A_1, A_2, A_i, etc.) and criteria (C_1, C_j, C_n, etc.) as attributes or characteristics that will serve as the basis on which the decision will be made. It is therefore essential to first agree on the criteria and their respective relative weights. Once the alternatives have been made explicit, the information that connects them —i.e. the evaluations (D_{ij}) and the weights (W)— must be adequately structured. The evaluations of each alternative i with respect to each criterion j constitute the decision matrix (for example, D_{11}). Briefly stated, the decision matrix describes the alternatives based on the established criteria. Consideration must also be given to the weights (e.g. W_{11}), which are grouped in the weight vector. Weights help decision makers prioritize preferences (R_{ij}) (see table III.4).

■ Table III.4
Multi-criteria decision matrix

Alternatives	Criteria		
	C_1	C_j	C_n
A_1	D_{11}	...	...
A_2	...	...	...
A_i	...	D_{ij}	...
A_m	...	...	...
Weight	W_{11}	W_j	W_n

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of S. Barba-Romero, *Manual para la toma de decisiones multicriterio* (LC/IP/L.122), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 1996.
Note: Rij: evaluation of alternative Ai with respect to criterion j; Wj: relative weight of criterion j.

This method's particularity lies in transforming measurements and perceptions into a single scale for the comparison and prioritization of different alternatives (Pacheco and Contreras, 2008).

In environmental decision-making, the objectives of a project may relate to such factors as the reduction of local air, soil or water pollution. For the management or remediation of environmental legacies, objectives would be established to protect public health, the environment and so on.

Multi-criteria analysis is useful for assessing sustainability in situations where a complex and interconnected set of environmental, social and economic issues must be taken into account, and where objectives often conflict. Unlike cost-benefit analysis, multi-criteria analysis is not limited to monetary units in its comparisons and, with its

robust and transparent structure, it provides opportunities for stakeholder and community participation (DCLG, 2009). Multi-criteria analyses, however, like cost-effectiveness analyses, provide no explicit justification that the benefits outweigh the costs.

In contaminated site management or remediation projects, this method is applied at different stages of the life cycle, including (i) the identification of ideas, (ii) the analysis of remediation alternatives, (iii) the prioritization of alternatives, and (iv) the construction of indicators for performance or management control during project implementation (Pacheco and Contreras, 2008). This method encourages discussions among project stakeholders, as well as the participation of experts in the field, and it facilitates access to information and decision-making. It also enables consideration of the intangible effects of remediation actions that cannot be quantified or appraised (such as the impact on the health or well-being of populations adjacent to the environmental liability) (Cinelli and others, 2021; Dean, 2022; Pacheco and Contreras, 2008).

Several methodologies exist for ranking the alternatives that can be used in the remediation of contaminated sites. Cinelli and others (2021) propose a practical example of the application of multi-criteria analysis in contaminated site remediation projects, and they relate it to compliance with the United States Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). They highlight the importance of including different stakeholders and their preferences in the decision-making process and in the implementation of the rules.

It should be noted that in a context of scarce resources for environmental mining liability management or remediation projects, multi-criteria analysis is a good option for determining alternatives for action, prioritizing the allocation of funds and increasing the efficiency of their use (Pacheco and Contreras, 2008). To ensure the efficiency of the decision-making process and to keep the multi-criteria analysis from becoming too complex, it generally involves no more than 30 people (Dean, 2022).

4. Cost-impact analysis

Cost-impact analysis identifies costs in monetary terms and lists benefits in physical units (for example, the reduction of fine particulate air pollution). The approach can be useful when the resources (including data) for cost-benefit and cost-effectiveness analyses are not available (Lewis and Tietenberg, 2020; see the following sections). Unlike those two methods, cost-impact analysis does not provide a ranking, but it does provide more comprehensive background information for decision makers (Nyborg, 2012).

C. Overview of cost-benefit analysis

Cost-benefit analysis emerged in the mid-nineteenth century (Dupuit, 1995) and is used to support decision-making in a range of interventions that affect society. It compares the total costs of those interventions with the total benefits. Possible decisions include public and

private investment projects, public policies and the drafting of regulations and standards. According to Livermore (2012, pp. 149–150), "cost-benefit analysis (...) holds special potential in the developing context to add quality, transparency, and efficiency to environmental, public health, and safety regulation".

In the case of environmental mining legacies, the authorities undertake remediation in order to eliminate environmental externalities and their associated risks. Once intervention by the State has been justified, the costs and benefits of remediation are determined, comparing them with the current situation (without intervention) and identifying all affected stakeholders (Boardman and others, 2018).

Cost-benefit analysis includes social valuations, so it considers the value of goods and services that do not necessarily have market prices (for example, environmental pollution and public health). It seeks to maximize the well-being of society as a whole and, for this reason, it is used most frequently to evaluate public investment projects. This is especially important when dealing with environmental mining legacies, since there are often no responsible parties for remediation and the State is required to cover the necessary investment (see chapter II).

Cost-benefit analysis is closely linked to the evaluation of the investment projects and plans that are included in countries' annual budget laws or decrees. The evaluation of projects and investment plans considers the direct and indirect costs and benefits that those programmes and projects generate for society. The management of environmental mining legacies, with a focus on sustainability in remediation and future use, is centred on the following aspects:

- It provides decision makers with criteria that guide the remediation and subsequent reuse of land to mitigate the environmental impact of project implementation and reduce maintenance costs in the medium and long terms.
- It helps raise the public administration's knowledge of the requirements for obtaining adequate financing within the framework of the socioeconomic evaluation. Benefits are taken into consideration beyond the traditional cost-benefit analysis.
- It facilitates the identification of opportunities for improvement in the management of environmental mining legacies, including the execution of pre-feasibility studies, the determination of costs and benefits in remediation projects, the updating of cost classifiers linked to environmental problems and capacity-building related to cost-benefit analysis.
- It considers a range of aspects including the construction, use and maintenance of the infrastructure necessary for the project, community demands and requirements, and how remediation and future use will contribute to reducing greenhouse gas emissions.
- It entails rethinking the risk analysis process and exploring future use scenarios that minimize environmental and economic impacts by eliminating risks and pollution.

Indirect payments and benefits are added to the costs and benefits expressed as financial expenses and revenues (for example, those related to the construction and use of infrastructure). These may include negative (or positive) effects on people and the environment, such as the impact on human health caused by contamination or the devaluation of properties due to the presence of environmental mining legacies (see chapter IV).

This handbook proposes the following basic objectives for the cost-benefit analysis:

- Measuring the appropriateness of an investment decision to remediate environmental mining legacies. In other words, verifying whether the costs of that decision are covered by its benefits, and whether the reported net benefit is positive.
- Comparing, based on the net benefit result, the best alternatives for carrying out the remediation. The aim is not only to select the remediation alternative with the lowest cost, but also to consider the additional benefits that could accrue from another higher-cost option (for example, if it were to generate activities in the areas of tourism or production), including environmental and social considerations.

In view of the foregoing, a cost-benefit analysis should include the concept of sustainability, which entails seeking to satisfy current needs without compromising the ability of future generations to satisfy theirs, ensuring a balance between economic growth, environmental care and social well-being (United Nations, 1987). Sustainable development represents a form of progress that maintains this balance today, without endangering tomorrow's resources. Environmental sustainability therefore entails the preservation of biodiversity without renouncing economic and social progress (Oxfam Intermón, 2020).

D. Overview of cost-effectiveness analysis

Cost-effectiveness analysis ensures an efficient use of resources by comparing alternative solutions (policies, programmes and projects) under the assumption that they yield equivalent benefits. Unlike cost-benefit analysis, cost-effectiveness analysis could be considered an alternative mechanism in cases when assessing the positive contributions of the remediation project is not feasible (see table III.5). Cost-effectiveness analysis allows the comparison of two or more alternatives, provided that they do not differ significantly in terms of the benefits they offer (Nyborg, 2012). According to Mishan and Quah (2021), cost-benefit analysis is superior for decision-making, since it indicates the total benefits (if it can be implemented).

Cost-effectiveness analysis can be carried out when:

- There is a legal obligation, a strategic decision or a policy that requires conducting the intervention and task in question. The aim is to define the best alternative for a defined investment type or area (with a given remediation objective) or to establish a prioritized ranking or portfolio of projects (for conceptual details, see Cuadros and others, 2012).

- The purpose of remediation is to eliminate a high level of risk to health and the environment (see chapter IV).
- Some infrequent aspects need to be assessed (for example, externalities without associated markets).
- Restricted remediation budgets do not permit excessive spending on pre-investment studies.
- The proportion of social benefits that cannot be valued at the profile level is significant.[1]
- The aim is to avoid methodological disputes (such as estimating the value of environmental assets), which may also include contentious value judgments (for example, placing a value on people's lives)(Stiglitz and Rosengard, 2015; Boardman and others, 2018).

■ Table III.5
Main differences between cost-benefit analysis and cost-effectiveness analysis

Treatment of costs and benefits, and outcome type	Cost-benefit analysis	Cost-effectiveness analysis	Comments
Identifies costs	✓	✓	
Identifies benefits	✓	✓	In the least-cost variant of cost-effectiveness analysis, benefits are identified to seek efficiency criteria and contrast them with costs.
Quantifies costs	✓	✓	
Quantifies benefits	✓	✓X	In some cases, quantification of benefits may be indispensable, even in a cost-effectiveness analysis (for example, the number of inhabitants to obtain an indicator of cost per inhabitant).
Places a value on costs	✓	✓	
Places a value on benefits	✓	X	Not determining the value of benefits considerably reduces the complexity of the analysis.
Determines the outcome for prioritizing and selecting alternatives	✓	✓	When there is a variation in benefits, cost-benefit analysis is preferred, although cost-effectiveness analysis is also useful.
Determines the outcome for making an investment decision	✓	X	Cost-effectiveness analysis can be applied only when the benefits are fixed or when the investment decision has been made and all that remains is decision on how it will be done.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[1] On account of the difficulties and costs that execution entails. However, the issue could be addressed in a pre-feasibility study (Contreras and Diez, 2015).

The direct cost of the resources to be used for the investment and operation of each alternative —such as preliminary studies, construction and maintenance costs, subsidies and project or activity financing— is taken into account. That is used to compare alternatives in terms of efficiency or effectiveness (for example, as regards such issues as contamination or congestion).

If indirect costs exist, such as lost production or social costs, but vary from one alternative to the next, they must be appraised and included. Otherwise, those differences must be reflected in the efficiency indicator or criterion to be used. Defining a clear criterion of efficiency and effectiveness that allows comparisons among the alternatives is therefore essential.

In carrying out a cost-effectiveness analysis, several types of efficiency can be considered:

- Least cost: all alternatives must consider the same level of achievement of the objective (for example, the search for alternatives for compliance with minimum standards or predefined rules).
- Cost per beneficiary: a variant of least cost expressed in values per beneficiary.
- Cost-impact (or cost-effectiveness): the impact level or outcome of each alternative is determined and related to its cost. Cost values can be linked to measurements such as PM_{10} emissions, CO_2 emissions, decibel numbers or natural species numbers.

E. Prioritization of projects at the national level

In presenting guidelines for comparing projects at the national level, the objective is not solely to choose among several alternatives for site remediation, but rather to find a way to prioritize projects in different parts of the country. Attention must therefore be paid to the following issues:

- The methodologies used in each project must be standardized in order to ensure consistency. Any deviation from the standard methodology must be adequately noted, described and justified.
- Synergies may exist between several projects in the same area, with the intensity of those synergies depending on the alternative. The analyses must present scenarios with and without synergies to assist decision-making, taking into account the priorities of those in charge of the task and the available financial resources.
- Data collection, mainly as regards benefits whose values are not observable in the market for cost-benefit analyses (see the section on identification and measurement of costs and benefits in chapter V), is onerous and costly. In order to optimize the available resources, it may be useful to create a database that

would then be reused in all evaluations, as greater precision would not justify data collection costs. The data should be prepared in a way that can be adapted to the context of a environmental mining liability.[2]

- When budgetary constraints and mutual non-exclusivity of projects exist, the set of selection metrics must be reviewed (see chapter VI), since ranking according to the net benefit provided to society by the project is, on its own, inconclusive (Nas, 2016).
- If several years elapse between the analysis and the final decision, an explanation indicating the reasons why other projects were prioritized must be included. In addition, it is important to check that there have been no substantial changes in local conditions. If such changes have taken place, the analysis must be amended or undertaken anew.

F. Applications of cost-benefit analyses and cost-effectiveness analyses in Latin America and the Caribbean

1. Countries and sectors using cost-benefit analysis

Cost-benefit analysis, like cost-effectiveness analysis, is intended to support and justify the investment decision-making process. In some cases, however, it is not mandatory, nor is this its exclusive purpose (see table III.6). In addition, it should be noted that in all the countries listed, cost-benefit analyses pursue more than a single objective and, in most cases, more than two.

While cost-benefit analysis appears to emphasize the economic outcome by specifying costs and benefits, it requires a thorough and comprehensive technical analysis. The vast majority of countries, especially those with specific and complete methodologies, use it at the pre-feasibility stage within the pre-investment phase (see diagram IV.3). As shown in table III.6, of the countries surveyed in OECD/IDB (2016), only Argentina does not use it to analyse and select alternatives: instead, it does so in the feasibility phase, after the selection of alternatives.

Cost-benefit analysis has a preferential and more systematized use in those sectors that have existed for longer in the region: for example, drinking water and energy, transport and sectors related to environmental and natural resource management. These methodological tools are also found in the areas of health and education infrastructure. Table III.7 provides an overview of the use of cost-benefit analysis by country in those sectors, and it highlights elements of relevance for its future replicability in extractive sectors and in remediation projects undertaken by national public investment systems.

[2] In examining the willingness to pay for environmental goods, data that consider additional aspects (for example, different socioeconomic groups) can be collected and systematized.

■ Table III.6

Latin America and the Caribbean (12 countries): general objective of cost-benefit analyses according to legislation, regulations or official documents, 2015

	A legal basis for the cost-benefit analysis exists	General objective of the cost-benefit analysis					
		Investment prioritization tool	Justification of the choice/ decision and project financing	Accountability/ transparency tool	An evaluation supports project design	Project monitoring tool	Public-policy learning tool
Argentina	Yes[a]		✓		✓	✓	
Chile	Yes[b]	✓	✓		✓		
Costa Rica	Yes[c]	✓	✓		✓		
Dominican Republic	Yes[a]		✓	✓	✓	✓	✓
El Salvador	No[d]				✓		
Guatemala	No[e]	✓	✓		✓		
Honduras	Yes[a]		✓				
Mexico	Yes[b]	✓	✓	✓			
Panama	Yes[b]	✓	✓		✓		
Paraguay	No[d]		✓	✓	✓		✓
Peru	Yes[b]	✓	✓		✓		
Uruguay	Yes[a]		✓		✓		
Total Latin America and the Caribbean		6	11	3	10	2	2

	A legal basis for the cost-benefit analysis exists	Main role of the cost-benefit analysis				
		Decision-making tool for allocating funding to agencies	Differs depending on the players involved	One decision-making tool among others	Does not have a decisive role in decision-making	Role and importance are increasing
Argentina	Yes[a]	✓		✓		✓
Chile	Yes[b]			✓		
Costa Rica	Yes[c]			✓		
Dominican Republic	Yes[a]	✓		✓		
El Salvador	No[d]	✓				
Guatemala	No[e]					✓
Honduras	Yes[a]			✓		
Mexico	Yes[b]	✓		✓		✓
Panama	Yes[b]	✓		✓		
Paraguay	No[d]			✓		
Peru	Yes[b]	✓				✓
Uruguay	Yes[a]					
Total Latin America and the Caribbean		**6**	**0**	**8**	**0**	**4**

Source: Organisation for Economic Co-operation and Development/Inter-American Development Bank (OECD/IDB), *Panorama de las Administraciones Públicas: América Latina y el Caribe 2017*, Paris, 2016.

[a] Yes, cost-benefit analyses are a legal requirement across the country, but only for a specific category of projects.

[b] Cost-benefit analysis is required by law across the country for all investment projects above a certain financial threshold.

[c] Different legal frameworks exist, depending on the agencies involved.

[d] No legal requirement exists, but the government recommends a cost-benefit analysis and it is used anyway.

[e] Does not exist.

■ Table III.7
Latin America and the Caribbean (7 countries): use of cost-benefit analyses in environmental and natural resource sectors

Country	Sector	Valuation of benefits	Comment
Argentina	Environment - Evaluation of the urban solid waste sector.	Hedonic pricing, contingent valuation and cost savings.	Benefits for landfill sanitation and solution of collection problems.
Bolivia (Plur. State of)	Agriculture: - Irrigation.	Productivity increases in areas favoured by the investments in question, for consideration in the economic and financial analyses.	Increased soil productivity benefits could be achieved through the remediation of environmental mining legacies.
	Environment: - Conservation and management of natural resources and ecosystems. Minor projects. - Watershed management. - Environmental quality control.	Alternatives for obtaining benefit values are expressed with an emphasis on contingent valuation, but only for major projects.	In the case of river basins, adequate management yields greater productivity, although only the identification of such cases is indicated, without carrying out assessments.
Chile	Rainwater evacuation and drainage	General explanation of the valuation of benefits through contingent valuation and hedonic pricing, with an emphasis on expected avoided harm.	Valuation system for avoided damage that could be equally applied to the remediation of environmental mining legacies.
	River defences	Avoidance of direct damage (destruction of infrastructure), indirect damage (to activities) and externalities (safety, health and aesthetics). Revaluation benefits are also possible.	Similar to the previous point.
	Environment: - Valuation of municipal waste.	Savings in landfill disposal, from sales (reflects added value) and from resource and energy savings in internal processes (recycling).	Value addition can also be a valuation alternative for the remediation of environmental mining legacies.
	Fishing grounds	Resource savings and extraction losses, and increased capacity.	There are also cases of supporting infrastructure to increase the productivity of natural resources.
	Forestry and agriculture: - Multipurpose reservoirs. - Irrigation and drainage.	Increased agricultural surpluses through improved farm yields and savings in production costs, conservation and release of resources. Increase through allocation of water for other uses (such as energy or mining).	Higher soil productivity on account of investments.
	Urban mega-parks	Indications for estimating willingness to pay through contingent valuation or hedonic pricing.	Although not at the urban level, the parks could play a role in some alternatives for the remediation of environmental mining legacies.

Country	Sector	Valuation of benefits	Comment
Costa Rica	Infrastructure in small irrigated areas.	Valuation of benefits from increased surpluses of agricultural produce, which must be reflected in both the economic and financial analyses.	Higher soil productivity on account of investments.
Mexico	Hydro-agricultural infrastructure.	Valuation of the benefit of increasing the agricultural social surplus by increasing the productive area, higher yields from current areas and crop changes.	As above.
	Environment: - Construction of a municipal wastewater treatment plant. - Integrated urban solid waste management.	Description of benefits through the increased net surplus from productive activities and decrease in diseases. The benefits from integrated municipal solid waste management projects generally involve cost reductions or the freeing up of resources as a result of changes in technology driven by the projects.	This results in higher productivity and health cost savings because better quality water is available, or because of the remediation of environmental mining legacies. The reuse of materials recovered from municipal solid waste generates productive benefits and increased material consumption.
Peru	Agriculture: - Small-scale irrigation. - Large- and medium-scale irrigation. - Flood protection and control.	Benefits from increased agricultural production, release of resources from alternative systems and cost savings through risk reduction. In medium and large investments, benefits include higher land values, higher water value and increased output. The benefits of investments in flood protection and control include cost savings related to emergencies, service interruptions and so on.	Increased soil productivity and protection of assets and activities.
	Tourism	Benefits from increased spending by tourists (foreign or domestic visitors).	Income from tourismcould contribute to the remediation of environmental mining legacies.
Uruguay	Marinas	Benefits from foreign exchange income from tourism and resource savings for domestic users.	As above.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Nuevo contenido sobre inversión pública y red SNIP", Santiago, 4 February 2021 [online] https://observatorioplanificacion.cepal.org/es/news/nuevo-contenido-sobre-inversion-publica-y-red-snip.

2. Countries and sectors using cost-effectiveness analyses

Cost-effectiveness analysis is primarily used in socially sensitive sectors, such as education and health, and in those undertaking infrastructure projects. However, it is also found in the sanitation, drinking water and sewerage sector, in information and communication

technologies, in policing and the armed forces, in the replacement of public lighting, in sporting and justice infrastructure, and in public sector training. Like cost-benefit analyses, cost-effectiveness analyses are also used in the environmental and natural resources sectors (see table III.8).

■ Table III.8

Latin America and the Caribbean (6 countries): use of cost-effectiveness analyses in the environmental and natural resources sectors

Country	Sector	Considerations in defining the efficiency criterion	Comment
Bolivia (Plur. State of)	Environment: - Conservation and management of natural resources and ecosystems. Minor projects. - Watershed management. - Environmental quality control. - Categorization of solid waste projects.	In smaller and more frequent investments, use of the cost-efficiency indicator —which indicates the expected change in relation to the goal established for each case– is recommended. In contrast, cost-effectiveness analysis should be used for major and medium-sized solid waste projects (economic evaluation of the project).	This sector is also considered in the cost-benefit analysis, but because of size and cost criteria, it warrants a relatively less complex analysis (avoid valuing benefits).
Chile	Environment: - Household solid waste.	Comparison and selection of alternatives through the cost-per-ton-disposed indicator.	Environmental considerations for analysis.
Costa Rica	- Final disposal sites for ordinary solid waste.	Creation of alternatives that can be selected using the lowest-cost method based on the present value of the costs and the equivalent annual cost. The indication of benefit value is used only in easily quantifiable cases.	As above.
Honduras	Agroforestry: - Irrigation system.	Selection of alternatives using indicators of equivalent annual cost per litre of water delivered and least cost, under conditions of equal quality and regular resource delivery.	This sector is also considered in the cost-benefit analysis. Efficiency criteria alternatives are used to replace the valuation of benefits.
Mexico	Environment - Integrated urban solid waste management.	Urban solid waste treatment and disposal projects are evaluated using cost-effectiveness analysis. Indicators for the cost-effectiveness analysis include the present value of costs, equivalent annual cost and average cost per ton of waste handled.	This sector is also considered in the cost-benefit analysis. Municipal solid waste collection reduces negative externalities on the community. Social benefits are created.
Peru	Public cleaning services	Selection of alternatives using cost-efficiency indicators of monetary units per metric ton of solid waste or per inhabitant.	Environmental concerns are taken on board in the analysis.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Nuevo contenido sobre inversión pública y red SNIP", Santiago, 4 February 2021 [online] https://observatorioplanificacion.cepal.org/es/news/nuevo-contenido-sobre-inversion-publica-y-red-snip.

3. Characteristics of national frameworks

In many of the region's countries, cost-benefit analyses and cost-effectiveness analyses are not applied in a sector-specific manner. Instead, general application guides exist, with broad, conceptual guidelines on how to conduct those analyses and the situations in which one or the other should be used. Cost-benefit analyses can be carried out in specific cases, even if the country in question does not have a reference tool or a guide (for example, large-scale investments financed through international agencies such as the Inter-American Development Bank and the World Bank in El Salvador).

For cost-benefit analyses, similar sectors consider the benefits in the same way. In all the countries, the generalized travel cost reduction benefit is applied in the transport sector. In special cases, benefits associated with increased productivity on account of higher sales are included.

In reviewing instruments that use cost-effectiveness analysis, national governments may adopt efficiency or effectiveness criteria that are not necessarily the same for equivalent sectors. In certain situations, no specific indicator is provided, which allows those that are specific to the type of project in question to be considered.

In those countries that have only general references that are not divided by sector, national public investment systems tend to be more recent developments. Since the 1970s, the implementation of such systems in the region's countries has encouraged the use of cost-benefit analysis as the main tool to guide, support and decide on public investment in most of the countries. The aims of national public investment systems include guiding and rationalizing the efficient allocation and execution of public investment resources in each country, which helps to increasingly institutionalize the adoption of cost-benefit and cost-effectiveness analysis in the region.

Those responsible for the systems are in charge of keeping updated the social prices (account or shadow) necessary for both the cost-benefit analysis and the cost-effectiveness analysis to generate economic or social values or indicators. In this way, when applied to the corresponding investments, the effective opportunity cost to the country's economy is revealed (see chapters V and VI).

In most of the countries surveyed by OECD/IDB (2016), cost-benefit analysis is carried out using an integrated financial analysis approach, and about half of those countries also include the quantification of environmental externalities. As regards opportunities for improvement, it was noted that countries do not systematically incorporate evaluations of the impact of investments on regional development, which could perhaps be remedied through a distributive approach with differences by territory (see chapter VI).

Chapter IV

Prior steps for a comprehensive and sustainability-focused assessment of a remediation project

Introduction

This chapter sets out the main variables to be taken into consideration in conducting the cost-benefit analysis and, subsequently, in evaluating remediation options. In particular, it identifies the components of a project through its life cycle and the preconditions for a cost-benefit analysis.

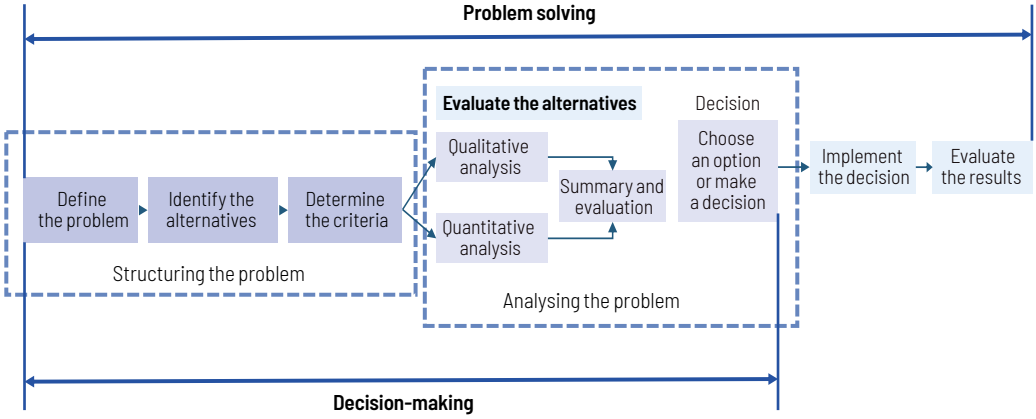
It describes the traditional steps in executing an analysis of this type and the other components that enable emphasis to be placed on sustainability. It also presents the conceptual model methodology for identifying the impacts and risks of mining environmental legacies and it stresses the importance of determining their area of influence. It then details the steps needed to conduct a risk assessment that covers conditions of vulnerability and the need to quantify the impacts of possible inaction.

Finally, it highlights the following: (i) mechanisms to guarantee the feasibility of the investment, (ii) methodological tools, and (iii) the information and documentation required to begin the cost-benefit and risk analyses.

A. Project cycle

Preparing remediation projects requires that the project be defined, a process that begins by identifying and analysing the problems, needs, opportunities or risks that require it to be carried out (in this case, those associated with mining legacies). Based on the above and to enable implementation, feasibility studies are conducted to assess the project's profitability. Decision-making begins with identifying and defining the problem and ends with the selection of an alternative (see diagram IV.1). A mining environmental legacy remediation project is deemed complete once it has been implemented satisfactorily.

■ Diagram IV.1
Stages in problem solving

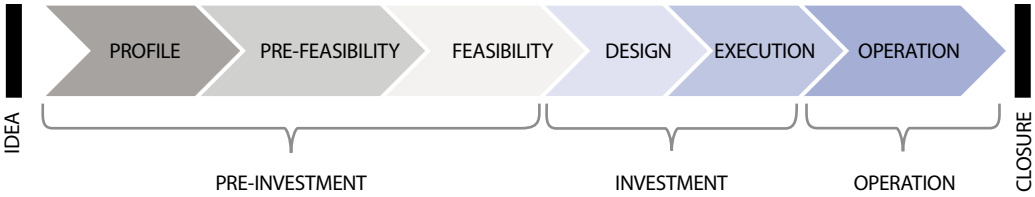


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of G. Toskano, "El proceso de análisis jerárquico (AHP) como herramienta para la toma de decisiones en la selección de proveedores: aplicación en la selección del proveedor para la empresa gráfica comercial MYE S.R.L.", Lima, National University of San Marcos (UNMSM), 2005.

The life cycle of a project —in this case, the execution of a remediation project— comprises three main stages: (i) pre-investment, (ii) investment, and (iii) operation. Between the original idea and project closure, there are several phases that ensure that the project achieves its objectives effectively and efficiently and in a way that serves the public interest (see diagram IV.2).

Adequate financial resources must be available during all stages of the project life cycle and must be incorporated into the project budget. In accordance with legislative requirements and the scale and nature of the project, a fund is also established to finance the future activation of the remediation plan. The profiles and numbers of the human resources involved vary throughout the project life cycle.

■ Diagram IV.2
Stages in the life cycle of a project



Source: E. Morín, *Guía general para la presentación de evaluaciones costo y beneficio de programas y proyectos de inversión*, 2018, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2018.

1. Pre-investment

The pre-investment phase comprises all the pre-investment studies that help minimize the uncertainty of the project's expected outcomes in the design, execution and operation substages. In general, three levels of depth are established for the execution of those studies: profile, pre-feasibility and feasibility (see table IV.1). When mining legacy remediation projects (like any other civil work projects) are the responsibility of the State, it is necessary to implement socioeconomic evaluation mechanisms, in accordance with their complexity, to guarantee financing. If the work required to remediate mining environmental legacies is complex or extensive, the socioeconomic assessment should include a cost-benefit analysis.

■ Table IV.1
Classification of investment programmes and projects in cost-benefit analyses

Study tier	Analysis type
Conceptualization	Technical data
Profile	Cost-benefit analysis (simplified)
	Cost-effectiveness analysis (simplified)
Pre-feasibility	Cost-benefit analysis
	Cost-effectiveness analysis

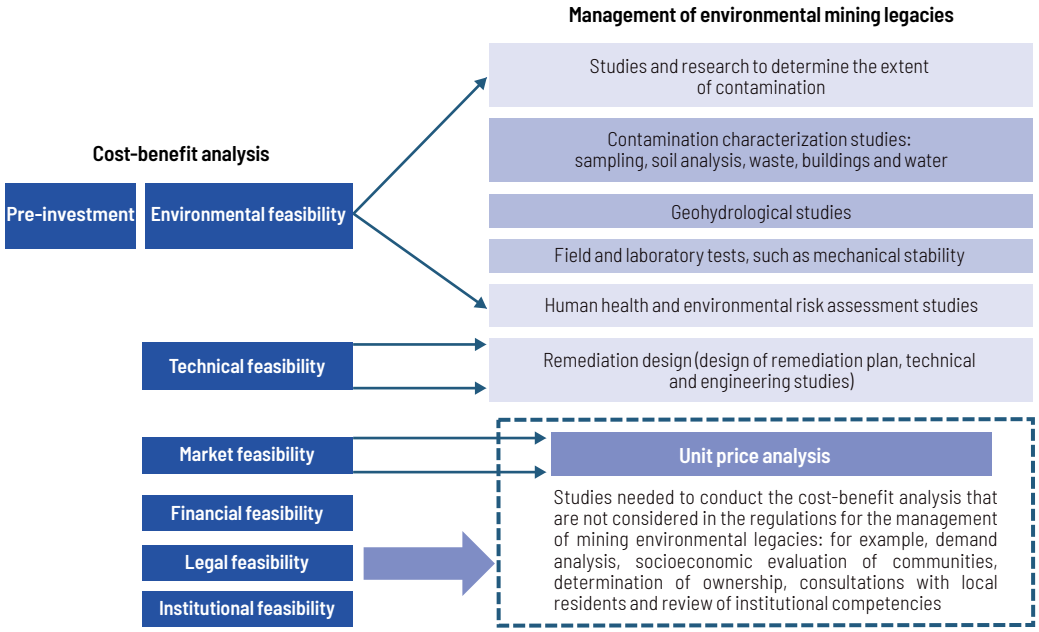
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of J. Meixueiro y otros, "Guía general para la presentación de estudios de evaluación socioeconómica de programas y proyectos de inversión: análisis costo-beneficio. Actualización 2015", Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2015.

Pre-feasibility studies, in both cost-benefit analyses and cost-effectiveness analyses, aim to increase the precision of the estimates of the variables that influence the project (such as costs and, in the case of cost-benefit analyses, benefits). In addition to the elements considered in the evaluation at the profile level, primary information sources are used, such as: (i) field work, (ii) technical studies, (iii) quotations, and

(iv) surveys designed specifically for evaluating the project (see diagram IV.3 and chapter VI). The quantification and valuation of costs and benefits are therefore more detailed and accurate and have a higher degree of reliability. The information used for the analysis at the pre-feasibility level must be verifiable and indicate the sources used. Cost parameters are obtained through basic engineering studies.

■ Diagram IV.3

Pre-investment stage in the life cycle of a project and its relationship with the management of mining environmental legacies



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Morín, *Guía general para la presentación de evaluaciones costo y beneficio de programas y proyectos de inversión*, 2018, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2018; U. Ruiz, *Guía técnica para orientar la elaboración de estudios de evaluación de riesgo ambiental de sitios contaminados*, Mexico City, Secretariat of the Environment and Natural Resources (SEMARNAT), 2006; Presidency of the Republic of Mexico, *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City, 2006.

During pre-investment, it is essential for the agency promoting the project to invest in studies that determine the following types of feasibility (Morín, 2018):

(i) **Market feasibility**: Demand, supply and price behaviours are studied to ensure the future use of the goods or services to be provided by the remediation project during its operation, in order to optimize the size, timing and location of the project.

(ii) **Technical feasibility**: Engineering studies are conducted to determine the efficient and effective use of the resources available to produce the goods or services to be offered by the project. The alternatives and the conditions under which the productive factors can be combined are evaluated. In addition, the

associated operating costs and revenues, as well as the disaster risk mitigation measures established for each alternative, are defined by quantifying the capital investment amounts and projecting them over time.

(iii) **Financial feasibility**: The financing mechanisms that will guarantee the execution and continuous operation of the project during its life cycle are determined.

(iv) **Legal feasibility**: To ensure that all phases of the investment project comply with legal requirements.

(v) **Environmental feasibility**: Analysing the impact the project will have on environmental conditions at the project site, the regulations to which it must observe and the restrictions on its execution or operation. Decisions are reached on whether the project can be implemented, whether it requires modification or whether it should be cancelled or relocated.

(vi) **Institutional feasibility**: Intended to verify whether the institutions involved in the project have the technical, legal, regulatory, financial and other powers and capacities to execute, operate and maintain the investment project (see box IV.1).

The project's socioeconomic evaluation (within the framework of the cost-benefit analysis) can only be carried out with feasibility studies, combined with specific studies, and enables a conclusion to be reached regarding the project's socioeconomic profitability (Morín, 2018; see diagram IV.3).

The cost of the study must be in line with the level of investment. For the remediation of mining environmental legacies, this involves a variety of initiatives with different characteristics (for example, the types of mining environmental legacies involved, their locations and the remediation techniques). Common elements associated with economic projections and technical forecasts therefore exist and which, when incorporated into a methodological handbook such as this one, allow cost-benefit analysis studies to be carried out at the profile level with a satisfactory level of confidence regarding the robustness of the results.

■ Box IV.1

Absence of specific budget items for mining environmental legacies

The remediation of mining environmental legacies can be considered social and environmental infrastructure projects. It is not easy to find, in the manuals or classifiers by object of expenditure, a budget item that covers the execution of mining environmental legacy remediation projects, since these classifiers are designed for traditional infrastructure projects. The emergence of new types of governmental tasks associated with environmental issues has not been accompanied by the development of corresponding classifiers (SHCP, 2018).

The lack of a specific budget item for the remediation of mining environmental legacies is one of the obstacles that arise when determining legal and institutional feasibility. In the case of Mexico, for example, there is no sub-item related to the remediation of mining environmental legacies in spending chapter 6000 (public investment), or in subchapters 6100 (public works on public property), 6200 (public works on own property) or 6300 (productive projects and development actions).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Ministry of Finance and Public Credit of Mexico (SHCP), "Clasificador por objeto del gasto para la Administración Pública Federal", *Diario Oficial de la Federación*, Mexico City, 26 June 2018.

2. Investment

The investment stage covers the implementation of remediation, rehabilitation or restoration, including components, equipment, process and procedure design, alleviation of impact and human resource management. This phase involves all the actions necessary to guarantee the project's correct operation over time (Morín, 2018).

3. Operation of the remediation project

The operation phase addresses the problem, need, opportunity or risk that gave rise to the remediation project. In other words, this is the stage at which the project generates benefits. However, it also entails operating and maintenance costs and the reinvestment of assets that are reaching the end of their useful life (Morín, 2018).

A management plan is drawn up for the entire mining environmental legacy remediation project cycle, detailing the most important guidelines, data and considerations (see diagram IV.4). The organization in charge of the project must keep this plan updated.

■ Diagram IV.4
Documentation for the remediation management plan

Remediation goals and criteria (see sections II.A. and IV.B.1.)	Legal issues (see section II.C.)	Technological recommendations and justification of the preferred remediation option (see sections II.A. and F. and chapter VI)
Review of best practices and reference standards (see, for example, Garbarino and others, 2018)	General guidelines and instruments (see chapter II)	Records of stakeholder engagement (see section II.E)
Contingency plan (for the entire project life cycle)	Socioeconomic plan (see chapter V and sections IV.B.1., VI. C and D)	Field research (see section IV.B.2)
Remediation plan (see section IV.B.5.b)	Budget (including contingency funds) and project duration (see sections IV.A and VI.B)	Human resources needed for the project (see section IV.A)
Inventory and record management (see sections II.B.6 and IV.B.2)	Follow-up and monitoring (see chapter VII)	Post-closure management plan (see chapter VII)

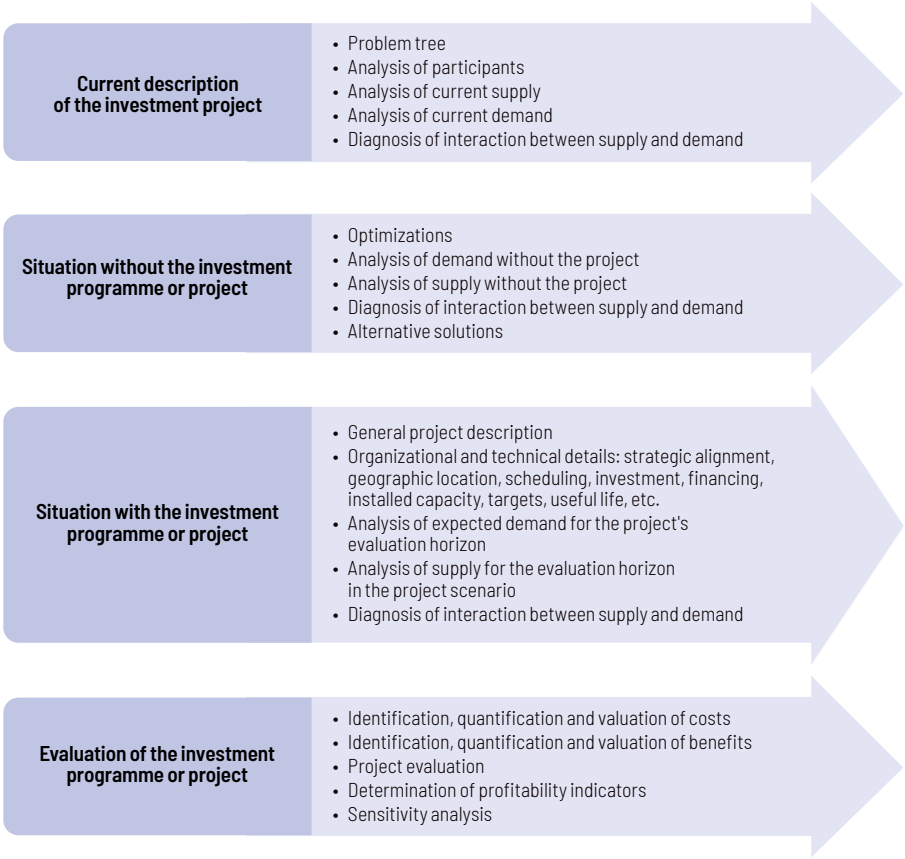
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of International Organization for Standardization (ISO), *Mine closure and reclamation - Managing mining legacies — Part 1: requirements and recommendations*, Geneva, 2023; *Mine closure and reclamation - Managing mining legacies — Part 2: case studies and bibliography*, Geneva, 2023; E. Garbarino and others, *Best Available Techniques (BAT): Reference Document for the Management of Waste from Extractive Industries in accordance with Directive 2006/21/EC*, Luxembourg, European Commission, 2018.

Note: These guidelines does not replace the rules set by the International Organization for Standardization (ISO). Compliance with the rules requires consultation of the references listed in ISO (2023a and 2023b).

B. Steps for conducting a sustainability-focused cost-benefit analysis

This guideline is geared towards to studies at the profile level that allow decisions to invest or not in remediation to be made on the basis of the cost-benefit analysis or that serve as support for decisions on a possible disbursement linked to more in-depth pre-feasibility or feasibility studies (see diagrams IV.2 and IV.5). This need may arise, for example, in mining environmental legacies that require the recovery of their components in specific quantities and qualities.

■ Diagram IV.5
Constituent parts of the cost-benefit analysis

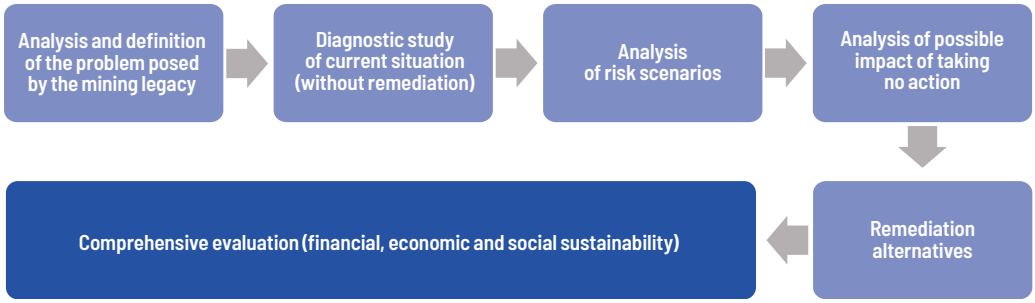


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Morín, *Guía general para la presentación de evaluaciones costo y beneficio de programas y proyectos de inversión*, 2018, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2018.

Prior to conducting the cost-benefit analysis, clarity is required regarding the obligations arising from existing accountability mechanisms (see chapter II). Like the definitions of mining legacies, these will influence the scope of remediation, rehabilitation or reactivation

projects. They are therefore essential to justify and support a cost-benefit analysis that leads to a request for resources. There are six key steps in conducting a comprehensive cost-benefit analysis for remediating a mining environmental legacy (see diagram IV.6).

■ Diagram IV.6
Steps in the cost-benefit analysis for remediating a mining environmental legacy



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of National Environment Commission of Chile (CONAMA), *Análisis y Desarrollo de Metodologías de Evaluación Económica para Planes de Descontaminación y Normas de Calidad Ambiental*, Santiago, 1997; Ministry of the Environment of Chile (MMA), *Guía metodológica para la elaboración de un análisis general de impacto económico y social (AGIES) para instrumentos de gestión de calidad del aire*, Santiago, 2013; S. Farrow and M. Toman, "Using environmental benefit-cost analysis to improve government performance", *Discussion Paper*, No. 99-11, Washington, D.C., Resources for the Future, 1998; Maastricht University/National Institute of Public Health and the Environment/Netherlands Institute of Mental Health and Addiction (Maastricht University/RIVM/Trimbos Institute), *Social Cost-benefit Analysis of Tobacco Control Policies in the Netherlands*, Maastricht, 2016.

1. Analysis and definition of the problem posed by the mining environmental legacy

The first step in a cost-benefit analysis is to clarify and characterize as clearly as possible the problem that the remediation project is expected to solve. Problem tree analysis is a tool that provides a general overview of the problem and its possible solutions, and it is widely used in the region's public investment sectors to quantify causes and effects (Wood, 1996).

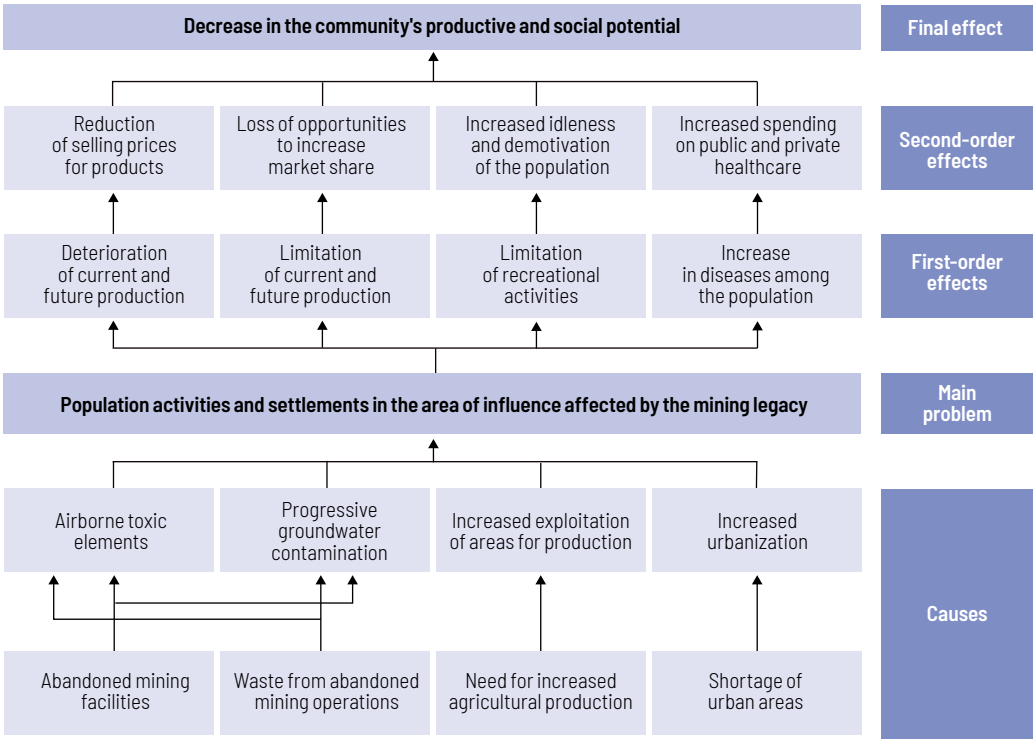
At this stage, all the problems identified in the affected community as of the study date are surveyed and classified as cause or effect with respect to a central problem (see diagram IV.7). The aim is to establish a causal relationship between all the problems that may be perceived within a community because of the existence of one or more mining environmental legacies. The breakdown of the cause and effect tree increases the possibility of identifying more effective solutions and more precisely defining the benefits of proposed remediation actions. Information on the problems caused by mining environmental legacies can be obtained primarily through consultations with local inhabitants, given their heightened sensitivity to the effects, and from written references such as studies and projects (see chapter II).

Contaminated sites can be identified through a detailed analysis of the origin of material transfers, hazardous waste and remaining mining facilities that have caused environmental damage. In addition, negative impacts on ecosystems may arise without being directly

related to hazardous materials or wastes. For example, illegal logging, the degradation of bodies of surface water by sewage discharge and the degradation of mangroves, wetlands, or environmental or natural protection areas can also cause damage.

■ Diagram IV.7

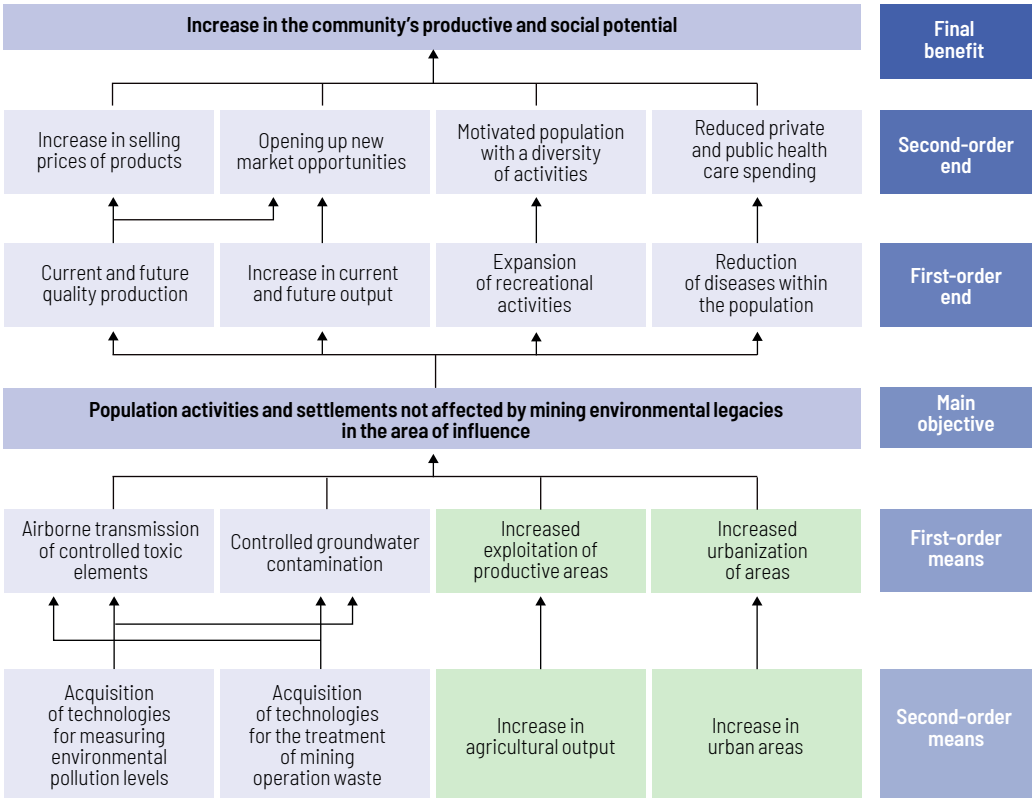
Example of a problem tree of a mining environmental legacy remediation project with facilities and waste from mining operations



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Ortegón, J. Pacheco and H. Roura, "Metodología general de identificación, preparación y evaluación de proyectos de inversión pública", *Manuals series*, No. 39 (LC/L.2326-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2005.

Next, the means-ends tree or objective tree is created, which is the positive version of the cause-effect tree. With this approach, the causes become the means to achieve the central objective, which is the resolution of the problem. In addition, the effects are transformed into the ends to be achieved by meeting that central objective (see diagram IV.8). Making it a central objective means that the population's activities and settlements are not affected by mining legacies, and that negative phenomena become positive. For example, if the cause of the problem were groundwater contamination, the desired objective would be for the groundwater not to contain contaminants, for the contamination to be confined and reduced and for it not to affect human health and activities. Other combinations that could generate alternative solutions can also be studied.

■ Diagram IV.8
Example of a means-ends tree for a mining environmental legacy remediation project



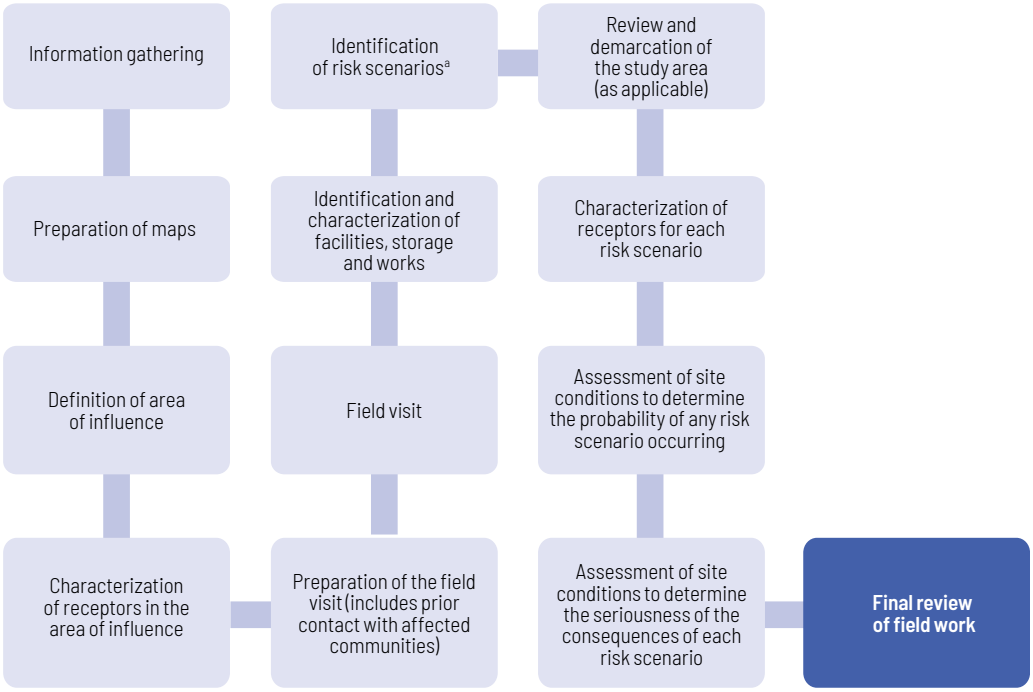
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Ortegón, J. Pacheco and H. Roura, "Metodología general de identificación, preparación y evaluación de proyectos de inversión pública", *Manuals series*, No. 39 (LC/L.2326-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2005.
Note: The exogenous elements corresponding to population growth are shown in green.

The maximum possible openness of the tree favours the identification a remediation project's specific contributions. For example, lower health spending can be studied by the groups of people affected, by the types of diseases and treatments and so on, which allows a more exhaustive assessment of the benefits. In the next stage of diagnosis, these differences allow detailed information (e.g. morbidity statistics) to be included, thus achieving adequate quantification. Indeed, the greater the number of causes analysed, the greater will be the number of actions aimed at resolving the problem (Ortegón, Pacheco and Roura, 2005).

2. Diagnosis of the current situation (without remediation)

The analysis of the current situation requires that preparatory work be carried out, even before the risk scenarios are assessed (see diagram IV.9). It is also based on the results of the sampling and site characterization research (geohydrological studies, field tests, geophysical studies, mapping and so on).

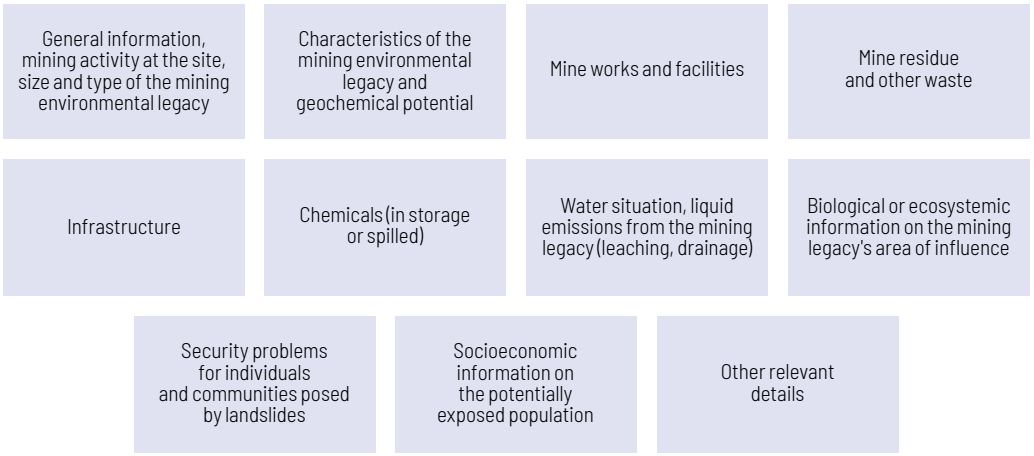
■ Diagram IV.9
Preparatory activities



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008.
[a] For each installation, storage area or site.

Once gathered and verified for quality control purposes, the information on mining environmental legacies is systematized in databases (for example, by means of data sheets; see diagram IV.10).

■ Diagram IV.10
Types of information collected after the field visit



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Next, to prepare the diagnosis of the current situation and in line with the steps listed in diagram IV.9, the following issues need to be examined in greater depth: (i) definition of the area of influence, (ii) characterization of the area of influence, (iii) characterization of the mining environmental legacy identified, and (iv) application of a conceptual model to the mining environmental legacy to establish the baseline.

(a) Definition of the area of influence

The geographical limits of the analysis are established: that is, the area in which the problem is located, where its causes are found and its effects are felt (see box IV.2). To that end, priority is placed on the following criteria:

- The location of the mining legacies identified and the entire area of expansion of their effects make up the basic criteria.
- If the area coincides with a political or administrative division (such as a town, commune, district or region), it is easier to obtain statistics and historical information, thus avoiding a specific data collection exercise.
- Natural boundaries, limits defined by infrastructure or any other significant element that may define the area are included (for example, hills, rivers, lagoons, lakes, highways, railways).
- Towns, communities and homes located within the area of influence of the mining environmental legacy are included.

■ Box IV.2
Graphic depiction of the area of influence

The area of influence must be clearly established according to the location of the identified mining environmental legacies. For this purpose, a map extract can be created using web mapping services such as Bing Maps or Google Maps (see plate 1). Another option is to record the mining environmental legacies on a sketch map or terrain graphic.

Plate 1
Mining environmental legacies (69, 742 and 1052) in the western sector of Copiapó, Chile

Source: M. Silva and G. Suazo, "Metodologías para el uso de factores de emisión: material particulado en depósitos de relaves abandonados", *Environment and Development series*, No. 170 (LC/TS.2020/92), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

A sufficiently large map area should be delimited to verify the most relevant characteristics of the activities potentially affected by the mining environmental legacy. If the map extract does not contain the complete information, it can be added by editing the map (when possible) or by adding symbols and written explanations.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of M. Silva and G. Suazo, "Metodologías para el uso de factores de emisión: material particulado en depósitos de relaves abandonados", *Environment and Development series*, No. 170 (LC/TS.2020/92), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020.

(b) Characterization of the area of influence

Once the area of influence has been defined, the main characteristics are described in order to contextualize and indicate the size of the problem and to provide a preliminary overview of the stakeholders and associated costs and benefits (see table IV.2).

■ Table IV.2
Categories of information about the area of influence to be collected

Population
• Population numbers and evolution (e.g. growth rate, milestones or other factors that could affect trends, such as the establishment of new industries or mines, seasonal factors or tourist attractions) • Territorial distribution of the population and settlement type (rural or urban) • Population distribution by age and gender and its evolution • Socioeconomic distribution of the population (e.g. poverty levels, employment, schooling, economic activities) • Disease and illness in the population • Physical distance between population settlements and the identified mining legacies • Historical or cultural heritage (e.g. for Indigenous groups; ISO, 2023a)
Activities
• Main types of productive activities (industry, forestry, agriculture, tourism, mining), productivity levels and relations with higher administrative divisions (e.g. a municipality with respect to its province or region) • Activities and employment levels • Land use • Other activities (cultural, sporting, religious)
Infrastructure and services
• Quantity, quality, type and location of infrastructure: - Public (roads, bridges and public buildings) - Private (housing and industrial, commercial or financial installations • Quantity, quality and type of services: - Public (drinking water, sewerage, energy, communications, public transport, health, education, law enforcement) - Private (leisure and entertainment)
Territory and ecosystems
• Natural and environmental resources, flora and fauna in the area • Natural parks and protected areas • Tourist attractions • Geomorphology, structure and composition of soils[a] • Hydrology, location, use and characteristics of water sources and courses[b] • Physical distances between those elements and the identified mining legacies
Climatological conditions
• Level and intensity of rainfall • Direction and intensity of winds[c]
Seismic activity
• Frequency and intensity of seismic activity
Specific data on problems detected in the tree
• For example, the number of hectares of affected crops and the related value of production, morbility rates compared to unaffected areas and the associated spending on health (by both individuals and the State)

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of International Organization for Standardization (ISO), *Mine closure and reclamation – Managing mining legacies — Part 1: requirements and recommendations*, Geneva, 2023.
[a] In combination with climatic conditions, these determine the severity of the effects of mining environmental legacies.
[b] These affect such factors as the filtration or infiltration of tailings water or the collapse of materials in landslides.
[c] These transport potentially dangerous particles.

(c) Characterization of the identified mining environmental legacy

All the characteristics of the identified mining environmental legacies are compiled to weigh and evaluate the severity of the current problems and the risk of long-term problems. This ranges from visual aspects, such as modifications to landscape aesthetics and impacts on cultural heritage, to issues such as air, soil and water pollution, noise and vibrations, changes in morphology and soils, loss of flora and fauna, and socioeconomic shifts (see chapter I). In this way, specific information is recorded to verify the existence of the previously explained risk vectors and to combine the elements of the previous item with the characteristics of the mining legacy.

In a given case, some of these risk vectors —or others related to site conditions, climate and the mining environmental legacy— may be present. All of them must be adequately described for the subsequent systematization of the risk scenarios (see chapter II).

(d) Conceptual model

The conceptual model is a tool that registers the characteristics of a mining environmental legacy through an iterative process, describes the exposure scenario through which receptors may come into contact with toxic substances at a contaminated site and serves as a basis for risk assessment (Ruíz, 2006; SEMARNAT, 2007; Congress of the Republic of Peru, 2014; European Commission, 2010; EPA, 2014; see box IV.3). Conducting a detailed risk assessment is important, even if the mining environmental legacy has already undergone a technical management process covering inventories, sampling and preliminary risk assessments (Arranz-González and others, 2020b).

The conceptual model provides an overview of the situation at the site and allows the sources, destinations and transport of contaminants to be recorded correctly in the environmental matrices. It also helps identify exposure pathways and potentially affected receptors or resources. On this basis, the contamination problem can be defined, together with its scope and the exposure and risks to be mitigated through remediation.

■ Box IV.3
Sample legal definitions of the conceptual model

The definitions of the conceptual model contained in Latin American legislation are broadly convergent. Some examples are highlighted below:

Chile: "Written account and/or graphic representation of the environmental system and of the physical, chemical and biological processes that determine the transport of contaminants from the source, through the channels that make up the system, to the potential receptors that are part of it" (MMA, 2013b).

Mexico: "A tool that allows the written or schematic representation of the prevailing conditions at a site and that shows the distribution, transport and release mechanisms of contaminants and in which the possible routes[a] and pathways[b] of exposure, as well as potential receptors, are inferred. The conceptual model also helps establish the study area" (SEMARNAT, 2007).

Peru: "Written account and/or graphic representation of the environmental system and of the physical, chemical and biological processes that determine the transport of contaminants from the sources of pollution to the potential receptors, through the environmental components that make up that system" (Congress of the Republic of Peru, 2017).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Congress of the Republic of Peru, "Aprueban criterios para la gestión de sitios contaminados: decreto supremo N° 012-2017-MINAM", *El Peruano*, Lima, 2 December 2017; Ministry of the Environment of Chile (MMA), *Resolución Exenta N° 406/2013. Aprueba Guía Metodológica para la Gestión de Suelos con Potencial Presencia de Contaminantes y sus Anexos, y deja sin efecto resolución que indica*, Santiago, 2013b; Secretariat of the Environment and Natural Resources (SEMARNAT), "Norma oficial mexicana NOM-147-SEMARNAT/SSA1-2004, que establece criterios para determinar las concentraciones de remediación de suelos contaminados por arsénico, bario, berilio, cadmio, cromo hexavalente, mercurio, níquel, plata, plomo, selenio, talio y/o vanadio", *Diario Oficial de la Federación*, Mexico City, 2 March 2007.

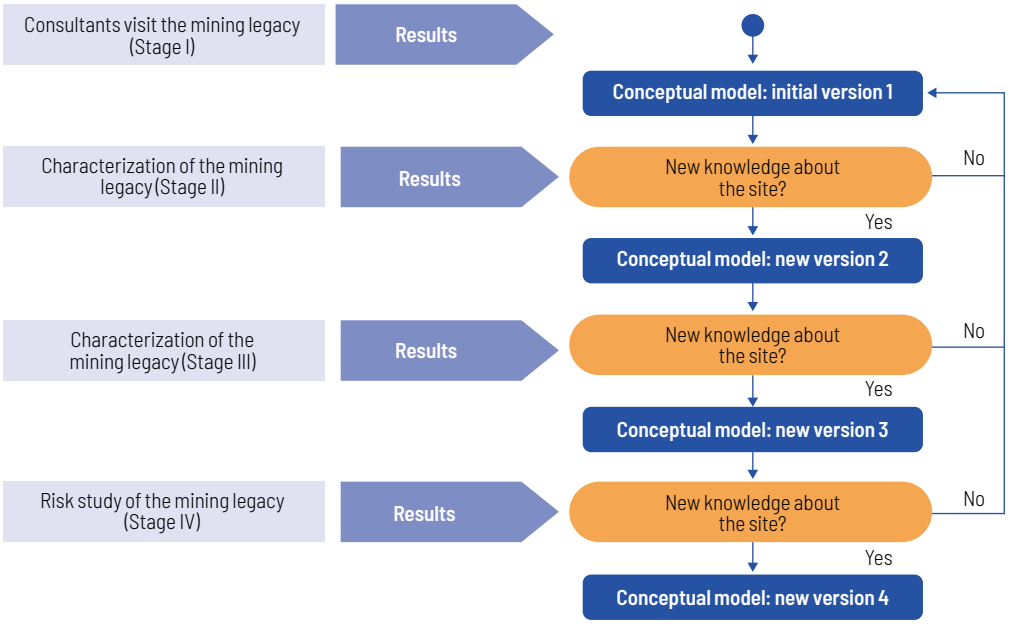
[a] Pathways through which the contaminant travels from the source to the receptor.

[b] Routes or forms of entry of contaminants into organisms (those routes that pose risks to human health include ingestion, inhalation and dermal contact).

The conceptual model is usually drawn up in the first stages of mining environmental legacy management and remediation. The results and information obtained from the site characterization studies described above are processed. As the characterization process progresses and knowledge about the site increases, the conceptual model can be amended (see diagram IV.11). When the preparation of the risk study begins, this process may or may not continue and the assumptions and conclusions underlying the conceptual model may be modified. At this stage, the conceptual model reaches its almost final version, since it already has the characteristics necessary for inclusion in the remediation proposal.[1]

■ Diagram IV.11

Iterative process for designing a conceptual model for a mining environmental legacy



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Secretariat of the Environment and Natural Resources (SEMARNAT), *Guía técnica para orientar la elaboración de estudios de evaluación de riesgo ambiental de sitios contaminados*, Mexico City, 2006.

The conceptual model enables the definition of the mining environmental legacy problem to be resolved by taking into account the contaminants and concentrations that pose a risk or exceed the nationally or internationally specified concentrations, the environmental matrices affected by the contaminants and the populations or groups of people that may be exposed to them (see chapter II). Factors that could affect the dispersion of contaminants are addressed (see diagram IV.12).

[1] The remediation proposal contains the decontamination plan, which is submitted to the authorities for evaluation and approval. This plan includes the remediation process, treatment, inputs, equipment, remediation levels and the sampling plan during and after remediation. It also provides such necessary information as location diagrams and treatment areas (see article 141 in Office of the President of Mexico, 2006).

■ Diagram IV.12
Factors affecting dispersion of contaminants

Physicochemical properties of contaminants	• Waste (e.g. slags, tailings, tailings or ashes), their concentrations and leaching of potentially toxic compounds • Effluents, leachates and liquid filtrations • Particulate emissions (dust) and their possible dispersion
Site geohydrological characteristics	• Site edaphological, geological and geohydrological characteristics • Physicochemical and mechanical properties of slags and tailings • Naturally occurring background concentrations in the mining legacy's watershed • Conditions of bodies of water and runoff in the immediate watershed of the mining legacy
Climate conditions	• Rain and wind patterns • Risk of extreme weather events
Time elapsed since the onset of contamination	• Exposure present in residential homes and individuals • Quality of food, crops and livestock in the area where the mining legacy is located
Physical characteristics of the site	• Mechanical stability of the mine and the waste and tailings deposits • Buildings and facilities, the volumes and mass of building materials (potential demolition waste) and their possible contaminant content

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: The list of examples is not exhaustive.

In line with the above, the conceptual model indicates the data to be taken into account during the remediation process and that contribute to cost estimation and the cost-benefit analysis (see diagram IV.13). The assessment of the situation will also help determine, in the post-remediation stage, whether the measures adopted yielded the expected benefits.[2]

■ Diagram IV.13
Relevant data for the cost-benefit analysis obtained from the conceptual model

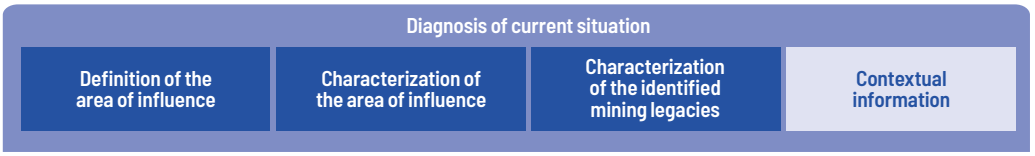
Volume and mass of contaminated soil and water	Type, volume and mass of waste (municipal solid, non-hazardous, high volume and hazardous	Risks to be reduced by exposure route and pathway and by vulnerable population group
Exposure routes to be interrupted	Situation and mechanical stability of open pits and waste piles (tailings, slag or earth piles)	Current measurable human exposure (through clinical trials)

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[2] For example, monitoring the lead levels in blood of children, which can lead to reduced intellectual development and other health problems in an exposed population (CDC, 2023; EPA, 2018; WHO, 2021a). Such an exercise would also involve calculating the savings (or benefits) that would be obtained if the children did not have those health problems, considering the costs of treatment and care over the course of their lives, as well as the losses avoided in terms of labour productivity.

This stage concludes with the diagnosis of the current situation, which summarizes the most important elements in identifying and explaining the problems that the project seeks to address. This is achieved by examining the interaction between the supply and demand for the good or service under study (see chapter V). Using the previously prepared trees, information is collected and systematized to quantify the problem and its causes and effects (see diagram IV.14), which helps develop appropriate alternatives (see section "Development of remediation projects using the conceptual model" below).

■ Diagram IV.14
Component elements of the diagnosis of the current situation



Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: Elements in dark blue are covered by the conceptual model.

(e) Relationship between the conceptual model and total costs

The conceptual model provides a foundation for cost estimation at all stages of the remediation process. The conceptual model's quality also influences the quality of the sampling, the characterization study and the Environmental and Human Health Risk Assessment Study and, therefore, has an impact on the quality of the remediation plan or programme. Consequently, it will affect the costs of the different remediation alternatives. In general, the greater the number of sampling points, the lower the associated uncertainty (see box IV.4).[3]

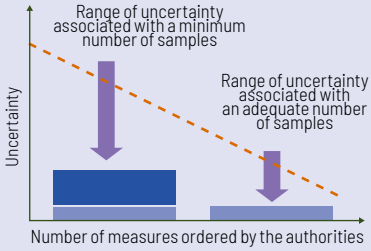
At the same time, the development of the conceptual model implies non-negligible costs that increase when environmental systems and ecosystems requiring protection are present (see diagram IV.15; for further details, see Ministry of Environment, Water and Ecological Transition of Ecuador, 2020). The costs of the studies that provide the information for drafting the remediation proposal (the decontamination plan) are summarized in the fixed investment in the framework of the cost-benefit analysis. When the problem is more extensive, the number of cost items rises, which implies increased project spending requirements.

[3] The currently available software packages (such as ArcGIS or Surfer) used to determine areas and volumes of contaminated materials are based on interpolation methods.

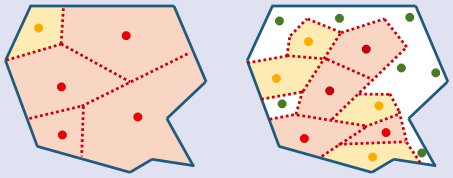
■ Box IV.4
Relationship between sampling quantity, uncertainty and remediation costs

An inverse relationship exists between the number of samples taken and the uncertainty regarding the extent of the contamination and the costs required for its remediation (see diagram 1). As a hypothetical example, if an area were to have only five sampling points and four of them had a high concentration (red dots) and one had a medium concentration (orange dot), the entire site surface would be considered contaminated (see diagram 2; Voronoi's polygon technique is used as an example and in schematic form). If the number of sampling points in the same area were increased, some without contamination could be identified (green dots). By making interpolations according to the selected geostatistical technique, a part of the site would be considered clean. The volume of contaminated soil appears higher when fewer sampling points are used, which has an impact on costs (see diagram 3).

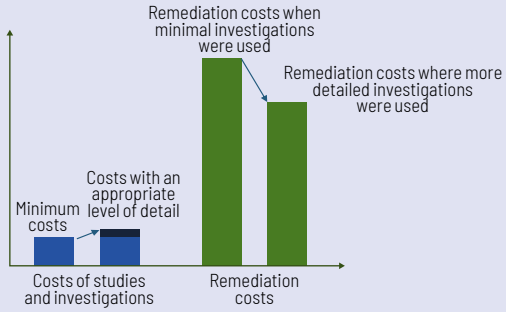
■ Diagram 1
Relationship between uncertainty and measures ordered by the authorities



■ Diagram 2
Application of Voronoi's polygon technique



■ Diagram 3
Relationship between remediation costs and more detailed investigations



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Appropriate site characterization studies can produce prioritized lists of materials ordered by volume, toxicity, texture and proportion of fines or degree of adsorption. These data will help establish which materials warrant priority for proper treatment or disposal and which materials pose the lowest risks to humans or the ecosystem.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

■ Diagram IV.15
Cost items for studies associated with a potentially affected ecosystem

Preliminary	Technical survey	Characterization of the site
• Site visits • Desk work to locate site • Identification of physical characteristics	• Topographic survey • Aerial photos • Inventory of facilities	• Sampling • Laboratory analysis • Specific studies (e.g. geophysical and hydrological) • Field tests

Characterization of the ecosystem	Evaluation studies	Final proposals
• Identification of species (terrestrial, aquatic or by trophic level) • Registration of species • Production of regional aerial photos • Sampling (at different times of the year and in different years) • Testing • Analysis	• Environmental and Human Health Assessment Study (EHHAS) • Ecotoxicological risk assessment study of selected ecosystem species	• Remediation proposal (decontamination plan) • Ecosystem management proposal to reduce exposure

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: The baseline scenarios assume that a population is exposed to the mining environmental legacy. Items associated with adverse effects on local ecosystems are shown in italics.

3. Risk scenario analysis

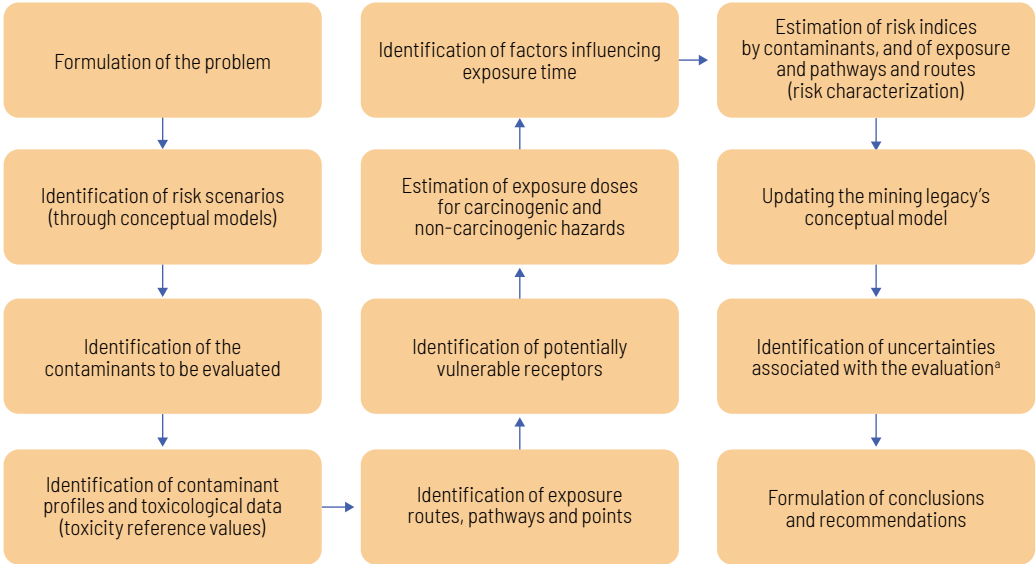
Once the current situation at the mining environmental legacy, its area of influence and potential exposure have been described and diagnosed, forecasts are made of the progressive damages associated with the legacy to identify long-term situations based on the existence of the previously identified risk vectors (see chapter II). Degrees of vulnerability are assigned to account for the level of risk and the likelihood of a contamination event occurring and increasing over time.[4]

Hazards related to the presence of waste (linked to exposure to contaminants), the facilities and the mine are then assessed. More specifically, it is determined whether there are risks of, for example, landslides, collapse or subsidence or other hazards associated with meteorological phenomena, as well as contaminants present at the site, which may be toxic depending on exposure conditions (see diagram IV.16).

[4] For example, increases in the instability and deterioration of membranes that protect tailings and tailings deposits, making contamination and expansion more likely.

Using the data, assessment matrices are created for each aspect of the mining environmental legacy, with the information and risk assessment for each element and criterion, which together produce an overall risk assessment of the mining legacy (see table IV.3). The vulnerability assessment is based on an estimate of the probability of contamination occurring.

■ Diagram IV.16
Risk assessment activities for potential receptors of exposure to contaminants present at the study site



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008.
[a] Regarding both the assumptions on which the assessment is based and the exposure doses and risks.

■ Table IV.3
Peru: qualitative risk assessment for mining environmental legacies C

Human safety	Human health and physical environment	Wildlife and conservation
Accessibility	Drainage in openings	Accessibility and exit routes for wildlife
Collapse potential	Evidence of previous flooding, drainage or spillage events	Wildlife attraction
Closing condition	Potential generation of acid drainage	Signs of wildlife
Potential for people falling into the opening and being injured	Potential for human access to poorly ventilated confined spaces	Vegetation in and around the site
Presence of signposts and fences to limit access	Other health hazards	Proximity to protected areas

Human safety	Human health and physical environment	Wildlife and conservation
Presence of debris, vegetation, rocks, residues, etc., inside		Sensitivity of the area (traditional land use, wildlife corridor)
Other hazards to human safety		Accumulation of contaminated water (related to mining activities)
		Other environmental concerns

Source: M. Chappuis, "Remediación y activación de pasivos ambientales mineros (PAM) en el Perú", *Environment and Development series*, No. 168 (LC/TS.2019/126), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020; on the basis of Ministry of Energy and Mining of Peru (MINEM), "La intervención del Estado en la remediación de pasivos ambientales mineros", *Informativo Minero*, No. 12, Lima, 2018.

In order to determine the current situation and establish long-term risks, scenarios are proposed for the assessment horizon based on vulnerability criteria within the mining legacy's area of influence. The intensity of these types of vulnerability will depend on the type of mining environmental legacy and the risk vectors that may arise or worsen at different times over a given period (see chapter II). The scoring system is established to reveal the intensity of each vulnerability (see table IV.4). It is sufficient for one type of affectation to be at level 3 for it to be assigned that value.

■ Table IV.4
Types and levels of vulnerability from exposure to the mining environmental legacy

Human health	Impacts on human health from direct contact with contaminants or contact with items exposed to contaminants (such as food, water or air)	3	Risks to human lives
		2	Contagion of serious diseases without risk of death
		1	Lesser impact
Social	Socioeconomic impact due to effects on productive or non-productive assets and activities, whether collectively or individually owned (sporting, cultural, recreational, religious)	3	Impact on low-income groups
		2	Impact on middle-income groups
		1	Impact on high-income groups
Eco-environmental	Alteration of the landscape and natural heritage, including the existing diversity of flora and fauna	3	Risk of disappearance of species and ecosystems
		2	Deterioration of species and ecosystems, without risk of disappearance
		1	Lesser impact, marginal alteration of the landscape

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

These levels or degrees of vulnerability are combined to determine a risk index that defines the scenarios that will be considered for the corresponding cost-benefit analysis.

$$\text{Risk index} = \alpha \times VHH + \beta \times VS + (1-\alpha-\beta) \times VE$$

Where:

α: Weighting of the relative weight of human health vulnerability within the risk index

β: Weighting of the relative weight of social vulnerability within the risk index

VHH: Human health vulnerability level

VS: Social vulnerability level

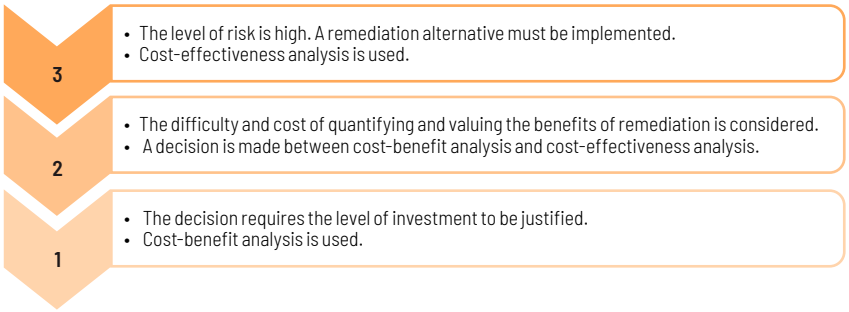
VE: Eco-environmental vulnerability level

The risk index is rounded to the nearest integer.

The weights correspond to the relative importance of each vulnerability criterion in the risk assessment of the mining legacy in the area of influence. They are previously defined as parameters of the cost-benefit analysis and are based on an appropriate diagnosis of the area that reveals the order in which those vulnerabilities are found. The weightings can be updated on a regular basis (for example, every one or two years).

Determining the risk index associated with the remediation project under analysis establishes the level of urgency or priority of the project according to its resulting risk level. In this way, a decision can be made regarding when an evaluation should be conducted to implement the project or not and regarding the selection of the best implementation alternative (see diagram IV.17).

■ Diagram IV.17
Actions according to risk index



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

(a) Multilevel tiered evaluation frameworks

Risk assessments should be performed iteratively. A tiered evaluation framework approach starts with a preliminary or basic assessment and, as the site investigation progresses, and if warranted by the legacy's complexity, more detailed and broader assessments can be produced. This model aims to balance the costs of adding detail and refinement to an assessment with the benefits that would yield, depending on the quality of the inputs and outputs (EPA, 1992b).

Tiered assessment frameworks determine whether more information is needed about toxic substance risk or exposure at contaminated sites (see section "Risk scenario analysis" above).

Three tiers are commonly established, which involve progressive efforts (costs) in the investigation according to the complexity of the studies carried out, taking into account the apparent significance of the level of contamination (see table IV.5).

■ Table IV.5
Main features of tiers in multilevel assessment frameworks

Study tier	Type of risk analysis by tier
Tier 1	The evaluation focuses on setting maximum values that cannot be exceeded in relation to the existing records and their evolution, according to the cases available in secondary sources (previous studies carried out in areas similar to the one of interest). The rigidity of the input values guarantees the protection of the exposed population. However, the risk values obtained from this simple model often produce conservative (overestimated) exposure assumptions, resulting in higher remediation costs.
Tier 2	Specific data for the mining environmental legacy are included in the risk models. Detailed sampling of the site's environmental matrices is carried out to determine the extent and severity of the damage. Technical and risk assessments are more extensive. Investments are made in specific inputs for the evaluation model (for example, geohydrological studies at the site and soil sampling to obtain parameters that establish more exactly the migration of contaminants and their concentrations at sites outside the source of contamination). More realistic assumptions are generated from the modelling.
Tier 3	This is a formal risk assessment. It is most often used on large or complicated sites and requires specific studies in the field. A probabilistic risk assessment is carried out, in which probability distributions of the assessment models' input and output parameters are determined; this is in contrast to considering the variables' point values, as in the previous tiers. The result is greater certainty, resulting in a risk estimate that is closer to reality, with more clearly defined remediation areas. If a higher level of investment is required, the remediation investment costs are also considerably reduced.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), "Superfund soil screening guidance", Washington, D.C., 2023 [online] https://www.epa.gov/superfund/superfund-soil-screening-guidance#user.

Some of the region's countries use two-tier methods (see box IV.5). In contrast, in one-tier systems, the preliminary assessment of a suspected contaminated site is part of the task of identifying, ranking and prioritizing contaminated sites and environmental legacies, and its objective is to create an inventory of such sites. Remediation is accordingly based on the results of a detailed and comprehensive risk assessment study.

■ Box IV.5
Examples of the use of two-level tiered evaluations

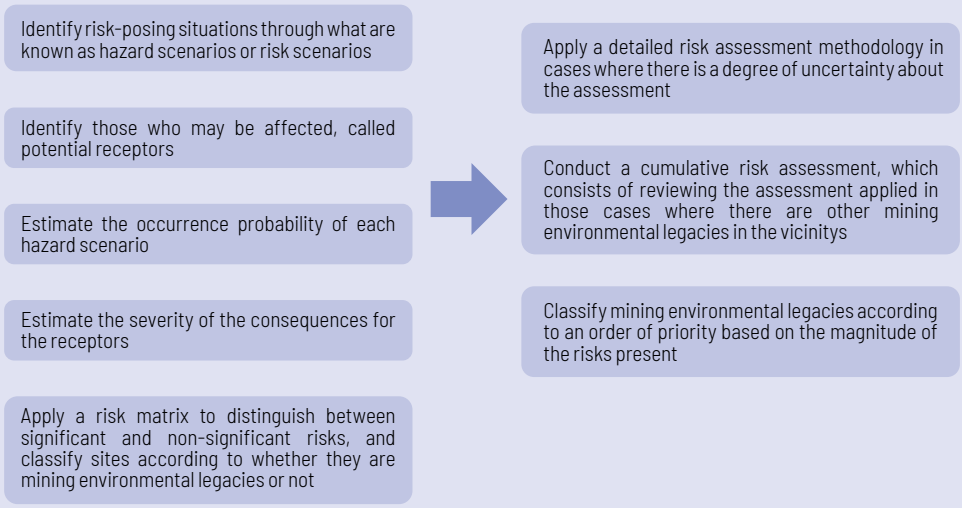
The Chilean (BGR/SERNAGEOMIN, 2008) and Spanish (Alberruche and others, 2014) tiered assessment systems address both physical (safety) risks posed by the structure or operation of the mine and environmental risks caused by people's exposure to contaminants present at the site. The first class of risks includes pits, adits or other similar hazards from mining activities that may have been left open, subsidence associated with underground workings or failures in tailings walls. Contamination risks include factors such as health hazards to potential receptors caused by the presence of hazardous waste abandoned in the mining environmental legacy (for example, arsenic, mercury or cyanide) and the risks associated with acid drainage.

The approach comprises two tiers of analysis:

Simplified safety and contamination risk assessment: Includes the essential analytical information of samples considered representative of each facility containing waste or contaminated soils in order to carry out the evaluation of the different risk scenarios. The information is qualitative and it incorporates both conservative criteria —which evaluate maximum exposure scenarios to ensure the protection of receptors— and criteria to economize in information gathering, which is based on the use of existing data or generic exposure data (see left-hand side of diagram).

Detailed safety and contamination risk assessment: Focuses on specific risks and justified cases where there is uncertainty with respect to the result yielded by the simplified risk assessment. The execution of a detailed risk assessment requires more budget and time, as it may require the use of specialists from outside the assessment team (for example, to conduct detailed field studies or apply specialized analysis techniques). In this way, the risk can be redefined more precisely (see right-hand side of diagram).

Stages of risk assessment in the BGR/SERNAGEOMIN tiered system (2008)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago, 2008.

Note: Hazard scenarios or risk scenarios are also referred to as "conceptual models" in other methodologies, as noted in previous sections.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P, Santiago, 2008.

4. Analysis of the possible impact of inaction

The potential socioenvironmental impacts of inaction are identified and estimated based on the results of the characterization studies related to the current situation diagnosis. Based on the characteristics of the mining environmental legacy (see diagram IV.12), an Environmental and Human Health Risk Assessment Study can be prepared for the current scenario (no-action or no-project scenarios).

Consideration must also be given to the future risks that will remain after each remediation alternative and that may be more or less economically feasible, depending on the risk reduction. This breakdown will ensure that when the analysis of the situation when addressed by a project (action scenario) is carried out, benefits that do not correspond to the project are not attributed to it (see box IV.6).

For the analysis horizon, supply projections for the next 20 to 30 years are recommended to reflect any changes that could occur. The analysis horizon is comparable to the payback period of an investment, and during this time the effects of constant exposure to potentially toxic elements on a group of people would be observed (Meixueiro and others, 2015).

■ Box IV.6
Component elements of the Environmental and Human Health Risk Assessment Study

Given that the Environmental and Human Health Risk Assessment Study links the remediation of the mining environmental legacy and the cost-benefit analysis, the study's terms of reference must specify that the final result is to include the following:

Current risk scenario (no-action scenario): Must indicate the level of risk in the current situation and the likely consequences of inaction on the three vulnerabilities (see table IV.4). Aspects that can be monetized are always taken into account.[a] No public intervention is considered regarding services and infrastructure to mitigate the effects of pollution on the community (for example, on health and public services such as water, drainage and roads).

Determining the social impacts of inaction.

Determining measures to optimize the current situation without project implementation: Refers to low-cost measures that could improve the current situation without the remediation project (see section "Optimization of the current situation" below).

Alternatives for future remediation scenarios: Must include those that are to be considered and compared in the cost-benefit analysis (see section "Remediation alternatives" below).

Cost estimates for the different scenarios and previous measures: To avoid additional steps and other bidding processes for those services. These studies must be conducted by a consortium of civil works specialists who will evaluate the risks and estimate the costs based on realistic market research.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of R. Efroymson, J. Nicolette and G. Suter, "A framework for net environmental benefit analysis for remediation or restoration of contaminated sites", *Environmental Management*, vol. 34, Berlin, Springer, 2004; J. Meixueiro and M. Pérez, *Metodología general para la evaluación de proyectos*, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2008; Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CrcCARE), *Remediation Action Plan Development: Guideline on Performing Cost-benefit and Sustainability Analysis*, Newcastle, 2019.

[a] See section "Risk scenario analysis" in this chapter.

The investigation must determine the potential socioenvironmental impacts and provide an economic estimate based on the characteristics of the contamination, the site and the actions to be taken (see chapter V). According to Meixueiro and others (2015), the investigation must specify that the characterization studies and the Environmental and Human Health Risk Assessment Study contain the following:

- **Demand analysis**: Demand is re-estimated during the evaluation horizon to include the impact of any optimizations undertaken. The aim is to find out what would happen to the affected communities' claims and rights if only the low-cost measures

were implemented (see section "Optimization of the current situation" below in this chapter) or, if no measures were taken, the costs that would have to be borne by the State, the savings that would not be accrued, the costs involved in maintaining the status quo (e.g. in services and infrastructure) and replacing the affected assets, and the losses that would be observed in social or health terms or in the value of properties, real estate and other assets that are difficult to monetize.

- **Supply analysis**: As in the previous analysis, it is necessary to re-estimate the supply during the evaluation horizon to include the changes that would occur if the optimizations were implemented and were to directly affect the current supply conditions. The aim is to find out what happens in the community in terms of environmental and public health issues when no measures are implemented (for example, places where agricultural, livestock or other goods are produced and places where they are no longer produced, and the increase in the number of people whose well-being or health has been harmed as a result of the contamination).
- **Supply-demand interaction diagnosis**: Intended to calculate the difference between what was not obtained or produced on account of the contamination (assets, health or ecosystems) and what would be needed to obtain or produce the same (i.e. goods of the same value, health and ecosystems) under current site conditions (for example, specialized health services, medicines, water treatment plants or food transportation).

In general terms, mining legacies can generate various impacts that arise directly and indirectly in the population, productive activities, infrastructure, services and the environment (diagram IV.18).

■ Diagram IV.18
Areas typically affected by mining environmental legacies

Population	- Effects on health and tangible and cultural heritage[a] - Human health impacts and vulnerability must be detailed and broken down in the scenario development analysis
Activities	- The effects on both the activities currently being carried out in the area of influence and those that could be carried out in the absence of the legacies[b] are studied - Examples: productive, cultural, religious or sporting activities - The issues contributing to the social vulnerability estimates in the scenario development analysis must be detailed and broken down
Infrastructure and services	- Direct effects on infrastructure and services - Examples: buildings, facilities or drinking water supplies - The issues that determine social and environmental vulnerabilities (for example, a transport service affected by a geomorphological alteration) must be detailed and broken down
Environment and nature	- Effects on biodiversity, ecosystems and the natural landscape - Environmental vulnerability must be detailed and broken down

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] If an impact first manifests itself in activities, infrastructure and services, and then has an impact on property, it must be classified as "Infrastructure and services".
[b] The effects on activities can also have an impact on people's health. If the alteration caused by the mining environmental legacy manifests itself first in activities, it must be recorded under that classification.

Based on the previously collected information, it is suggested that an impact classification that includes the risk index be built (see section "Risk scenario analysis" above). Table IV.6 presents a sample scheme to introduce the specific characteristics of each impact, which will facilitate the identification of remediation alternatives to totally or partially reduce those impacts (see table IV.6) and, later on, to determine the benefits (see box IV.7). If a type of impact that does not fit into any of the above classifications arises in the case under study, another type of impact can be added, specifying what type it is.

■ Table IV.6
Analysis of mining environmental legacy impacts in the area of influence

Impact areas	Specific elements of the area	Impact type	Detail
Population	Population group 1 (e.g. local inhabitants)	Respiratory illness due to air pollution	Harmful particles originating from the mining legacy and carried by wind
	Population group 2	Impact 2	
Activities	Activity 1 (e.g. agriculture)	Loss of agricultural output, restriction of land use or deterioration of soil quality	Vegetable production affected by soil quality and alteration of the soil's physicochemical properties
	Activity 2	Impact 3	
Infrastructure	Buildings close to external waste dumps	Visual and landscape	Airborne dust affecting building aesthetics
Services	Ground transport services	Loss of visibility due to airborne dust	Airborne dust that affects visibility
Environment and nature	Threatened plant species	Surface water pollution	Contaminated water mixes with the natural irrigation of the species and causes damage

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

5. Remediation alternatives

At the conclusion of the Environmental and Human Health Risk Assessment Study, solutions to the identified problems are devised through the development of scenarios to resolve the mining environmental legacy's environmental problems.

In light of budget constraints caused by limited financial resources and time limitations, about three alternatives for mining legacy remediation projects should be examined. In selecting alternatives, the level of risk to the environment and human health is taken into account (see table IV.7). A decision is then made as to whether to proceed with site remediation and, if so, remediation levels and actions are indicated.

(a) Optimization of the current situation

Before designing the project alternatives for resolving the problems detected and evaluated in the current situation diagnosis, low-cost measures and investments to optimize the situation are studied. If remediation is not necessary, the possibility of monitoring the

site or considering natural attenuation in a regulated manner should be evaluated; this, however, is a scenario in itself and involves costs. In this way, the solution alternatives are not oversized, since the actions indicated may reduce or eliminate some of the identified problems or part of the overall problem.

Current situation optimization measures typically represent less than 10% of the programme or project's total investment amount (Government of the State of Mexico, 2014). These solutions include, for example, the adoption of measures targeting the population that seek to reduce, to some extent, contaminant exposure through certain channels. They may also include changes in the management and operation of the water supply to reduce exposure or the reinforcement of perimeter closures to prevent entry into the contaminated area (EPA, 1989).

These actions can be considered emergency measures, as they considerably reduce the morbidity rate in the population (see table IV.7). The implementation of these measures needs to be taken into account when reassessing the level of risk and impacts. As these decrease over time, they should be included not only in the design of remediation alternatives, but also in the levels of impacts and associated costs that could be avoided with the remediations under study, which influences the assessment (see chapter VI).

(b) Remediation projects

At the conclusion of the Environmental and Human Health Risk Assessment Study, a decision must be taken as to whether or not the site is to be remediated. In addition to confirming remediation, the level and the measures to be taken must be determined. Similarly, the situation sought (with a project) should be detailed using the decision tree as a tool to evaluate causes, means and ways to achieve them (for the purposes described in the previous step; see section "Analysis and definition of the problem of the mining environmental legacy"). Depending on the type of the mining environmental legacy, the characteristics of the area, the level of risk and other factors, alternatives can be designed that fit into the following categories (adapted from Efroymson, Nicolette and Suter, 2004; Meixueiro and Pérez, 2008):

(i) Scenario (hypothetical) in which all contaminants are removed from the site. This maximalist scenario details the total cost that the mining company has passed on to society and the amount of funds it should have saved during its operations to repair damages.

(ii) Alternatives to reduce, although not totally, the final effects of a mining environmental legacy:

- Reduction of mining environmental legacy contaminants (metals or other substances): Some of the waste is removed from the site due to its high degree of toxicity, and the less toxic remainder remains on site. This is conditional on the stabilization of the waste and contaminated soils, the construction of cover, storm drainage and revegetation systems, and the implementation of an exposure monitoring programme and hygiene programmes in the affected communities.

- Reducing the level of transfers to sites to control dispersion: A confinement cell is built on the site for highly toxic waste. Such waste can only be confined after undergoing treatment that reduces the contaminants' mobility and toxicity in line with the measures described in the second scenario.
- Control of access by people and activities to contaminated sites in order to allow a natural process of contaminant degradation.

(iii) Alternatives to radically eliminate contaminants and thus to minimize their transfer.[5]

(iv) Alternatives that, through site revitalization, control and eliminate the identified effects of the mining environmental legacy (see chapter II):

- Site reuse.
- Reuse of the site to convert the mining legacy into a asset. In general terms, two methods exist:
  - Through a company with a mining concession in the area, the operations of which incorporate platforms, tailings and infrastructure that make up the mining environmental legacies in the area, thereby assuming responsibility for them.
  - Through minor mining, where waste is used by extracting valuable elements from it.[6]

The categories of remediation alternatives will not be available for all types of mining environmental legacies; some will be more suitable for certain types than others.

Mining environmental legacies can be economically reused or reprocessed if they are transported to a processing plant or if the possibility of reusing them increases over time, on account either of a potential increase in the price of their valuable elements or improved processes (Chappuis, 2020). Moreover, while the damage or threat of damage to the environment and people may still exist, what changes is the emergence of a responsible party to remedy it.

Infrastructure legacies can be reused or completely demolished, but are unlikely to undergo only abatement (partial demolition; see chapter I). For highly complex, hazardous or harmful mining environmental legacies, consideration should be given to elimination (for example, water from underground mines rising to the surface can be processed by neutralization techniques or passive methods using plants, microorganisms or artificial wetlands; see chapter II).

Since, in general, techniques and methods can be combined to generate multiple alternatives, the criteria used to select the final alternatives for evaluation must be specified. In that context, the concept of environmental sustainability must be upheld by pursuing only those options that have little or no impact on the environment.

The details of the chosen project are set out in the remediation plan.

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5 Non-elimination of the contaminant leaves reduction as the only alternative.

6 Secondary mining follows the tenets of the circular economy, a trend that is becoming increasingly relevant both regionally and globally.

(c) Development of remediation projects using the conceptual model

Based on the conceptual model, sustainable remediation alternatives linked to the cost-benefit analysis can be created by following the steps below (see section "Conceptual model" in this chapter).

(i) Once the vulnerable groups to be addressed have been identified and prioritized, the most significant ones are selected, in light of the risks detected and evaluated by the Environmental and Human Health Risk Assessment Study. In other words, attention is given to the risks that contribute the most to the total risk indices (see section "Risk scenario analysis" above in this chapter). Then, a matrix is drawn up to show the contribution percentages by exposure route and pathway, contaminant and population group (see table IV.7). Matrices of this kind enable the determination of the physical matrix (soil, water or waste) and the possible sources of contamination, which in turn leads to the identification of the primary and secondary risks to be addressed depending on the exposure pathway. It is essential that these risks be eliminated, as they represent the largest proportion of the total risk (EPA, 2014, 2022, 2023 and 2024; Environmental Protection Scotland, 2017; Iturbe and Flores, 2014).

■ Table IV.7

Example of a risk index matrix by exposure route and pathway, and by contaminant for soil

Population group: children aged 1 to 6					
Exposure route	Contaminant Exposure pathway	C1	C2	Cn	
Surface soil	Ingestion	$RI_{C1,Ing}$	$RI_{C2,Ing}$	$RI_{Cn,Ing}$	$\sum_{i=1}^{n} RI_{C,i,j}$
	Inhalation	$RI_{C1,Inh}$	$RI_{C2,Inh}$	$RI_{Cn,Inh}$	$\sum_{i=1} RI_{C,i,k}$
	Dermal contact	$RI_{C1,dc}$	$RI_{C2,dc}$	$RI_{Cn,dc}$	$\sum_{i=1} RI_{C,i,t}$

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), *Framework for Human Health Risk Assessment to Inform Decision Making*, Washington, D.C., 2014; "Risk assessment guidance: EPA guidance", Washington, D.C., 2022 [online] https://www.epa.gov/risk/risk-assessment-guidance; "Superfund soil screening guidance", Washington, D.C., 2023 [online] https://www.epa.gov/superfund/superfund-soil-screening-guidance#user; "Risk Assessment Guidance for Superfund (RAGS): part A", Washington, D.C., 2024 [online] https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part.

(ii) The most significant areas and volumes of materials in terms of risk are established so they are managed in an orderly fashion during the preparation of the remediation plan. Priority is given to the elimination or treatment of those volumes that pose risks. During this stage, it is recommended that additional studies be carried out so that the volumes of materials to be remediated are correctly calculated and appropriate technologies are applied in the intervention. The studies should focus on the following issues:

- Leaching of materials. Intended to reveal the extent to which the material will allow the migration of contaminants in a porous medium.
- Granulometric distribution of materials. The higher the proportion of fines in a material, the greater the likelihood that contaminants will concentrate in those fractions and be subject to wind dispersion.
- Chemical species of potentially toxic elements. The bioavailability and toxicity of metals and metalloids depend on this characteristic.

(iii) When environmental authorities evaluate environmental and human health or ecotoxicological risk characterization and assessment studies, they usually apply the legal principle of "in case of doubt, in favour of the environment (and the population)".[7] This binary criterion is not intended to set levels; instead, it requires two conditions:

- The party responsible for the mining environmental legacy performs the uncertainty analysis in a complete and transparent manner, in accordance with the risk assessment guidelines available in each country or, failing that, with international recommendations.
- The authority, through its professional judgment and experience, can establish whether the risk assessment process, together with its uncertainties and conclusions, are appropriate under the legal framework and precedents. It can also determine whether they are relevant to the socioeconomic situation and human rights of the communities potentially affected by the contamination. The authority can also impose measures that are more rigorous and costly than they really should be, because of the uncertainty generated by the lack of study quality and detail, and not necessarily because it is so on the site (see box IV.5).

(iv) Potential use of the remediated site is defined according to six categories of factors:

- **Legal use**: Refers to the classification of the properties that make up the mining environmental legacy according to the land use plans of the municipality or demarcation in which it is located: i.e. according to the legally established land use (Office of the President of Mexico, 2016). For example, if another use is to be given to a site that is legally for agricultural use, the zoning plan must first be modified.
- **Current real use of the site**: Refers to the type of activities currently being carried out at the site. The legal and real uses do not always coincide. Returning to the previous example, although the site is set aside for agricultural use, it may actually fulfil residential or recreational functions.
- **Local economic dynamics**: Established economic activities in the area have a significant influence on the long-term opportunities for reusing the site or for reintegrating it economically into the region. If those activities have little or no

[7] This principle is included in the legal framework of Ecuador, among other countries.

presence, reuse of the site will be severely limited, as will the sustainability of the remediation in terms of self-sustainability.

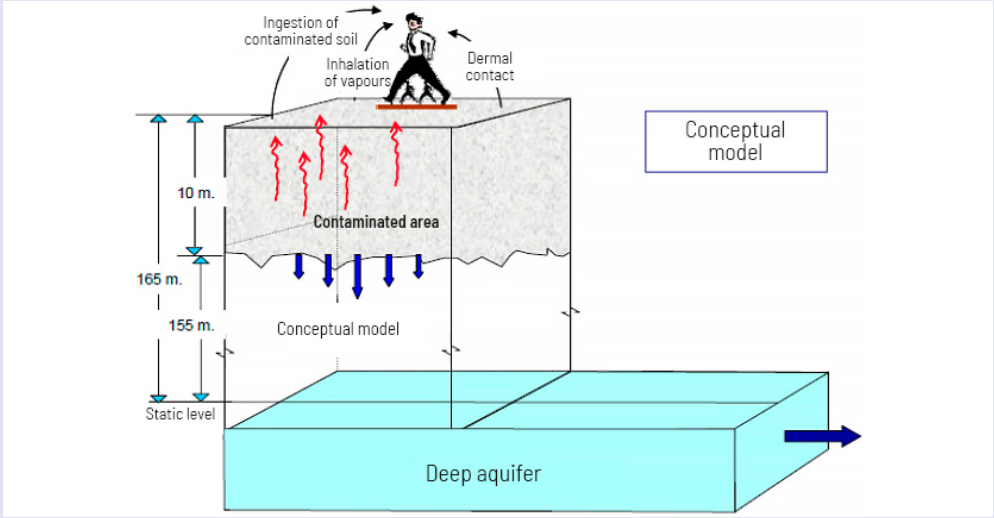
- **Behaviour and expectations of the neighbouring communities**: Current use is taken into account (see "Current real use of the site" in this listing): i.e. how people are currently transiting through or using the site and how the site is affecting their daily activities, as well as their expectations about its future use (see chapter II).
- **Weather conditions**.
- **Other relevant site idiosyncrasies** (such as existing infrastructure).

A wide range of revitalization options exist, ranging from purely passive uses, such as revegetated areas, to intermittent renewable energy projects, such as solar plants. It is strongly recommended for expert decision-makers to identify potential future uses of the site (see box IV.7).

■ Box IV.7
Example of scenario development

The main problems detected in a hypothetical mining environmental legacy are exposure to ingestion of contaminated soil particles, inhalation of vapours and possible dermal contact, which affect people making irregular use of the site (for example, as a shortcut to another town or to take public transport) (see plate 1). In this case, it is assumed that possible leachates from the contamination do not reach the deep aquifer. In addition, the scenario is limited to a single activity and point of contact (contaminants, for example, do not come into direct contact with community homes).

Plate 1
Exposure scenario with respect to soil contamination at a site

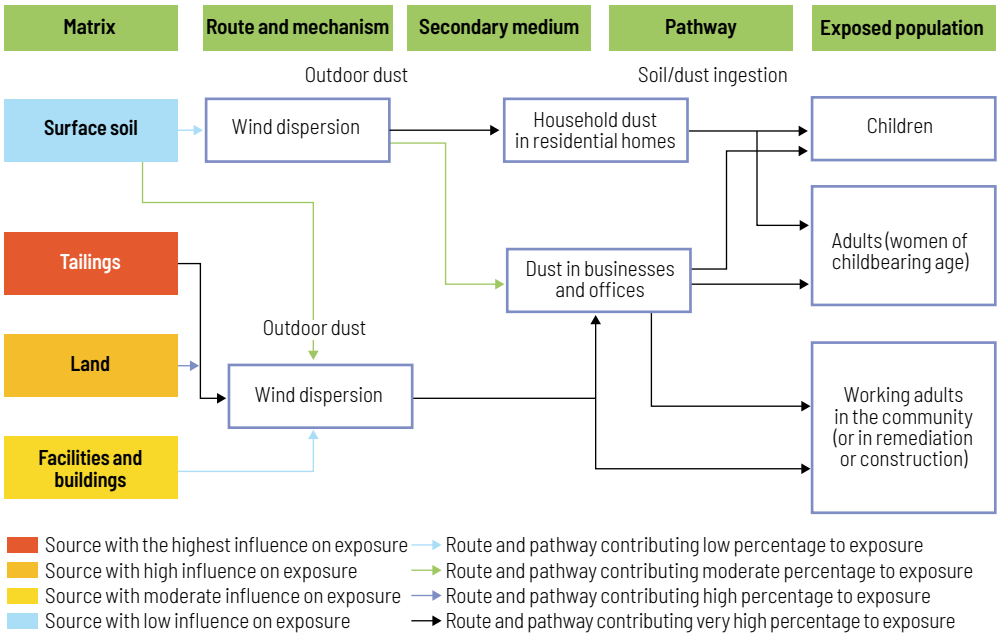


Source: W. Schmidt, R. Flores and U. Ruiz (eds.), *Remediación y revitalización de sitios contaminados: casos exitosos en México*, Eschborn, Deutsche Gesellschaft für Internationale Zusammenarbeit/Secretariat of the Environment and Natural Resources (GIZ/SEMARNAT), 2013.

The conceptual model is applied to the case in order to construct a remediation scenario. The conceptual model distinguishes between exposure matrices, routes and pathways (see diagram 1). Based on that distinction, the materials that pose the greatest risks, the exposure routes and pathways that contribute most to the risk index and the most significant exposure points are indicated.

In view of the above, the remediation scenario can be built considering the material (tailings, earthworks and so on) to be stabilized and covered, the contaminated structures to be demolished, the contaminated soils to be removed and their integration into the overall remediation plan to be used as part of the cover systems, together with the verification and monitoring of exposure in highly vulnerable populations.

Diagram 1
Conceptual model with different exposure routes



Source: Prepared by the author.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (BGR/SERNAGEOMIN), Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P, Santiago, 2008; Secretariat of the Environment and Natural Resources (SEMARNAT), *Guía técnica para orientar la elaboración de estudios de evaluación de riesgo ambiental de sitios contaminados*, Mexico City, 2006; "Norma oficial mexicana NOM-147-SEMARNAT/SSA1-2004, que establece criterios para determinar las concentraciones de remediación de suelos contaminados por arsénico, bario, berilio, cadmio, cromo hexavalente, mercurio, níquel, plata, plomo, selenio, talio y/o vanadio", *Diario Oficial de la Federación*, Mexico City, 2 March 2007.

(v) According to the scenarios outlined in the Environmental and Human Health Risk Assessment Study, a measure is created for each source of contamination, intended to control the exposure route and pathway through which the contaminants come into contact with vulnerable population groups. Consequently, a distinction must be drawn between the scenarios used to prepare the study and the scenarios constructed to carry out the remediation. A remediation scenario or alternative may consider one or more study scenarios.

(vi) Once the measures have been identified, the potential costs of the remediation work are assessed, even before a detailed cost estimate is prepared. The specific characteristics of the mining environmental legacy and of the technologies considered will influence these estimates (for example, the type of cover system required, which will depend on the toxicity of the waste; see box IV.8).

According to Limón and Herrejón (2013), successful contaminated site remediation experiences show that, in general, costs increase in the event of:

- Remediation measures that include material movements (excavation, loading, transport and disposal).
- Remediation measures involving the use of high-cost treatment inputs or treatment process with technology readiness levels below 7 (for further details, see Manning, 2023).
- Remediation measures involving the use of special machinery.
- Lack of experience in the execution of a specific remediation process.

■ Box IV.8

Hypothetical example of three common scenarios for the remediation of environmental mining legacies with costs

In this example, a mining environmental legacy contains 500,000 tons of tailings (primary source of contamination) and 5,000 tons of contaminated surface soils (secondary source of contamination). Three different alternative solutions are examined in terms of material movement costs.

Description	Schematic feasibility study
Total removal of contaminated materials from the site. Off-site transport of all contaminated materials to a high-security hazardous waste dump.	• Eliminates all risks. • Shipping hazardous waste to a landfill costs between US$ 75 and US$ 150 per ton. • Costs: - Waste: between US$ 37.5 million and US$ 75.0 million - Soil: between US$ 375,000 and US$ 750,000 - Cost of material transport, excavation, loading and payment to operators • If the contaminated materials are excavated, loaded and shipped by road in 40-ton vehicles, 12,625 trips will be required. Assuming 10 vehicles are loaded per day, 1,262.5 days (4.2 years) will be required to complete the disposal of the waste and soil.
Removal of the most toxic waste from the site. Maintenance of the remaining waste present at the site once it has been mechanically stabilized with cover and revegetation systems.	• Eliminates all risks. The responsible party assumes the obligation to maintain the coverage systems. • The assumption is that there are 50,000 tons (10%) of highly toxic waste and an area of 2 hectares for the disposal site. • Costs: - Highly toxic waste: between US$ 3.7 million and US$ 7.5 million - Coverage systems: between US$ 10 and US$ 150 per m2, depending on the complexity of the system; cost of between US$ 200,000 and US$ 3,000,000 - Excavation and loading costs on the site, mechanical stabilization costs and payment to operators

Description	Schematic feasibility study
Stabilization of the most toxic wastes and construction of a high security cell within a mound for their storage.	• Eliminates major risks. The responsible party assumes the obligation to maintain the coverage systems. • The coverage system consists of the same 2 hectares and the cell is 2 000 m^2. • Costs - Security cell: US$ 1,500,000 - Cost of coverage: between US$ 200,000 and US$ 3,000,000 - Excavation and loading costs on the site, mechanical stabilization costs and payment to operators

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Treadwell & Rollo, *Environmental Site Investigation Report. Pier 70 Master Plan Area. San Francisco, California*, San Francisco, 2011; D. Iglesias, "Costos económicos por la generación y manejo de residuos sólidos en el municipio de Toluca, Estado de México", *Equilibrio Económico*, vol. 3, No. 2, Saltillo, Autonomous University of Coahuila (UAdeC), 2007.

(d) Synergistic effects of reuse

Some elements of reuse projects may perform similar functions as coverage systems, and their inclusion may improve the project's financial sustainability (see chapter VI).

Accordingly, infrastructure and constructions intended for future uses should be integrated with the remediation measures. For example, the construction of buildings or parking lots, which can be used as coverage systems and which, at the same time, provide other usage options.

6. Comprehensive evaluation

The final step in a cost-benefit analysis for the remediation of mining environmental legacies is to carry out a comprehensive assessment that addresses the three dimensions of sustainability (see chapter VI). At this stage, the results of the Environmental and Human Health Risk Assessment Study should be available, the targeted exposure routes and pathways of the vulnerable population groups should be known and the first approximations of costs should have been calculated. In order to collect complete data, obtain a reasonable overview of the measures that could be adopted and study the technical-environmental, financial, economic and social feasibility of those measures, a comprehensive assessment is conducted in order to ensure a sustainable remediation.

After the formulation phase, remediation alternatives are identified, including an analysis of the risks (see section "Risk scenario analysis" above),[8] impacts, stakeholders and environmental sustainability (see diagram IV.6).

[8] Scenarios are defined that indicate the impacts and costs to be avoided. These will vary depending on the alternative, the level or percentage of harm reduction associated with the defined risk (see chapter VI).

Chapter V
Cost-benefit analysis for comparison of remediation alternatives

Introduction

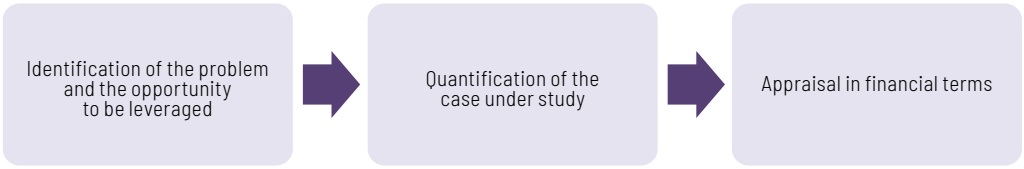
The purpose of cost-benefit analysis is to compare and evaluate remediation alternatives using the net welfare criterion. Net welfare is composed of changes in the utility of each member of society. The methodology seeks to assign a monetary value to all costs and benefits, and it therefore includes variables that are not usually valued at market prices, such as natural and environmental resources.

Cost-benefit analysis is the alternative traditionally recommended for comparing investment projects, since it enables a project's economic, social and environmental benefits to be estimated, identified and appraised. For the remediation of mining environmental legacies, it also pursues the goal of ensuring that risks are reduced to acceptable levels. It is recommended that the redistributive impacts of investments be included along with the social equity criterion. In this way, a remediation alternative that maximizes the net benefits among all intervention options can be identified.

A. The supply-demand approach in the cost-benefit analysis of mining environmental legacies

Analysing mining legacies from the viewpoint of supply and demand helps clarify the sustainability objective and explain the problem to be solved (see diagram V.1). It is important to first analyse the situation not yet addressed by the remediation project (the current situation) and to explain in detail the underlying assumptions (Meixueiro and others, 2015).

■ Diagram V.1
Objectives of presenting the interaction between supply and demand



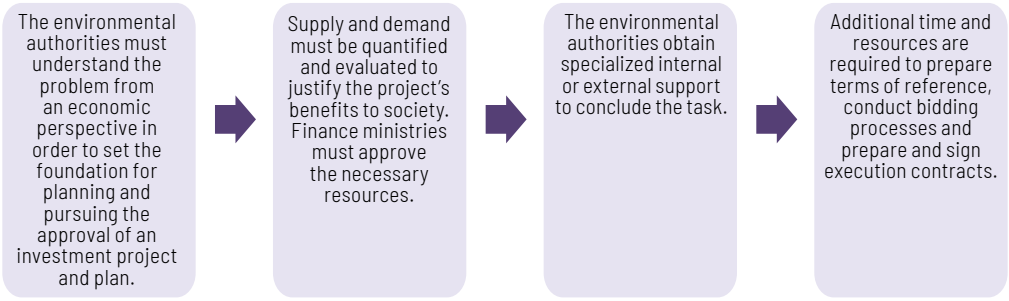
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The human right to a healthy environment and to freedom from exposure to health risks is a community's demand, and costs are incurred if the mining environmental legacy infringes on that right. The demand therefore requires that the collective good not be damaged or, if this occurs, that it be repaired. The State has the obligation to protect collective goods and to ensure that they are remediated, as far as possible, by the party responsible for the contamination.

The first step in estimating the demand is to value the quantity of goods and services required for the investment projects and plans intended to remediate the mining legacy's impacts and, therefore, to satisfy the population's needs (Meixueiro and others, 2015). Next, the main characteristics of the population making the demands must be precisely described, together with the remediation activities to be carried out. The demanding population includes not only the nearby settlements: it comprises all those economic agents who obtain an increase in their utility through the improvements in the quality of the environment brought about by the remediation.

Supply refers to the ability to remediate damage and control the risks posed by mining legacies as established by environmental regulations. It is determined on the basis of the resources and the goods and services that economic actors, such as the State, allocate for that purpose (Meixueiro and others, 2015). To correctly determine the supply, the study area and area of influence of the project and investment plan are defined (see diagram V.2 and chapter IV).

■ Diagram V.2
Importance of supply and demand analysis in the remediation of mining environmental legacies



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

B. Identification and measurement of costs and benefits

All economic, social and environmental impacts are identified and recorded for each project alternative. The costs and benefits associated with each impact are given in monetary terms in order to identify the alternative that yields the greatest net welfare to society as a whole.

The inputs used in the production of a good normally entail costs, since they cannot be used elsewhere. The main resources used in most projects include productive inputs, capital, foreign exchange, labour and fuel (see chapters III and VI). The outputs of the intervention, whether measurable or not in market terms, can be broadly associated with the benefits. Savings from avoided harm that may materialize in the future should also be treated as benefits (see box V.1).

■ Box V.1
Analysis by damage avoided

Mining environmental legacies are associated with various risks that are defined by their characteristics and external conditioning factors, such as climate and topography (see chapter II). Over a given horizon, there are risks of damage associated with the probability of adverse events related to mining legacies (which may or may not be triggered by meteorological phenomena). Previous damage must be listed and characterized in as much detail as possible.

If background and information on previous damage is available, its possible future occurrence can be forecast and projected with greater certainty. Damage avoided also depends on the characteristics of the area, its productive uses and the activities that are —or could be— carried out at the site within the analysis horizon. If there is no specific data for the locality, information from other sectors or similar cases can be analysed.

Each level of damage will be related to the intensity and severity of the phenomenon. It is possible that the risk associated with a mining environmental legacy, which has a component of uncertainty, cannot be expressed in terms of a continuous probability function, but rather in scenarios with alternative levels of harm. It therefore is necessary to consider ranges to determine a high, medium or low risk, depending on the possibility of different types of damage occurring (see chapter V). The remediation project will lessen the likelihood or severity of the potential adverse event.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Posner and M. Adler, "Rethinking cost-benefit analysis", *Yale Law Journal*, vol. 109, New Haven, Yale University, 1999; Ministry of Social Development and Family of Chile, *Metodología formulación y evaluación de proyectos de evacuación y drenaje de aguas lluvias*, Santiago, 2017.

1. Market-determined prices

Based on the assumption of equilibrium in a perfectly competitive market, the potential for the most efficient use of resources is considered, reflecting the opportunity cost (Lewis and Tietenberg, 2020). Social (also known as accounting or shadow) prices reflect opportunity costs in the economy and, in cost-benefit analyses, are used to determine market equilibria in both project and non-project scenarios (Contreras, 2004).

Unlike observable market prices, social prices indicate the relative scarcity of goods and represent the prices that would prevail in the absence of distortions from taxes, subsidies, externalities or the underutilization of productive resources (Squire and van der Tak, 1975; Nas, 2016). Social prices are used to estimate costs and benefits from a market perspective.

The institution that regulates public investments in each country is responsible for calculating the social prices of inputs (for a more detailed discussion, see Brent, 2008). Social prices must be updated periodically to correctly reflect prevailing market conditions (see examples of coefficients used to calculate social prices from observable market prices in table V.1).

■ Table V.1
Chile, Paraguay and Nicaragua: social prices

Country	Labour			Currency	Capital (*Percentages*)
	Skilled	Semi-skilled	Unskilled		
Chile	0.97	0.95	0.91	1.0	6.0
Paraguay	0.91	0.88	0.78	1.05	16.5
Nicaragua	-	-	-	1.015	8.0

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of E. Contreras, "Precios sociales: marco teórico para el cálculo de tasa social de descuento, divisa y mano de obra", *Documento de Trabajo*, Santiago, University of Chile, 2018, unpublished; Ministry of Social Development and Family of Chile, Informe *Precios Sociales 2023*, Santiago, 2023.

Similarly, all benefits determined through the market will be measured in social prices. Monetary effects are not included, as these typically involve a displacement of demand (for example, production in the affected locality is favoured to the detriment of other parts of the country) and do not alter total national output (Nas, 2016; Boardman and others, 2018).

2. Costs and benefits without market prices

In order to correctly quantify project costs, the negative externalities that would arise if the remediation project alternative in question were implemented must be quantified and appraised. Negative externalities include such factors as noise, congestion, temporary inaccessibility and contamination of some local resources. In addition, an adequate margin must be left to allow for the possibility of new externalities arising in the future.

The benefits, in turn, may include environmental and cultural assets whose value goes beyond the price assigned to them in the market (see table V.2). In evaluating them in monetary terms, the total value they represent for individuals must be taken into account. However, it should be noted that the value of nature in the cost-benefit analysis depends on the value that individuals place on it within the scope of the analysis. Cost-benefit analysis does not usually consider the value of a resource to humankind or the value of environmental goods independently from economic agents (Baum, 2012). One alternative would be to consider the possibility of including the intrinsic value of nature in those countries where it is deemed to possess its own rights.

■ Table V.2
Categories of value types of environmental goods

Category	Subcategory	Description	
Value in use	Consumption of rival goods	The economic value (utility) of the natural resource (corrected for externalities).	Extraction of natural resources.
	Consumption of non-rival goods		Fresh air and hiking.
	Option value	The value attributed by economic agents to a possible future use of the resource (for example, its recreational value).	
Non-use value (or passive use value)	Legacy value	The value that economic agents assign to the possibility of future generations taking advantage of the resource and the value perceived as intrinsic (independent of the type of use).	
	Existence value	The value of the very existence of the good or resource (for example, an endemic species).	

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of F. Cross, "Natural resource damage valuation", *Vanderbilt Law Review*, vol. 42, No. 2, Nashville, Vanderbilt University, 1989; T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016; A. Boardman and others, *Cost-Benefit Analysis: Concepts and Practice*, Cambridge, Cambridge University Press, 2018; L. Lewis y T. Tietenberg, *Environmental Economics and Policy*, London, Routledge, 2020.

The tools most commonly used to quantify the value of environmental goods are stated valuation and disclosed valuation (see table V.3).

■ Table V.3
Environmental valuation methods

Valuation methods	Definition	Subcategories
Declared valuation	Specific hypothetical data are produced for a given case	Contingent valuation: structured surveys are used to determine individuals' willingness to pay for a good or set of goods (for example, improved water quality or the protection of local biodiversity).
		Discrete choice experiment method: a variant of the contingent valuation method. Respondents are presented with a series of scenarios that differ in certain specific characteristics and, in this way, their willingness to pay can be ascertained.
Revealed valuation	Indirect data from other markets are analysed	Hedonic pricing: the value of a good or service is broken down into several components to estimate their values (for example, the value of the local air quality is calculated through the prices of a site).
		Avoided costs: disbursements made on account of a change in the environment are analysed.
		Travel costs: spending for travel towards a particular environmental good enables its value to be estimated.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of D. Azqueta, *Valoración económica de la calidad ambiental*, Madrid, McGraw-Hill, 1994; T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016; L. Lewis and T. Tietenberg, *Environmental Economics and Policy*, London, Routledge, 2020; E. Mishan and E. Quah, *Cost-Benefit Analysis*, Abington, Routledge, 2021.

While these methods help quantify the value of environmental goods to consumers, their limitations must be acknowledged. In declared valuation methods, respondents may give unrealistic answers because hypothetical scenarios are involved, or they may respond strategically if they are aware that their contributions will influence the final evaluation (Mitchell and Carson, 1989). Arrow and others (1993) concluded that contingent valuation methods can provide relevant data if good quality surveys or experiments are designed and if guidelines are provided. At the same time, the weakness of revealed valuation methods involves the use of economic data, which do not reflect the passive use value or provide answers that are merely indicative on the contribution of environmental quality to the total value of the asset in question (Atkinson and Mourato, 2008; Boardman and others, 2018). By combining the two approaches, their respective strengths can be leveraged (Atkinson and Mourato, 2008).

To determine the value of human life in a cost-benefit analysis, one method used has been to estimate the loss in future income or consumption that would be caused by the death of the individual. The value of statistical life reflects individuals' willingness to pay for a decreased risk of loss of human life (Viscusi, 1993; Mishan and Quah, 2021). Since assigning a price to human life can be controversial, an alternative approach to cost-benefit analysis may be preferred (see sections III.D and VI.D). In the event that a hypothetical price is placed on human life in the cost-benefit analysis, the concept must be explained adequately to decision makers and all stakeholders, especially those affected by the mining legacy.

C. Evaluation of costs and benefits

Cost-benefit analysis is used to identify the project that provides the greatest social welfare from a set of alternatives. According to orthodox theory, social welfare is linked to allocative efficiency and is conceptualized in those terms in many cost-benefit analyses (Boardman and others, 2018). This handbook also seeks to explicitly include the equity criterion.

Any project of a public nature is likely to divide society into winners (such as the populations surrounding a mining legacy) and losers (such as taxpayers residing in other areas). Likewise, cost-benefit analysis seeks to fulfil the Kaldor-Hicks criterion or the Pareto improvement. According to those concepts, the gains in welfare of the winners must outweigh the welfare losses of the losers. In theory, the first group should be able to fully compensate the second and be in a more favourable situation than before the project's implementation.[1]

The changes in social efficiency brought about by the project arise from changes in consumer and producer surpluses and in government revenues. Consumer surplus is defined as the difference between the maximum utility obtained from the consumption of a good and the prevailing price levels. Typically, it derives from the discrepancy between the willingness to pay for a good and its current price. For goods traded on the market, social prices can be used. Otherwise, their value must be estimated using a declared or disclosed valuation method. Producer surplus, in turn, is calculated as the profit from the sale of the good and is measured as the difference between the prevailing social price and the minimum price at which its producer would be willing to sell. Government revenues are the additional monetary income generated as a result of project implementation. Only consumer surplus and government revenues associated with a real change in production contribute to consumer surplus in the cost-benefit analysis (Mishan and Quah, 2021).

D. Project evaluation and comparison

The values of costs and benefits must be comparable between alternatives. For this reason, distributional and temporal considerations are relevant in evaluating the impacts identified. For the distributional factors, studies are conducted into how each economic agent receives the individual impacts, while for the temporal factors, an analysis is carried out of how the flows of costs and benefits occurring over several years are consolidated into a single figure. The aspects of equity and temporality are explored below.

[1] Theoretically, a Pareto improvement can occur, whereby the project increases total welfare without decreasing the utility of any member of society. While that situation would probably enjoy universal support, in practice the conditions for such an improvement are not met (Nyborg, 2012).

1. Use of weightings for distributional considerations

Cost-benefit analysis takes the current situation as its starting point and analyses the possibility of improving social welfare by reallocating resources so that the improvement in the winners' utility outweighs the drop in that of the losers. The trade-off between the two groups becomes a matter of redistributive policy outside the investment decision. Change in social welfare is the aggregate of the changes in individual utilities.

This handbook recommends that the distributive approach be used in the cost-benefit analysis, in addition to the traditional efficiency approach. The distributive approach distinguishes gains and losses among different economic agents and assigns a different valuation to each group.

Revesz and Livermore (2023) take equality as a separate objective and advise using cost-benefit analysis to maximize social efficiency and then compensating through redistributive policies. However, separating criteria of efficiency and equity may lead to an economically optimal situation that is not necessarily socially desirable (Gómez, 1998). Given the high level of inequality that characterizes Latin America and the Caribbean (ECLAC, 2023) and the absence of adequate compensation mechanisms, the neoclassical cost-benefit analysis approach based solely on allocative efficiency is likely to ignore or even exacerbate socioeconomic gaps.

There are two reasons why cost-benefit analysis may produce results that do not fulfil the equity criterion. First, the willingness to pay may be biased in favour of the interests of wealthier segments of the population (Nyborg, 2012). Second, high transaction costs and the wide dispersion of affected parties can make compensation complex and expensive.

To include distributive effects, welfare weightings differentiated by socioeconomic or interest groups should be used. Such weightings offer a way to address equity when existing income redistribution mechanisms are inadequate or when equity matters to society. While the obligation to use weightings appears sporadically in national guidelines (Boardman and others, 2018), in cost-benefit analyses of projects with local development implications —such as remediation projects— they are used more often (Nas, 2016).

Weightings should be obtained in a comprehensive manner and by means of a transparent mechanism (Contreras, 2004). They can be based on lessons learned from earlier completed projects or on social welfare functions with varying embedded levels of normativity (Adler, 2016; Nas, 2016). In practice, weightings can be defined according to the proportion of social spending that the State allocates to each social group or other similar criteria.

Critics of weightings claim that coefficients lack consensus due to their normative content, undermine efficiency and can even produce inequitable results (Mishan and Quah, 2021). However, cost-benefit analysis is itself normative (Sen, 2000; Nyborg, 2012) and high levels of inequality undermine the region's productive efficiency (ECLAC, 2018). Considering equity in the evaluation of projects is therefore justifiable in striving to correct externalities that affect rural populations.

2. Temporal comparability: the analysis horizon and the discount rate

The analysis horizon and discount rate chosen must allow reliable and realistic results to be obtained. The years for which benefits and costs are calculated, aggregated and compared, and the discount rate that modifies each year's values to present comparable values, both influence the results. Possible biases must therefore be minimized.

The environmental effects of a remediation project can be substantial and very long-lasting, affecting future generations. In contrast, most of the costs are usually concentrated in the project's early years. Normally, a time horizon is defined on the basis of the useful life of the factors from which the benefits of the investment arise. In order to avoid underestimating the total benefits, O'Mahony (2021) suggests considering analysis horizons longer than 100 years, a practice already followed in infrastructure projects.

The social discount rate transforms future flows of costs and benefits into current values. Because of its impact on the final result, determining that rate has become a controversial issue (*The Economist*, 2014; Stiglitz and Rosengard, 2015). In a perfectly competitive capital market, the prevailing interest rate would represent both consumers' temporal preferences (between current and future consumption) and the rate of return on capital (that is, the opportunity cost rate of capital use).

In evaluating cost-benefit analyses, the social price of capital is considered more accurate, but its information requirements make it difficult to apply (Nas, 2016; OECD, 2018). Consequently, several formulas have been proposed that favour temporal consumption preferences or capital returns, or that seek to combine the two approaches. Because of market imperfections, the two rates differ. According to Edwards (2014), the intertemporal consumption preference rate would be "more appropriate for discounting long-term flows, as it would better represent the degree to which current generations value future generations".

A high rate means that agents attach more importance to an immediate payoff, while a low rate indicates that they assign more importance to the distant future (Torche and others, 2009). At the extreme, a discount rate equal to zero would imply an equally weighted valuation of all generations' welfare. In accordance with environmental considerations, the social discount rate should reflect a concern for the future with a perspective of sustainability that remains aware of future generations.

The discount rates used internationally in cost-benefit analyses have been decreasing over recent decades (Boardman and others, 2018). For environmental projects with long time horizons, several countries have begun to use discount rates that decrease over time to reliably reflect the benefits materializing in the future, taking into account uncertainty and the interests of future generations (Revesz and Livermore, 2023; Arrow and others, 2014).

In most of the region's countries, the social rate is calculated as a weighted sum at the intergenerational level that includes consumers' intertemporal preferences and the rate of return on capital. The rates of international loans extended to countries for financing portions of their public investments are also included.

3. Risk and uncertainty

The accuracy of results generated by cost-benefit analyses may be affected by risk (known distribution of event probability) and uncertainty (unknown distribution of event probability). To improve decision-making, the effects of possible changes in the assumptions or main parameters on the expected change in net welfare should be assessed (Revesz and Livermore, 2023). When the results do not vary significantly in response to changes in the assumptions, they are considered robust (Bonner, 2022).

To measure the risks associated with each option, the discounted value of those equivalents that are certain —in other words, the expected net benefits for each year corrected by the risk factor— is calculated. If decision makers are risk averse (if, for example, they prefer a project with a lower total net benefit rather than risk escalating costs), a risk premium is applied (Stiglitz and Rosengard, 2015).

If uncertainty exists regarding some parameters (such as group weights or different discount rates), sensitivity analysis can be used. In this case, scenarios are developed and evaluated by modifying the values of the parameters responsible for the uncertainty, and upper and lower limits are established. To achieve this, historical data, evidence gathered during experiments or the preferences of decision makers are used. A sensitivity analysis is not necessary if the events that may influence the outcome are expected to occur randomly (Nas, 2016).

In cost-benefit analyses, three main forms of sensitivity analysis are used (Bonner, 2022):

(i) Partial analysis: analyses the impact on the indicators of a change in a single variable.

(ii) Analysis of best and worst case scenarios: optimistic and pessimistic scenarios are generated and analysed.

(iii) Monte Carlo simulation: a probabilistic analysis tool frequently used in cost-benefit analysis that can be useful when there are correlations between two or more parameters of interest. The probability distribution is estimated and a random sampling of data within that range is repeated thousands of times; the average values are recorded and the final distribution of net benefits is calculated (OECD, 2018).

Chapter VI
Comprehensive evaluations for sustainable remediation

Introduction

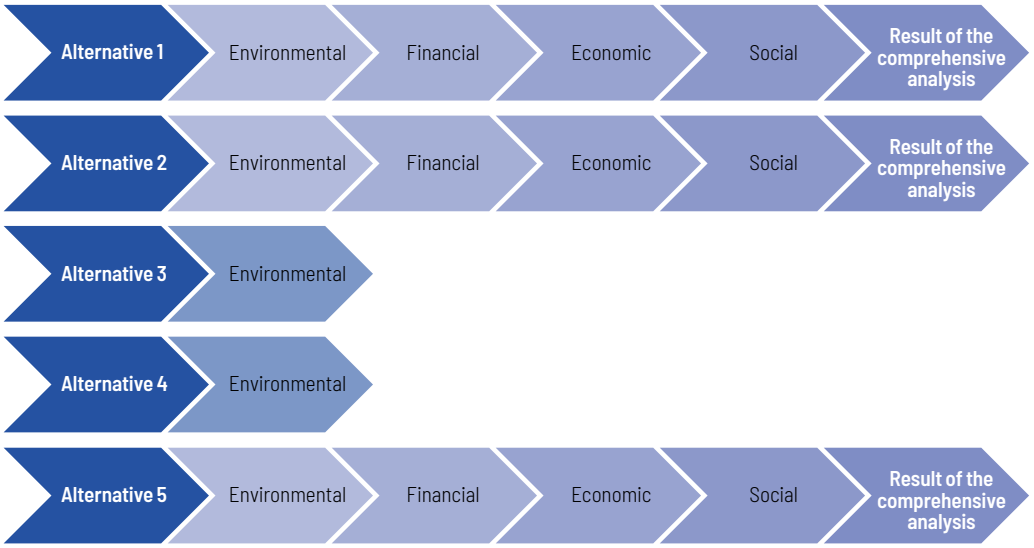
This chapter discusses comprehensive evaluations for sustainable remediation in greater detail. The choice of the tool to be used for assessing projects depends on a series of factors, including national guidelines, the resources available to the institution in charge of the analysis and the preferences of decision makers (see chapter III). In general, it proposes the use of cost-benefit analysis, which enables the cost-benefit balance of individual remediation alternatives to be determined. In particular, in order for the evaluation to meet the sustainability criteria associated with the selection of remediation alternatives, the following dimensions should be taken into account: (i) environmental, (ii) financial, (iii) economic, and (iv) social.

The first step ensures that the remediation alternative meets the environmental criterion, which consists of controlling or eliminating risk and negative effects on the environment and communities. In the second step, by means of the financial evaluation, all the remediation's costs and financial outflows to be met by the party responsible for implementing the alternative in question are analysed, in addition to its potential revenue flows. In the third step, the economic evaluation expands on the financial evaluation by including all the costs and benefits that will accrue to society from implementing the remediation alternative. Finally, the social analysis complements the previous evaluations and incorporates the distributive component by considering lower income groups.

A. Dimensions of a comprehensive evaluation

The comprehensive evaluation is carried out in order to select the most appropriate alternative from the point of view of social welfare (economic analysis)—while also considering its financial viability and the highest possible degree of social equity— for remediating the identified environmental legacy. The technical analysis prioritizes environmental sustainability and risk reduction as preconditions for the other analyses (see diagram VI.1), which highlights the importance of the regulations in force in the country.

■ Diagram VI.1
Sequence of stages in evaluating remediation alternatives

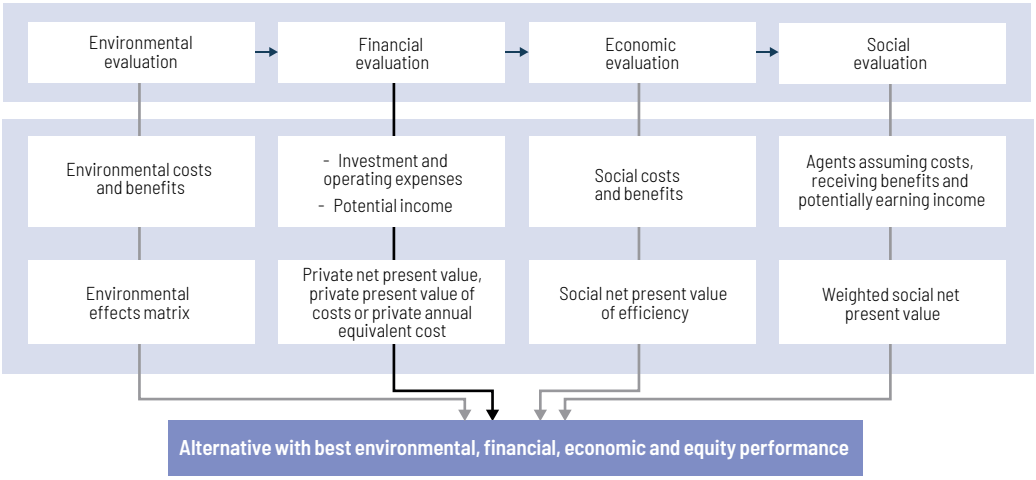


Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Cost-benefit analysis enables all the financial, economic, social and environmental aspects to be combined in a single monetary figure (or range). Differences in environmental terms between individual alternatives (beyond the minimum acceptable) will be included later in the cost-benefit analysis through their respective social benefits and costs (provided that the relevant environmental impacts are included in the quantitative analysis). However, a cost-benefit analysis can also be prepared that expresses some aspects in other units, without the need to monetize them (such as noise reduction in decibels or expansion of forest cover in hectares; see section III.A).

Following a fixed order, the stages after the environmental evaluation feed back into each other. If the balance sheet for the party responsible for the remediation is obtained in the financial evaluation, in the economic evaluation that balance sheet is extended to all of society's economic agents, covering both tangible and intangible aspects. Finally, the social analysis complements the economic analysis by reassessing the distribution of social costs and benefits among all agents according to socioeconomic criteria (see diagram VI.2).

■ Diagram VI.2
Organization and products of the comprehensive evaluation

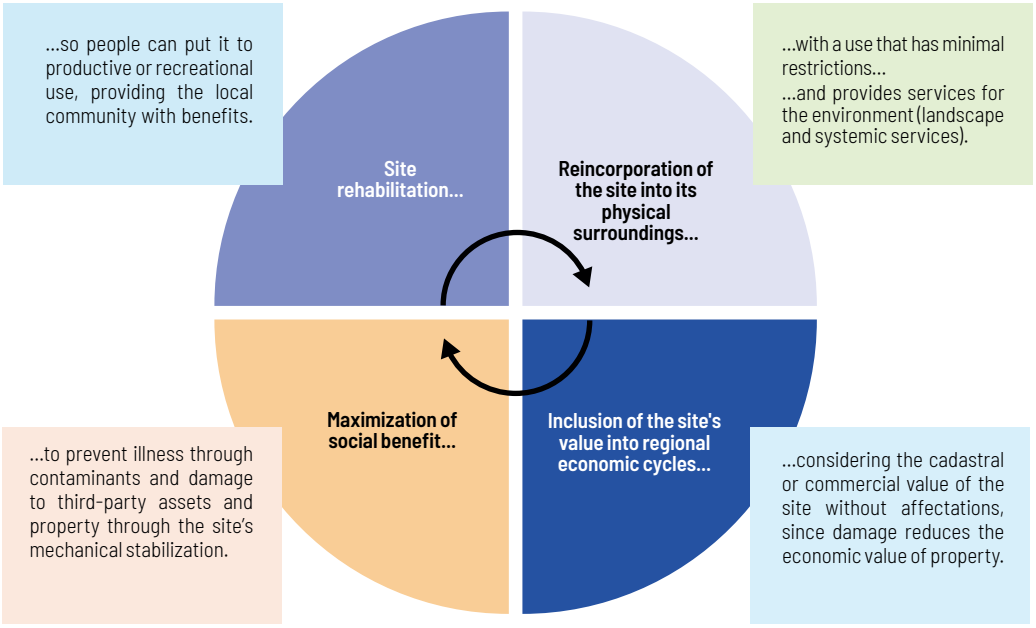


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of G. Jenkins, K. Chun-Yan and A. Harberger, "The integrated analysis of investment projects", *Cost-Benefit Analysis for Investment Decisions*, Kingston, Queen's University, 2011.

Remediation projects aim to (re)incorporate sites into regional ecological and socioeconomic ecosystems (see diagram VI.3). Alternatives must be identified that enable the goals set out in the objectives tree to be attained and that mostly differ in aspects elucidated in the comprehensive evaluation (see section IV.B). Sustainable remediation practices are not only those that reduce overall impacts (such as the contamination of soil and water resources) but also those that positively affect aspects of the local environment, potential impacts on worker safety and economic activity options in the community.

The intervention should ensure that actions, works and other interventions lead to the site providing the resources necessary to maintain itself in good condition and, in the long term, reduce operating and maintenance costs and impacts. In this area, the participation of the directly affected community must also be considered to ensure optimal execution of the remediation (r3 Environmental Technology, 2014; see chapter II).

■ Diagram VI.3
Main categories covered by a comprehensive evaluation with sustainability aspects



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*, Cincinnati, 2008; "Green remediation best management practices: mining sites", Washington, D.C., 2012.

B. Environmental evaluation

Environmental sustainability is a requirement in any remediation project alternative, but individual alternatives may present quantitative differences (see chapters II and V).

Any remediation project must first ensure that the remediation objectives are met. The regulatory framework in force defines the minimum standards and thus determines the parameters of the environmental evaluation. As a general principle, the project's impact on the environment and neighbouring communities must be minimized.

If the analysis is based on a ranking, environmental data should be included in the assessment as monetary costs and benefits. Then, the project that provides the greatest additional net social benefits should be chosen. It is therefore imperative that economic agents adequately measure the value of all types of environmental resources (see section V.B.2).

Alternatively, each dimension can be measured in specific units. In that case, it is important for the elements used to assess a remediation project's environmental sustainability to be included in an orderly and systematized assessment (such as a matrix), taking into account the following factors (Fortuna, Simion and Gavrilescu, 2011; EPA, 2008 and 2012)[1]:

[1] Chile, Brazil, Mexico and Peru have provisions or regulations governing risk assessments. To date, they do not include the evaluation of aspects that hamper or bolster the sustainability of both the remediation and future site use.

- The reincorporation of the site into its surroundings, in terms of both its use with minimal restrictions and the services it will provide (from a landscape or systemic services perspective). A natural process is exploited or imitated.
- The risks involved in the movement of materials, the use of materials for construction and water consumption, as well as their possible mitigation.
- The volume of fossil fuels or other natural resources that will be required for each remediation alternative and, consequently, their greenhouse gas emission levels. Alternatively, consideration can be given to the generation of renewable energy.
- The level of reuse or recycling of soil or undesirable materials.
- The percentage of the site that will have vegetative cover.
- The potential for promoting recovery technologies that destroy contaminants.
- The potential for the site's future use to provide services to offset the mining environmental legacy's social impacts.
- Decontamination of local air, soil and water resources.
- The protection of biodiversity.
- Waste treatment, including reuse.

Additional measures taken throughout the project's life cycle can improve the environmental performance of the technologies applied (see chapter II)(Holland and others, 2011):

- Implement technologies on site when possible.
- Recycle or reuse unaffected soil or demolition materials.
- Use renewable energy to operate the remediation system.
- Reduce transport needs.
- Provide local workers with training.
- Organize collaborative community events.

C. Private or financial evaluation

The financial evaluation[2], nalyses all the remediation's financial costs or expenditure that the party responsible for implementing the alternative in question would have to meet, in addition to its potential revenue. That party may be a national or municipal institution or a private concession-holder[3].

2 The analysis described is a simplified financial evaluation, as it does not consider any taxes or incentives that may exist in the country to promote investment in fixed assets or any external financing for the project (Sapag, Sapag and Sapag, 2014). The exclusion of the tax situation from the horizon flows does not pose major complications, since they must be carried over to the economic evaluation (with a different value, as will be explained below).

3 It is less likely to be the holder of a private concession because the resource to be concessioned is considered a liability and not an asset. In the case of abandoned legacy sites, the responsible party is usually a government institution (see chapter II).

While net social gains determine a project's desirability —relative to the other alternatives and the status quo (see "Economic evaluation" below)— private evaluation becomes particularly important in the search for remediation financing (see chapter II). In addition to contingency funds, the costs contribute to the subsequent preparation of the project budget.

Costs and income must be itemized and assigned over time to obtain the corresponding indicators. The relevance of the variables will depend largely on the nature of the remediation alternative (see table VI.1).

■ Table VI.1
Relevant financial variables for the cost-benefit analysis

Investment	Operation and maintenance	Income
Rent		Unit profit margin (and final price of the produced good)
Fixed investment[a] and capital goods	Depreciation of the good or service	Optimal production level
Supplies		Sales volume
Employees		
Taxes		
Civil liability insurance payments		
Employees' social security contributions		
Financing cost of requested credits or loans		

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] Fixed investment includes the costs of studies, such as the technical and topographical analysis of the site, its characterization, the risk assessment and so on. These studies provide the information needed to prepare the remediation proposal (decontamination plan), the planning and detailed engineering of the remediation, the estimated costs and, subsequently, the cost of the remediation and post-remediation works.

1. Financial costs of each remediation alternative

All the expenses required for the implementation and operation of each project alternative must be detailed. Those expenses fall essentially into one of two categories (MIDEPLAN, 2010):

(a) Investment

Investment costs are necessary to implement the alternative and include the acquisition of assets, such as land to install operating units or material collection centres, machinery and equipment. This item includes only disbursements made by the agent (for example, no financial outflow occurs if the agent, such as the municipality, already possesses the land or premises or if they have been transferred to a concession-holder). The financial evaluation and the economic evaluation differ in this respect, as the latter covers the entire economic value, regardless of the owner.

If it is known beforehand that other agents or different agents will contribute more assets, these must also be taken into account, without including the corresponding outflows (because they do not occur in financial terms). If their value is included in the evaluation, the financing option for the assets required by each alternative must be analysed.

(b) Operation and maintenance

Operating and maintenance costs are recurring and must be met during the life of the remediation project, including the post-closure phase. These include, among others, the cost of hiring labour for remediation work and the acquisition of inputs for treating contaminated sites. Assuming that the agency in charge of the remediation project continues to manage the site after the project is completed, the costs associated with maintenance in future phases will also be included in its balance sheet.

Only actual expenses are considered costs. If the organization assuming the total or partial execution of the project already has pre-existing personnel (such as project leaders, community relations agents or administrative staff), the fraction of the employees' total remuneration that corresponds to the hours worked on the project is considered. In contrast, for personnel belonging to an external company who provide operation or maintenance services, the cost of contracting those services should be recorded, not the value of their labour. Costs can also be used to identify the best way to combine internal and external services, taking into account transaction costs and the risks posed by incomplete (that is, those that fail to provide for all possible risks) and unfulfilled contracts.

Table VI.2 presents an example of financial costs for one hypothetical alternative. Each type of expense must be linked with its frequency, which can be regular (daily, monthly, annual) or irregular. Similarly, whether the disbursement identified will vary between those recurrences must be indicated, along with the rate of that change. In determining the rate of change, any fluctuation owing to factors other than shifts in the exchange[4] rate may be taken into account (for example, changes in tariffs on imported inputs or progressive supplies due to technical reasons).

■ Table VI.2
Investment, operation and maintenance costs of the alternative

Investment (line items)	Quantity (unit)	Unit price	Total cost	Frequency	Forecast
Demolitions	1 200 (m^2)	US$ 120/m^2	1 200 x 120 = 144 000	Year 0	...
Restoration of land	5 000 (m^2)	US$ 40/m^2	5 000 x 40 = 200 000	Years 0 and 1	...
Operation and maintenance					
Acid water treatment	500 000 (m^3/year)	US$ 0.70/m^3	500 000 x 0.7 = 350 000	Annual up to year 10	Decrease with x% rate
Monitoring and evaluation	4 (units/year)	US$ 5 000/unit	4 x 5 000 = 20 000	Every 2 years up to year 10	Constant

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[4] The sources of possible variations will only be technical since, for simplification purposes, all amounts considered are constant values of the currency used.

2. Financial revenue from remediation

Examining revenue is relevant when remediation alternatives involve the reuse, renovation or revitalization of contaminated sites, resulting in their increased or new use. This income can be obtained on a recurring basis (for example, if the site is used for agricultural production, tourism activities or other types of production that are in demand) or through one-off sales (for example, the sale of the site or of its repurposed components to a mineral exploitation company).

In cases of exploitation —whether for tourism, sporting or other uses— net income is calculated by deducting the costs of that exploitation that go further than remediation. That includes infrastructure works and administrative and maintenance costs, particularly if the implementing agency remains in charge of the site and takes advantage of the assets. If a detailed analysis for the area is not available, the prices to be considered can be estimated using the prices of similar activities or exploitations in other regions with equivalent characteristics.

As with expenses, the periods and frequencies of income are determined and their variation over time is indicated. The data are entered into the same type of table.

3. Private cash flow

In the cash flow system (see table VI.3), the expenses and revenue associated with each remediation alternative are set out, together with their respective frequencies. This system focuses on annual periods. In year zero, the project is analysed through studies and the main investment is made. Subsequent years are then included until the final horizon is reached. If the investment is made over a period exceeding one year, it is allocated accordingly for each year, invariably starting from year zero.

■ Table VI.3
Financial cash flow for remediation project alternative A

Financial cash flow for remediation project alternative A					
Period (year)	0	1	2	3	N
Expenses (costs)	C_0	C_1	C_2	C_3	C_N
• Investment					
- Item 1 (land)					
- Item 2 (works)					
- Item i (materials)					

Financial cash flow for remediation project alternative A					
• Operation and maintenance					
- Supply of nutrients					
- Land treatment					
• Other operating and maintenance costs					
Income	I_0	I_1	I_2	I_3	I_N
• Income type 1					
• Income type 2					
• Income type i					
Cash flow (income minus expenses)	F_0	F_1	F_2	F_3	F_N

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The configuration allows annual costs (C_j) and total revenues (I_j) to be recorded. Thus, the cash flow (F_j) is given by the difference between C_j and I_j. Several criteria, analysed together or independently, are used to determine the cash flow horizon (N):

(i) At the end of the useful life of most of the investment, which usually includes machinery and equipment, new investments are required. This demands a fresh review of the decision. If assets have different useful life expectations, reinvestment in assets with a shorter useful life should be considered.

(ii) The time required to decontaminate the site. The verification period is defined as the years in which outflows are made to reach the desired level of decontamination (unless this occurs in the same time frame as most of the spending).

(iii) The term of the concession or third-party assignment contract, which in turn can be defined according to the criteria for optimizing project financing. If the alternative in question includes revenues, a horizon can be defined to ensure a sufficient number of revenue years for the concession-holders to recover their investments. Otherwise, the horizon may determine the amount to be paid to the concession-holder, possibly annualized.

4. Financial indicators

Financial indicators enable comparisons between alternatives with potentially different cash flow horizons (for example, a shorter-term treatment plan that requires a larger investment; see the previous section and chapter V). Those indicators reveal, in one expression or value, different values in different years using the private or financial discount rate. That rate represents the cost of deferring or anticipating cash flows and enables the present value of future cost and benefit flows to be calculated. The following alternative options may be used to define the rate r, depending on the agent in charge of the project:

- The long-term debt rate prevailing in the local financial market, under the (theoretical) assumption that the agent will use external financing to launch the project.
- The relevant rate of return required by a potential concession-holder, to the extent that agent is considered.
- The opportunity rate of resources of the State, provided that the agent is a state institution. In this case, the financial and social discount rates coincide.

(a) Future value and net present value

The future value (FV), also known as capitalized value, shows what the value of a present monetized flow will be at a given point in the future. The present value (PV), or discounted value, is the value today of a certain amount in the future (see diagram VI.4).

■ Diagram VI.4
Intertemporal financial equivalents

$$FV_{TOMORROW} = PV_{TODAY}\,(1 + \text{discount rate})^{\text{No. of periods}}$$

$$FV_{TODAY} = \frac{FV_{TOMORROW}}{(1 + \text{discount rate})^{\text{No. of periods}}}$$

Source: N. Sapag, R. Sapag and J. Sapag, *Preparación y evaluación de proyectos*, Mexico City, McGraw-Hill, 2014.

With these equivalences, the fundamental indicators of the intertemporal analysis can be obtained: the net present value (NPV) and the internal rate of return (IRR) (Sapag, Sapag and Sapag, 2014; see the following section).

According to these indicators, both costs and benefits may arise in each period of the horizon. It is therefore important to calculate a resulting flow that discounts the respective costs from the benefits.

The net present value indicates, in a single figure, the difference between cost flows and benefit flows. Based on rate *r*, flows F_0 to F_N are aggregrated to obtain the private or financial net present value:

$$NPV = NPVp = \sum_{t=0}^{N} \frac{F_t}{(1+r)^t}$$

Where:

N: the number of periods included in the analysis horizon.

r: the applicable discount rate.

The possible outcomes for each alternative are:

- NPVp > 0: net gain for the agent.
- NPVp < 0: net loss for the agent.
- NPVp = 0: the agent reports neither gains nor losses with the implementation of the alternative.

If an alternative needs more years to reach the target, this is indicated in the final value. When the private evaluation includes revenue, this indicator is sufficient to enable the alternatives to be compared.

The net present value can also be used to calculate the cost-benefit ratio. A project is desirable if the ratio is greater than 1. However, the result varies depending on whether recurring costs are categorized as net costs or net benefits (Nas, 2016).

In cases when no benefits accrue, the net present value is maintained solely in terms of costs and is called the present value of costs (PVC) or, if held at a uniform annual rate over the whole period, the annual value of costs.

(b) Internal rate of return

The internal rate of return is related to the net present value and is usually obtained as a complementary indicator, reporting the level of profitability generated by the project alternative. In other words, it indicates the premium as a percentage of the amount invested. From another perspective, it enables the maximum discount rate for achieving positive net project cash flows over time to be calculated (with a higher rate, the net present value would be negative). Mishan and Quah (2021) suggest that it may be appropriate to treat future spending as negative benefits, along with any deterioration in the physical environment.

The internal rate of return causes the net present value to become zero and discounted income and expenses to be equalized:

$$0 = \sum_{t=0}^{t=n} Ft/(1+IRR)^{t}$$

If equivalence with the decision criteria is established for net present value, possible outcomes and associated decisions for the internal rate of return include:

- IRRp ≥ r: the premium percentage (the intrinsic profitability) of the project alternative equals or exceeds the minimum profitability required by the private agent, represented by rate r.
- IRRp < r: the premium percentage does not exceed the minimum required by the agent.
- The internal rate of return, unlike the net present value, can yield multiple results. In other words, it is possible for more than one rate to produce a net present value equal to zero (when the net flows have more than one change of sign). In such cases, the internal rate of return does not provide any interpretation for the decision. Since the indicator does not reflect the increase in wealth, but only the return on

invested capital, and as indicated above, this indicator should always be used as a complement to the net present value and not exclusively. In addition, the internal rate of return does not include the scale. Consequently, it is not useful in comparing large projects with expected net benefits in the millions (or billions) of dollars with smaller projects with net benefits in the thousands (Nas, 2016).

(c) Present value of costs

If the alternatives do not guarantee the generation of income, the cash flow may consider the outflows or costs only. In this case, flows Fi comprise only Ci, which yields the present value of costs:

$$PVCp = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

When a financial criterion is applied, the alternative with the lowest present value of costs should be chosen, provided that the alternatives fulfil the remediation objective equally. Like the net present value, the present value of costs enables comparisons of alternatives with different horizons.

(d) Equivalent annual cost

The equivalent annual cost (EAC) is complementary to the present value of costs and, when only cost information is available, it converts that value into equal annual instalments. The equivalent annual cost is obtained from the present value of costs with the corresponding rate r:

$$EAC = PVC \times \frac{r \times (1+r)^N}{(1+r)^N - 1}$$

This represents a fictitious situation with a constant cost flow in all years of the horizon, equivalent to a real situation. Irrespective of whether the situation has a different flow structure each year, it is represented correctly in the calculated present value of costs. Equivalent annual cost is used to compare alternatives regardless of their horizon (for example, to check alignment with an annual budget or to obtain an annual measure of pro-rated cost per inhabitant or per hectare of land).

(e) Net present value: the right criterion?

An indicator's suitability for summarizing the cost-benefit analysis depends on the circumstances. In general, net present value is usually the indicator of choice for evaluating and comparing results. However, net present value does not provide a reliable ranking of projects when they are not mutually exclusive (that is, when co-dependence exists) or when active budget constraints exist. This issue must be taken into account in prioritizing different projects at different sites (Nas, 2016; see table VI.4).

Net present value may favour alternatives that generate more abundant but intermittent benefits rather than more stable benefit streams (Knoke, Gosling and Paul, 2020), which is detrimental to some forms of reuse (such as secondary mining, agriculture or tourism). The way it deals with future profits also makes no distinction between consumption and reinvestment (see the discussion of methodological adjustments in Robison, Barry and Myers, 2015, and the normalized composite terminal value in Mishan and Quah, 2021).

■ Table VI.4
Comparison of project alternatives according to the net present value and cost-benefit ratio criteria

Alternative	Investment (in year 0)	Net present value	Cost-benefit ratio
A	1 000	100	1.1
B	500	60	1.12
C	400	80	1.2
D	100	15	1.15

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016.

D. Economic evaluation

The economic evaluation expands on the financial evaluation, and the costs and benefits of the implementation of the remediation alternative under review for society as a whole are recorded in a cash flow. The starting point is each alternative's revenue and spending; these are obtained from the private evaluation but are transformed into social costs and benefits. These flows include real (non-monetary) economic effects and social and environmental effects (see chapter V). All the project's positive and negative impacts can be expressed in monetary terms using social prices (see section III.A). The social discount rate converts future cash flows into present units. Indicators equivalent to financial indicators, but with economic significance, are calculated:

- NPVs: net present social value.
- PVCs: present value of social costs.
- EACs: equivalent annual social cost.

Project input payments cover the cost of the use of resources that the economy would allocate to this project, forgoing their use in alternative projects, regardless of to whom they belong in practice. The economy's internal transactions are not taken into account,unless the resources in question are used.[5] In addition, other agents are considered, such as the

[5] Payments for services should be valued on the basis of the resources used, while profits and taxes —which are only transfers and do not extract or contribute resources to the economy— should be discarded. Instead, they are resources that move from one agent to another (Contreras and Diez, 2015).

population that would potentially be affected, either positively or negatively, were the remediation not carried out or were it carried out under certain conditions (for example, residents who are harmed or benefited by the transport of machinery and vehicles for specific tasks).

1. Social costs of remediation

The social costs of remediation relate exclusively to the costs associated with the implementation of the remediation alternatives. They do not represent the costs of the mining legacies that are to be eliminated.

(a) Correction of financial expenses to social value

The readily identifiable resources used to implement and operate the corresponding alternative, as outlined in the previous step (see section "Private or financial evaluation" above), are corrected to represent the social value through the following methods (see chapter V):

(i) Application of the correction factor

As part of social prices, most of the region's countries use correction factors to obtain the price of the labour prevailing in the labour market. Taxes, profits and any other types of charge that imply transfers and not economic cost are extracted from prices.

To transfer this price to the social value, the coefficient of the supply prices (which are observable and subject to transaction) is applied by means of the following formula:

$$SPL = scf * PPL$$

Where:

SPL: social price of labour (in monetary units).

PPL: private price of labour (gross wages, in monetary units).

scf: social value correction factor (social price parameter).

Correction factors are generally used at the national level and are periodically updated and segmented according to the type of labour involved (skilled, unskilled or semi-skilled) and taking into account differences between urban and rural areas (see section V.B.1). Distortions in the foreign exchange market affecting the prices of tradable goods, which are frequently used in public investment projects, are also adjusted by a correction factor.

(ii) Direct determination of social prices

In some cases, because private prices are not available, social prices are determined directly. Examples include the social value of time or carbon and the statistical value of life. The latter is used for various purposes, including to quantify the benefits to human life of an environmental improvement.

(iii) Extraction of transfer charges

For resources without correction factors or social prices, the social value is calculated by deducting taxes, tariffs, profits and other components associated with a transfer, rather than with the resource's observable market value. The extraction of charges (which do not entail an economic cost) is not applied to the prices of resources for which a correction factor is used, since the factor already includes the extraction.

(b) Inclusion of additional costs in investment and operating expenses

Indirect and secondary costs arise as a consequence of the effect that may occur in activities related to the remediation (such as transporting supplies or producing nutrients). These costs are not closely related to the direct resources used in the project. It is essential that the costs be quantified and valued in order to record the amounts involved and the frequency with which they occur.

(c) Cost projection

As in the private evaluation, and in relation to the evolution of social costs over time, elements other than the evolution of the currency included to determine values are established. The currency must be the same and must cover the same period for all recorded costs (see section "Private or financial evaluation" above).

If social costs for the population are determined, those costs may vary with demographic trends. The rate of population growth or decrease in the area of influence is therefore included.

2. Social benefits of remediation

(a) Revenue that represents an increase in productivity or consumption

The main sources of economic income in the remediation of mining environmental legacies include the following:

- Revenues reported in the private evaluation that do not involve a mere transfer between agents (see section "Private or financial evaluation"). Revenues from increased productivity are quantified and valued. These will be reflected in any future sale of remediated land. The prices recorded for sales in the private evaluation reflect the increase in productivity.[6]
- Studies with a regional focus may include tourism or other activities carried out at the site (for example, artificial reservoirs for swimming or sport fishing). The social benefit of increased well-being is calculated as the price of access to activities multiplied by the

[6] If third parties acquire land for exploitation purposes, it is reasonable to assume that the corresponding price is a minimum share of the new economic value of that land. The buyer must add production costs to that price, under the assumption that the production will be marginal so as not to affect or alter its prices. Consequently, a minimum share of the social benefit from the remediated land will be the difference in third-party prices before and after remediation.

number of accesses. Those activities, however, can displace similar consumption in other areas of the economy. Benefits are not considered in economy-wide studies, as they represent transfers between agents at the national level (Boardman and others, 2018).

- When price information is not available, productivity gains are recorded in terms of the additional amounts of output generated as a result of land remediation.

b) Additional social benefits

Additional social benefits accrue from the elimination of losses caused by inaction. All the problems detected and affected areas are evaluated (see chapter IV). Based on the observed impacts, the probable damage and associated costs that could be avoided are estimated (see box VI.1), including externalities. A sequence is built from the problems of mining environmental legacies to the benefits of the remediation alternatives. If the valuation is costly or complex, it may only go as far as quantification.

■ Box VI.1

Examples of costs to be avoided derived from identified impacts and valuation methods

Area of impact	Impact type	Probable damage and cost (with quantification)	Valuation mechanisms
Population	Respiratory diseases due to air and soil contamination	Decrease in working days	Statistics for sick leave and workday value
		Increase in personal healthcare spending	Health insurance statistics
		Increase in public health spending	Public health system statistics
	Risk of a disaster	Impact on people's health and safety	Statistical value of life
		Impact on infrastructure and real estate	Value of potentially damaged assets
Economic (business) activities	Loss of agricultural output	Crops that cannot be produced	Value of potentially damaged assets
		Crops with compromised quality	Prices and quantities
		Crops with compromised yields	
Environment and nature	Decrease in surface and groundwater quality	Decrease in the variety of flora and fauna	Valuation surveys: contingent valuation and hedonic pricing
		Foul odours	
	Deterioration of landscape due to dumps and tailings	Loss of the natural value of the area	
	Protection of biodiversity	Loss of endemic species	
	Greenhouse-gas emissions	Global and local climate change	Social price of carbon

Source: Economic Commission for Latin America and the Caribbean (ECLAC)..

Following the example of estimating the damage and costs of workplace absenteeism due to the negative effects of the mining environmental legacy, the proportion of sick days in the area because of respiratory diseases attributable to air pollution caused by the site is calculated. Then, an estimation is made of the extent to which it would be reduced by the remediation alternative under discussion. Finally, the annual value is obtained by multiplying the resulting sick days by the average wages of the persons in question. A similar process is followed for the decrease in labour productivity, which is related to higher health spending, using statistics on average annual spending and the proportion thereof allocated to illnesses caused by the mining legacy.

For economic activities, such as agricultural production affected by reduced land yields, a distinction is made between the effects on the quality, quantity and type of output. In the first case, an approximation to social benefit is obtained by identifying the price gap between top quality and the quality produced as a result of the mining environmental legacy and multiplying it by the quantities produced. If the output amount is reduced, the difference between the current and the optimal quantity is multiplied by the price of the product. Finally, if the mining environmental legacy does not allow the exploitation of certain types of higher value-crops, but remediation would enable the current lower-value crops to be replaced by them, both quantities and prices before and after remediation are considered.

Environmental impacts that affect activities and the population indirectly (such as a decrease in the variety of flora and fauna in the area) are estimated in terms of the population's willingness to pay (demand) to resolve that natural and environmental deficit. However, survey-based methods (see chapter V) are complex and costly, and may not be suitable for a profile-level study (as proposed in this handbook). A simpler alternative is to make use of previous studies.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The alternatives are distinguished by a range of factors including their ability to reduce probable damage. Each alternative is assigned the proportion of damage reduction it produces so that those same proportions can be applied to the quantified or valued benefits. The proportion applied may vary over time, depending on the capacity of the alternative to remediate the site gradually or once a certain level of treatment or permanent actions has been reached. Based on the above, each year of the analysis horizon is assigned the corresponding proportion (see box VI.2).

■ Box VI.2

Reduction progression for cost reduction benefit i (expressed in the value of the fully reduced impact

Year	Remediation alternative 1		Remediation alternative 2	
	Percentage reduction	Benefit value	Percentage reduction	Benefit value
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	p_m	pm x value of the fully reduced impact	0	0

Year	Remediation alternative 1		Remediation alternative 2	
4	p_m	pm x value of the fully reduced impact	0	0
5	p_y	py x value of the fully reduced impact	p_u	p_u x value of the fully reduced impact
6	p_z	pz x value of the fully reduced impact	p_u	p_u x value of the fully reduced impact
N	p_q	pq x value of the fully reduced impact	p_u	p_u x value of the fully reduced impact

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: p_m, p_y, p_z, p_q ... only different percentages.

The cost of the impact, as if it were completely reduced as calculated, is used as a reference; the value is expressed as the value of the fully reduced impact. In the first alternative, the effects of remediation are first felt in the third year. The value of the benefit for each year is obtained by applying the percentage reduction (pm) to the value of the fully reduced impact. The benefit values may vary over time according to the reduction percentages determined for each alternative. It is essential that this progression analysis be performed for each type of impact and that its corresponding avoided cost be converted into a benefit.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

(c) Projection of social benefits

Most of the remediation project's social benefits are associated with the population in the area of influence, and the expected evolution of the population is applied as an index to value those benefits. Relevant data from census statistics are obtained from municipal records (housing plans) or cartographic information. Digital satellite cartography available on the Internet also enables areas of population expansion to be visualized.

3. Social cash flow and indicators

Using the values obtained, the corresponding cash flow is calculated in a similar way as in the private evaluation, but with the relevant items (see table VI.5):

■ Table VI.5
Simplified social cash flow model

Social cash flow for remediation project alternative A					
Period (year)	0	1	2	3	N
Social costs	SC_0	SC_1	SC_2	SC_3	SC_N
Investment corrected to social value					
Opportunity cost of land					
Social value of works					
Others (corrected)					

Social cash flow for remediation project alternative A					
Operation and maintenance					
Supply of nutrients					
Land treatment					
Others (corrected)					
Social benefits	SB_0	SB_1	SB_2	SB_3	SB_N
Social benefits type 1					
Social benefits type 2					
Social benefits i					
Cash flow (benefits minus costs)	SF_0	SF_1	SF_2	SF_3	SF_N

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: As in the private evaluation, the horizon N —that is, the number of years considered for the analysis— takes into account the time needed to achieve the desired level of remediation and the useful life of the investment's main components.

(a) Social profitability indicators

(i) Discount rate

As in the private evaluation, project implementation generates economic value streams in each annual period. A discount rate is therefore needed to equalize the figures for the different periods. The State assumes the role of the investment agent. As it represents society as a whole, the social discount rate is used for its investments (see chapter V).

In most of the region's countries, the social rate is calculated as a weighted sum of the value between generations, consisting of the intertemporal preference rate of consumption (measuring how much of today's consumption is given up in order to consume tomorrow) and the rate of return on capital (from the fiscal treasury). In countries that have loans from international organizations to finance some of their public investments, the rates of those loans are also considered.

(ii) Sustainability considerations in the discount rate

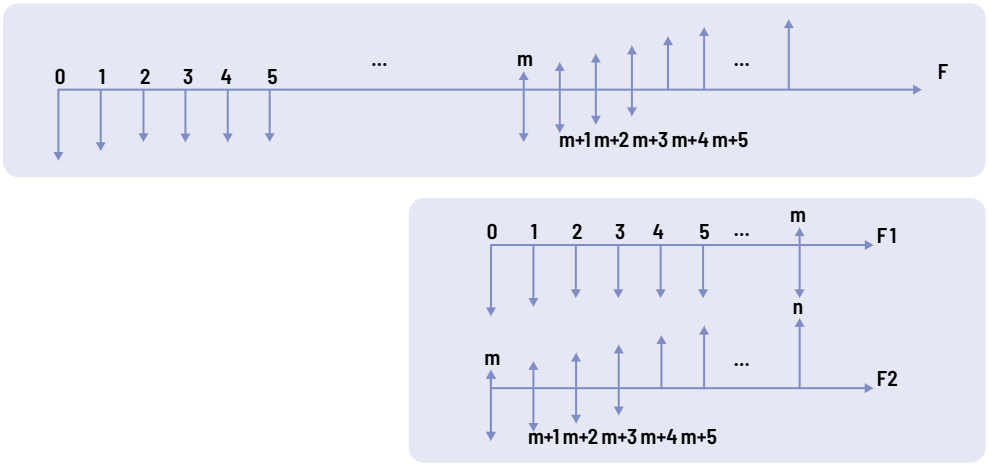
The level of the flow discount rates determines whether the future benefits exceed the costs of the first years, which is a necessary condition in obtaining an indicator that favours project execution.

Compared to developed countries, the region's social discount rates tend to be high due to the greater weight of interest rates caused by the scarcity of capital. For that reason, this handbook proposes considering the use of one of the following adjustments for the social discount rate in the cost-benefit analysis of a mining environmental legacy remediation project. If these options are not directly implemented, they can also serve as a sensitivity analysis to support one of the alternatives.

Splitting of cost periods and benefit periods

The analysis horizon is divided into two sections: one short-term and cost-intensive, and the other long-term and more benefit-intensive. Diagram VI.5 shows that in the initial years up to a certain period m, the resulting flows in each year are mainly negative, and the benefits remain below the costs. From period m+1 onwards, the flow becomes positive. Figures F1 and F2 (in diagram VI.5) show the equivalence of this situation separated into two flows as if both started from period zero. In other words, the second tranche's flows are considered as if they were starting from today instead of starting from the corresponding period, whereby a lower discount rate is imposed on them.

■ Diagram VI.5
Flow equivalence for an environmental capital project



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Thus, the flow becomes equivalent to the sum of the flows of both periods, as if they were parallel (F = F1 + F2). The final result of the corresponding indicator is the sum of the indicators of both flows at present value today with the single social discount rate:

$$NPV(F,r) \equiv NPV(F1,r) + NPV(F2,r) = \sum_{t=0}^{t=m} \frac{Ft}{(1+r)^t} + \sum_{\substack{t=m+1 \\ i=0}}^{\substack{t=n \\ i=N-m}} \frac{Ft}{(1+r)^i}$$

Where:

r: social discount rate applicable to public projects

m: number of the period where the horizon is divided

N: final project horizon

Ft: net flow (benefits minus costs) for period t

Application of the zero rate

If a discount rate r = 0 is used,[7] today's generation values the well-being of all generations equally (Torche and others, 2009). If r = 0, the denominator $(1 + r)^t$ will always be equal to one. The net present value is given by the simple sum of the net cash flows for each period:

$$VNP(F) = F_1 + F_2 + F_3 + \cdots + F_i + \cdots + F_N = \sum_{t=0}^{t=N} Ft$$

(b) Alternative with only costs valued (cost-effectiveness analysis)

If the parameters of the scenario require a cost-effectiveness analysis instead of a cost-benefit analysis (see section III.D), applying a treatment to the discount rate in order to compare the alternatives is not necessary. In such cases, the present value of social costs and the equivalent annual social cost are determined as follows:

$$PVCs = \sum_{t=0}^{t=N} \frac{Cst}{(1+rs)^t}$$

$$EACs = PVCs \times \frac{rs \times (1+rs)^N}{(1+rs)^N - 1}$$

Where:

PVCs: present value of social costs

EACs: equivalent annual social cost

rs: social discount rate

N: number of periods in the horizon

If the alternatives fulfil the required remediation in an equivalent fashion (not equally, but with the same end result), the present value of social costs alone will determine preferences by revealing their intensity in the required resources. However, consideration could be given to an alternative that, although it implies a higher present value of social costs, includes a lower cost composition for individuals, especially if they belong to vulnerable socioeconomic groups (see section "Social evaluation").

In the event that the remediation alternatives do not have the same level of remediation performance[8], the social equivalent annual cost —which enables the differences to be studied and the choice of alternatives to be supported— may be used. If the benefits are not valued, the cost indicator is associated with the estimates of change in relevant dimensions (see table VI.6).

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7 This approach follows the guidelines established by the United States Environmental Protection Agency (EPA) by aggregating future environmental project flows without discounts (Edwards, 2014).

8 Even when benefits re not valued, their identification and possible quantification will reveal the differences between the alternatives under study (for example, their different impact on ecosystems).

■ Table VI.6
Examples of cost-efficiency indicators for the use of a cost-effectiveness analysis

Type of avoided cost with difference between alternatives	Cost-efficiency indicator
Respiratory diseases due to soil contamination	Equivalent annual cost/number of patients reduced
Loss of agricultural output	Equivalent annual cost/number of hectares reclaimed
Surface water pollution	Equivalent annual cost/m^3 of recovered flows
Harmful elements present in the environment	Equivalent annual cost/number of elements reduced
Threatened biotic varieties	Equivalent annual cost/number of varieties recovered

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

E. Social evaluation

Social analysis complements the evaluations described above, since in evaluating remediation alternatives, a choice can be made for those that favour lower income groups the most, thereby introducing a distributive element. To achieve this, clarity must exist regarding the social cost or benefit (or portion thereof) associated with the different economic agents affected.

1. Characterization of the affected parties

In the previous section, the method for estimating social costs and benefits and for calculating the indicators derived from them was shown and analysed. This section takes the analysis further and underscores the importance of defining the parties that will meet the costs and receive the benefits.

The identification of the parties impacted by the project is carried out in the initial phases of the integrated analysis mechanism (see chapter II). The analysis of the affected parties is based on the criterion of equity, since in general those identified as the intervention's "winners" do not usually coincide with the groups that bear its costs. In addition, among the beneficiaries, groups willing to contribute to project financing can be found.

If some of the affected parties increase their productivity as a result of a remediation project (for example, through soil remediation), they could become providers of financing for remediation projects, with part of the gains being passed on to finance investment costs or expenditures. Other groups can be identified as those that effectively absorb the socioenvironmental impacts of mining legacies[9]. Their social characterization, as well as the intensity or magnitude of the associated impacts, could imply that special consideration is required for decision-making purposes (distributional considerations).

[9] The environmental effects may imply later harm to the population registered in the social analysis. Environmental analysis is therefore considered as part of the technical analysis of alternatives.

In this instance, the analysis of social vulnerability is taken further, with the groups of affected populations disaggregated with greater precision (for example, whether they mostly comprise low-, middle- or high-income sectors). The affected population is identified by groups (see table VI.7).[10] The cause-and-effect tree helps identify the main affected groups and their characteristics (see chapter IV). The groups are also defined according to the information available in each country. In general, criteria and information exist at the national level and, on the basis of that, limits can be established.

■ Table VI.7
Mechanisms for the classification of affected parties

General group	Source for specific classification	Cut-off criteria
State	Budget law or organic laws setting powers and limitations	Investment budgets, stand-alone income or legal responsibility
Companies	Ministry of the economy or business promotion agency	Annual sales level, employee numbers or tax brackets
Population	Ministries of development or planning or social studies agencies	Percentiles according to income level or commercial stratification

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The main groups can be broken down into local residents, farmers, and ethnic or age groups, or by conditions of vulnerability or other significant characteristics. More groups may emerge during the analysis of alternatives (such as suppliers of remediation technologies and inputs, groups linked to the reuse of mining environmental legacies, secondary mining companies and additional beneficiaries of remediation).

Deciding the extent to which economic efficiency can be sacrificed to include greater equity is both a political and an economic question. In view of the structural gaps and rigidities of social and territorial inequity in the region's countries (for example, the higher costs faced by the rural population compared to urban dwellers; see ECLAC, 2022c), the fact that the assessment of the affected parties assigns proportions of costs and benefits to the different actors involved already provides important information when considering the result of an overall net present value indicator, without including distributional factors (see box VI.3).

■ Box VI.3
Example of the use of weightings

Two alternative projects for remediating a mining environmental legacy that reduce risks equivalently are analysed. Those risks are difficult to convert into valued costs, however, so a cost-effectiveness analysis is applied. If the total social costs are CsA and CsB, where CsA < CsB, the economic analysis would suggest opting for alternative A. However, when the evaluation of the affected parties is included, it is seen that the calculated social cost for both alternatives comprises a social cost for small farmers (Cs_agric) and another for the municipality (Cs_munic). In other words, for both A and B: Cs = Cs_agric + Cs_munic.

[10] The General Analysis of Economic and Social Impact for air quality instruments of the Ministry of the Environment of Chile uses a grouping by the population, the private sector and the State. These groups can, in turn, be subdivided, which is in line with the differentiation between state agencies and companies, as well as the population.

In alternative A, farmers would lose part of their income, since the crops they usually plant are not compatible with —or are adversely affected by— the assets acquired by the municipality to remediate the effects of the mining legacy. In contrast, under alternative B, they are not forced to change their crops, but the acquisition of the assets entails a higher cost, which also implies a higher outlay for the municipality. So, for A, Cs_agric > Cs_munic, while for B the inverse is true.

Before applying any factor or weighting, the decision maker could adopt a criterion of equity versus efficiency. Depending on the amounts and the socioeconomic characteristics, the decision maker may choose the alternative that does not harm small farmers. The importance of examining the affected parties lies in making relevant, complementary information available to the decision maker, in addition to the economic analysis.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

In view of the above, the evaluation of the stakeholders involved begins with a general classification. This is followed by a specific classification for each of them and the assignation to them of the amounts of net benefits or costs, according to the type of analysis chosen (cost-benefit analysis or cost-effectiveness analysis; see table VI.8 and chapter II). Note that not all stakeholders are considered affected parties in the social analysis.

■ Table VI.8
Allocation of social benefits and costs to identified stakeholders

General classification	Specific classification	Stakeholders	Associated net social benefit[a]
State	Ministry or dependent agency	Sectoral ministry	Amount spent on studies
	State-owned company		
	Municipality	Department of natural resources and the environment	Amount of physical investment
Private sector	Corporations and large companies	N large agricultural companies	Proportion of benefits from increased output
	Small and medium-sized companies		
	Microenterprises	N individual farmers	Proportion of benefits from increased output
Population	High-income socioeconomic group	X inhabitants of the area of influence	Proportion of benefits from disease reduction
	Middle-income socioeconomic group		
	Low-income socioeconomic group	X inhabitants of the area of influence	Proportion of benefits from disease reduction
	Intermediate socioeconomic group[b]	X inhabitants of the area of influence	Proportion of benefits from disease reduction

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Ministry of the Environment of Chile (MMA), *Guía metodológica para la elaboración de un análisis general de impacto económico y social (AGIES) para instrumentos de gestión de calidad del aire*, Santiago, 2013.
[a] Costs are included when the evaluation does not calculate the value of benefits.
[b] More groups can be added depending on the country's own characterization.

In order to ensure a degree of intergenerational equity, future generations should be included in the general, specific and affected party classifications when they are impacted by costs or benefits (such as reduction of biodiversity loss). Although benefits are difficult to assess, this issue is particularly relevant if the effects on future generations are specific to only a few remediation alternatives.

2. Social analysis methods

Equity considerations can be incorporated into economic evaluations by means of several methods[11]. If data on the population's socioeconomic distribution are available, a distinction can be drawn between groups of agents, and the net social benefit accruing to each of them can be calculated.[12] After identifying the affected parties, the classification criteria are specified by socioeconomic level, degree of impact and estimates of the numbers that make up each group. This information is systematized (see table VI.9), and an equity or distributive analysis is prepared.

■ Table VI.9
Characterization of the affected parties

Affected party	Socioeconomic level	Degree of impact	Quantity estimation
Group 1, beet growers	Low, subsistence production	High, due to the increasing contamination of surface waters caused by mining legacies	500 families
Industrial farmers	Medium-high		
Rural inhabitants			
Other			

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Some projects may offer opportunities for improving equity and developing the local business environment. Preference will probably be given to those remediation alternatives that have the potential to attract alternative sources of financing, increase the use of labour and promote economic activity among both microenterprises and small and medium-sized enterprises.

3. Evaluation of equity considerations

Up to this point, the analysis allows the introduction of variations or the confirmation of an alternative choice that supports the result of the economic evaluation. In addition, in order to obtain indicators comparable to those obtained in the two previous evaluations, the net present value or present value of costs of the individual groups related to the stakeholders must be calculated. In other words, the social flow previously constructed for each of the agents must be divided in such a way that:

[11] Equity considerations can be incorporated into the economic analysis without the need for an additional formal step.
[12] See section II.E on analysing stakeholders.

$$NPVi = \sum_{t=0}^{N} \frac{Fit}{(1+r)^t}$$

Where:

NPVi: net present value of stakeholder i

Fit: flows of stakeholder i in each period t

rs: social discount rate used (could be the one differentiated by groups)

The overall net present value calculated in the previous evaluation must be such that:

$$NPV^{o} = \sum_{i=1}^{K} NPVi$$

Where:

NPVº: overall net present value previously calculated with the corresponding rate

NPVi: net present value of each stakeholder

K: number of stakeholders

Based on the above, different assessments of equity considerations can be used:

(a) Simulate values for equity-enhancing externalities

The values of the externalities associated with the project alternatives that favour equity and that are not quantifiable (in other words, those are not included in the indicators described above) are simulated.

If an alternative presents a positive externality that promotes greater equity, it must be assigned simulated values. A first analysis mechanism to incorporate this element is the sensitization exercise conducted when comparing scenarios (Gómez, 1998; Ortegón, Pacheco and Roura, 2005; see box VI.4).

■ Box VI.4

Example of the use of weightings (continued)

Returning to the example in Box VI.3, assume that the more costly alternative bolsters the productivity of small farmers by reclaiming land and increasing yields. In addition, there is another group of industrial farmers who will also benefit.

The industrial farmers already benefit from the additional yield, so a lower-cost alternative that allows them to reclaim land is sufficient for them.

If the difference in present value of costs of both alternatives equals 1,000 monetary units, the alternative that favours the small farmers is recorded with a value exactly equal to this as the equity externality value to leave both alternatives with a result of indifference. Now both have the same present value of costs.

This would be like asking whether an efficiency equivalent to 1,000 monetary units should be sacrificed in order to favour a lower-income group. The decision maker can compare this value with other relevant amounts (for example, the amounts of assistance offered, the higher productive level of that group over the analysis horizon or the total cost of the solution). Again, the value of the analysis lies in making the result available to decision makers.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

(b) Verify compensations

For each net present value of stakeholder i, the losers (those with NPVi < 0) and winners (NPVi > 0) are identified. Effective mechanisms are then established for the latter to compensate the former (see box VI.4). The task at this juncture is to specify the proposed compensation in accordance with the Kaldor-Hicks criterion and to incorporate it into the project's terms (for an example, see box VI.5).

Although compensations are recommended, the dispersion of economic agents affected by the project and transaction costs may prevent winners from compensating losers in a project (Nyborg, 2012).

■ Box VI.5
Example of compensation for specific groups

Compensation mechanisms are used in remediation project alternatives when they are economically suitable (NPVs > 0). Each project alternative can create both winners (such as farmers with increased output) and losers (such as local residents whose property values are reduced by the installation of treatment plants nearby). An effective compensation mechanism would include measures targeting the injured parties (for example, measures to increase the residents' incomes).

Compensations from multilateral agencies, such as the World Bank and the Inter-American Development Bank, are implemented through the socioenvironmental safeguards of the projects they finance. A sustainable project must consider the possibility of a community being physically or economically displaced on account of its activities. A participatory venue for decision-making among project stakeholders is therefore required —including, in particular, the affected community— in order to reach an agreement to compensate them equitably and correctly for the value of their properties.

Compensation may be monetary or, if a monetary value cannot be assigned to the assets sacrificed by the community, in kind. For example, compensation packages may include new housing and assistance for relocation if the land used for agricultural production was inhabited prior to resettlement.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "EAS 5: adquisición de tierras, restricciones sobre el uso de la tierra y reasentamiento involuntario", *Nota de Orientación para los Prestatarios*, Washington, D.C., 2018; Inter-American Development Bank (IDB), *Marco de Política Ambiental y Social*, *Washington*, D.C., 2020.

(c) Use weightings

Different weightings are applied to the various agents that make up vulnerable social groups. A weighting greater than one is used for the net present values of stakeholders *i* in the groups to be favoured (such as microenterprises or vulnerable populations; Contreras, 2004) in order to increase the relative weight of those affected parties.[13] The new overall net present value, aggregated by means of the weights, may change the selection order of the recommended alternatives (see box VI.6). The weightings are defined before carrying out the cost-benefit analysis or the cost-effectiveness analysis (see chapter V).

[13] Regardless of whether NPVi > 0 or NPVi < 0, the result will be higher in absolute terms.

■ Box VI.6
Use of weightings in the calculation of net present value

Following the example of alternative A in table VI.4, it can be assumed that the project has a 100-year horizon, that the initial one-time investment of 1,000 monetary units is made entirely within the first year, and that decision makers apply a social discount rate of 3.8%.

In addition, it is assumed that all project benefits will favour the local inhabitants, whose size or distribution will not change over time. Finally, it is expected that the initial investment will come the central government's budget and that the weight of local populations in the central budget is negligible (equal to zero).

If, from the first year onwards, the benefits provided by the project increase by 5 units, to reach a potential of 100 units in year 10, then the net present value will be 100, the cost-benefit ratio will be 1.1 and the internal rate of return will be 4% (see table).

Net flow of costs and benefits over the analysis horizon for alternative A (years 0–100)

Year	Unweighted	Low-income group	High-income group	Weighted
0	-1 000	0	0	-1 000
1	5	6	4	15
2	10	12	8	30
3	15	18	12	44
4	20	24	16	59
10	50	60	40	148
99	50	60	40	148
100	50	60	40	148

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Now, assuming that three-fifths of the benefits accrue to the poorest local groups (for example, due to their exposure to contamination because they are closer to the mining legacy) and that the remainder favours local higher-income groups, the net present value can be recalculated using a default weighting of 1.8 for the low-income groups. Thus, the net present value increases from 100 to 628, the benefit-cost ratio is 1.6 and the internal rate of return is 6%. The higher net present value is based on social welfare, which prioritizes equity. In order to compare this alternative with the others, the effects of each on the stakeholders must be evaluated and the methodology must be applied consistently.

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

F. Sensitivity analysis

To find a range that reflects future flows of costs and benefits, risk and uncertainty are incorporated into the estimates (McSweeney, 2006). Sensitivity analysis is used to quantify the impacts of changes in the assumptions (see chapter IV). In this way, decision makers can better appreciate the potential effects of project implementation while considering the assumptions used to build the scenario.

According to Bonner (2022), each cost-benefit analysis should, at a minimum, assess the sensitivity of the results to the social discount rate, the analysis horizon, wages, the statistical value of life (if used in the analysis), environmental impacts, growth rates and benefits. If the possible events and their probabilities are known, an analysis of the expected value can be carried out (see box VI.7).

■ Box VI.7
Examples of sensitivity analysis

Using the hypothetical example of alternative A shown on table VI.4, the net present value obtained can be subjected to a partial analysis based on the change in the social discount rate (assuming, for example, that the default rate applied represents the midpoint between consumer rates and return on capital; see table 1).

■ Table 1
Partial analysis of sensitivity to changes in the social discount ratel

Social discount rate	Scenario 1: 1.8%	Scenario 2: 3.8%	Scenario 3: 5.8%
Net present value (weighted)	2 160	628	7
Cost-benefit ratio (weighted)	3.16	1.63	0.7
Net present value (unweighted)	1 135	100	-320
Cost-benefit ratio (unweighted)	2.1	1.1	0.7

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The analysis of the expected value can be combined with the analysis of scenarios (see, on table 2, an example in which it is assumed that the main risk, together with costs, arises from a change in the exchange rate, which would impact the value of imported goods used in the remediation project).

■ Table 2
Analysis of expected value according to interest rate changes

Assumptions				
Change in currency value	Investment cost	Event probability[a]		
Depreciation	1 200	0.3		
Stability	1 000	0.55		
Appreciation	800	0.15		
Expected value				
Scenario 1				
Change in currency value	Net present value	Cost-benefit ratio	Net present value[a]	Cost-benefit ratio[a]
Depreciation	1 960	2.63	588	0.79
Stability	2 160	3.16	1 188	1.74
Appreciation	2 360	3.95	354	0.59
Expected value			2 130	3.12
Scenario 2				
Depreciation	428	1.36	128	0.41
Stability	628	1.63	345	0.90
Appreciation	828	2.04	124	0.31
Expected value			598	1.61
Scenario 3				
Depreciation	-193	0.84	-58	0.25
Stability	7	1.01	4	0.55
Appreciation	207	1.26	31	0.19
Expected value			-23	0.99

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Australian Transport Assessment and Planning (ATAP), *Australian Transport Assessment and Planning Guidelines: T2 Cost Benefit Analysis*, Canberra, 2022.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Australian Transport Assessment and Planning (ATAP), *Australian Transport Assessment and Planning Guidelines: T2 Cost Benefit Analysis*, Canberra, 2022.

[a] Weighted.

G. Interdependence with other projects

When multiple projects exist in a single area, evaluations of projects in the vicinity of the remediation project should, to the extent that is possible, be taken into account. The potential impact on the outcome of the cost-benefit analysis of other projects in the pipeline or in progress should be incorporated into the project analysis. These projects may be public, private, remediation or any other type of projects.

Synergistic effects occur when the implementation of another project leads to an increase in benefits or a decrease in costs. An increase in benefits can occur, for example, when the conversion of a mining environmental legacy near a lake creates new economic activities. As regards costs, the implementation of a local remediation project may encourage the training of the local workforce or entail the purchase of capital goods, which can be reused in another project.

Conversely, project benefits decrease if projects are implemented with conflicting objectives or accumulate negative externalities, which are often not individually accounted for. This may result in increased costs: for example, if one type of infrastructure becomes inaccessible or if the simultaneous implementation of two or more projects leads to the overuse of productive resources. Positive and negative effects are not mutually exclusive and can affect multiple projects in different ways.

In projects where the effects do not materialize (or do not materialize to the expected degree), uncertainty can be examined by means of a sensitivity analysis of the other projects' effects (see previous section). Project start-up may be delayed or even fail, especially in the case of large, novel or complex projects in which the net benefits do not meet expectations. Although the net present value of a particular project may be the same when accounting for the effects on other projects, the external costs involved may be important for adjusting the financial indicators (see section VI.D and box VI.8).

■ Box VI.8
Synergistic effects between remediation projects

It is assumed that decision makers can choose between remediation projects and that these will be implemented according to their priority. The budget is 1,000 monetary units. Alternatives A, B, C and D, shown on table VI.4 and representing four remediation projects for four similar mining environmental legacies, have been shortlisted. Sites A and B are located in the same area, while the others are more remote.

At the same time, another project (E), funded by external sources, was given the green light. It is located near sites A and B, and project implementation would positively influence the cost-benefit analysis of those two projects (see table). The aim is to turn site E into a world-renowned place for leisure and culture, which would attract domestic and foreign tourists. Project A's future income would also depend on tourism. The remediation of site E would increase future benefit streams from project A. At the same time, the project would entail the purchase of capital equipment that could be reused and the training of the local workforce in new remediation technologies. This would result in a reduction of training costs and implementation times for projects A and B. Projects C and D would not be affected by project E.

Analysis of a project's synergistic effects

Alternatives	Without project E (0% effectiveness)			With project E (100% effectiveness)		
	Investment	Net present value	Cost-benefit ratio	Investment	Net present value	Cost-benefit ratio
A	1 000	100	1.1	**900**	**310**	1.34
B	**500**	**60**	1.12	450	110	1.24
C	**400**	**80**	1.2	400	80	1.20
D	**100**	**15**	1.15	**100**	**15**	1.15
E	**1 200**	**155**	1.13	1 200	155	1.13

Alternatives	With project E (50% effectiveness)			With project E (25% effectiveness)		
	Investment	Net present value	Cost-benefit ratio	Investment	Net present value	Cost-benefit ratio
A	950	215	1.23	**980**	**153**	**1.16**
B	480	90	1.19	**490**	**70**	**1.14**
C	400	80	1.20	**400**	**80**	**1.20**
D	100	15	1.15	**100**	**15**	**1.15**
E	1 200	155	1.13	1 200	155	**1.13**

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016.

Note: For simplicity, unweighted net present values are used, and the effectiveness ratios are assumed to be uniform for both costs and benefits. In addition, the possibility of establishing a feedback loop between projects A and E, with additional (albeit decreasing) increases in the future flow of benefits, is not considered.

By sensitizing the positive impacts of project E, it is assumed that, in the best case scenario, the annual benefits of project A will increase by 10% and, at the same time, the investment costs of projects A and B will fall by 10%. If this occurs, instead of choosing projects B, C and D, the net present value is maximized by implementing alternatives A, C and D. As the effectiveness coefficients decrease, however, the order of preference also changes. With an effectiveness rate of 25%, the net present value of project A and the combined net present value of projects B and D are almost identical. By assigning probabilities or a by using a probability density function, the expected values for projects A and B can be calculated.

If the joint implementation of projects A and E increases final demand more than the individual implementation of project E, it is possible that the benefit streams of E will also increase through the implementation of project A. Those effects would be recorded in an ex post evaluation. In the event that a final decision has not been made regarding project E and the budget allows for its implementation in combination with other remediation projects, the combined effects of the projects should be considered (for example, by means of statistical models based on conditional probabilities).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of T. Nas, *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books, 2016.

Chapter VII
Feedback in the project monitoring process

Introduction

This chapter provides guidelines for monitoring a remediation project. It clarifies the difference between monitoring and evaluation, and it emphasizes the need to choose relevant indicators so that both the monitoring and the evaluation of a project are carried out correctly. Timely indicators enable the implementation of sustainable remediation projects and the correct monitoring of the goals set and the project's socioenvironmental and economic impact.

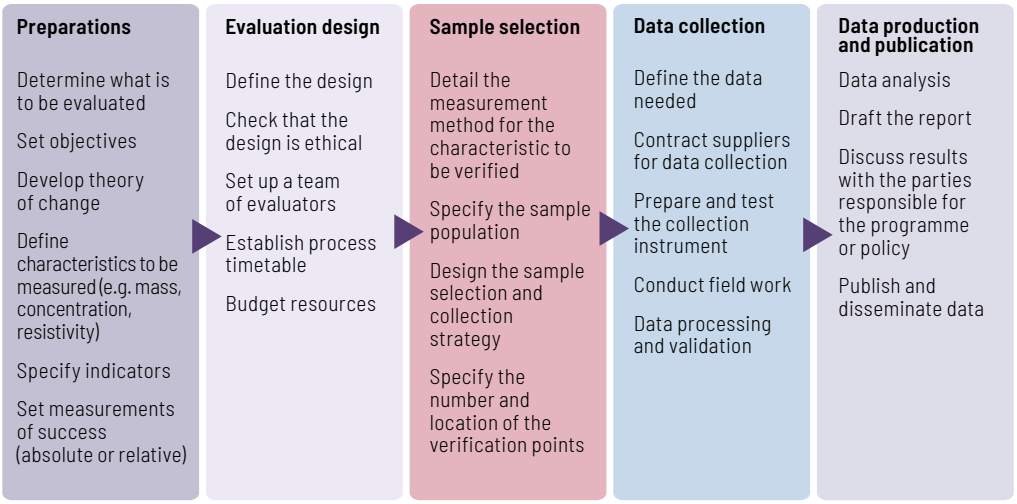
Since the remediation of a mining environmental liability does not occur immediately, a remediation project requires constant monitoring and follow-up of the actions carried out in order to avoid risks and possible negative socioenvironmental impacts. Monitoring must consider and include all stakeholders, particularly neighbouring communities, throughout the entire project life cycle in order to ensure adequate participation in decision-making. Monitoring activities must also be kept in place after the mining environmental legacy has been remediated.

A. Types of feedback

For the region's decision makers, and in line with global trends, the results obtained in a project are increasingly important in relation to the products delivered. The importance of the results achieved lies in their links to data-driven public policy and results-based management. Data-driven public policy enables projects to be monitored for accountability, for informing citizens about budget spending and for guiding decision-making (CEPEP/SHCP, 2019;

see diagram VII.1). Similarly, results-based management provides a set of principles, guidelines and tools to guide public actions as regards strategic planning, risk management, and monitoring and evaluating project performance. It is a participatory model that seeks to improve programme delivery and strengthen decision-making, effectiveness and efficiency in project management, learning and accountability (OECD, 2023).

■ Diagram VII.1
Steps in implementing a data-based evaluation



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit (CEPEP/SHCP), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City, 2019 [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

Evaluating a project involves conducting a systematic analysis to determine whether the objectives and the actions carried out are in alignment. It also enables the determination of the efficiency, effectiveness, quality, results and impact of the projects that are implemented and their component parts (for example, community engagement efforts; EPA, 2020). All this helps define the sustainability of the actions taken (CEPEP/SHCP, 2019).

A conceptual distinction must be drawn between evaluation and follow-up or monitoring. Evaluations are carried out at specific and clearly defined moments. They can take place *ex ante*, as a decision support tool, or *ex post*, in order to measure the project's results and impacts. In addition, it is customary to conduct interim evaluations to check whether the activities are being carried out as expected or planned or whether adjustments are needed. It is advisable for evaluations to be carried out by an agent unconnected with the project's execution in order to guarantee objectivity.

In contrast, follow-up or monitoring is a process that entails generating and analysing, by means of indicators, information on the fulfilment of a programme's goals and on the management of the resources assigned to it. It is an activity carried out continuously during project execution to identify issues that can be adjusted, generally in the short term. Monitoring is usually carried out by the project's executing agency (see table VII.1).

■ Table VII.1
Differences between follow-up or monitoring and evaluation

	Follow-up or monitoring	Evaluation
Frequency	Continuous	Periodic, with specific cut-offs
Purpose	Continuous improvement of programme management	Influence on major programme decisions
Method	Identification of areas for improvement (usually in the short term) through the generation and analysis of target achievement data	Assessment of the relevance of the programme or public policy (or of one of its elements)
Usefulness	Indicator monitoring makes it possible to determine whether: - Resources are being deployed as planned - Programmed activities are being carried out - The problems foreseen are being resolved - Activities are being carried out in a sustainable manner	Indicator evaluation helps determine whether: - The programme or project is producing the expected impacts on the beneficiary population - The programme or project has been implemented in a sustainable manner and is contributing to other objectives, such as climate change mitigation, and if resources are applied efficiently - The programme or project is meeting the objectives for which it was designed
Agents	Programme execution agency	External to the programme's operation
Instruments	Indicators, matrices, information systems, and so on	Methodologies, terms of reference, questionnaires, surveys, interviews, statistical software, and so on
Depth of information	Emphasis on implementation, answering the question: What?	Personalized; often focused on performance or impact and on the questions: Why? and How?
Cost	Generally, the cost is low, as the executing agency has information produced by its day-to-day work	Depending on the job in question, it may be high

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit (CEPEP/SHCP), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City, 2019 [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

Performance indicators are one of the main tools for project analysis and monitoring, both during the project's life cycle and after the conclusion of remediation. An indicator is a specific, observable and measurable characteristic that can be used to track changes and progress in a parameter, characteristic or programme towards the achievement of a specific result.

In the follow-up or monitoring stage, indicators are used throughout the project life cycle; in the evaluation stage, in contrast, their use mainly enables the project's results and impact to be estimated (see box VII.1).

■ Box VII.1
Usefulness of indicators in monitoring and evaluation

Indicator monitoring will make it possible to determine whether:

- Resources are being deployed as planned.
- Programmed activities are being carried out.
- The problems foreseen are being resolved.
- Activities are being carried out in a sustainable manner.

Indicator evaluation will help determine whether the programme or project:

- Has the expected impacts on the beneficiary population.
- Has been implemented sustainably and contributes to other objectives, such as climate change mitigation or the efficient allocation of resources.
- Is meeting the objectives for which it was designed.

Finally, indicators can reveal areas for improvement, either during or after implementation.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit (CEPEP/SHCP), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City, 2019 [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

The selection of timely and relevant performance indicators is key in: (i) facilitating decision-making and making adjustments during the project execution monitoring process, and (ii) determining the alignment between the project's results and objectives or socioenvironmental impact after its implementation through an *ex post* evaluation.

B. Selecting relevant indicators

The operational effectiveness and efficiency of a remediation measure can be assessed in different ways, and a verification or monitoring system is needed to understand the status of the system being evaluated. Monitoring must be designed with care, which requires consideration of the characteristics to be measured (for example, mass, concentration or indirect measurements such as resistivity by geophysical methods), the number of verification points, their location, sample collecting and the method used to measure the characteristic to be examined.

According to the Government of Australia (2016), a robust monitoring plan must comply with the following steps (Green, 1979; Legg and Nagy, 2006; Lindenmayer and Likens, 2010):

- Define clear and unambiguous monitoring and remediation objectives.[1]
- Identify suitable reference sites for comparison with the remediated areas.
- Select appropriate sampling indicators and methods.
- Establish adequate spatial and temporal coverage for achieving the objectives.
- Use sufficient replication to enable the statistical analysis of the results.
- Avoid or minimize bias (margin of error) in selecting monitoring sites.
- Conduct pilot tests to assess the effectiveness of the sampling design according to the site conditions.
- Provide training and contribute evidence to ensure that the methods are repeatable and comparable over the long term and between different observers.
- Maintain quality control so the data can be used to produce inferences and statistical analyses.

Regarding measurement methods, it is critical to determine how monitoring will provide information on the progress of remediation actions, appropriate cost-effective techniques based on site conditions and whether the monitoring techniques suffer from any shortcomings. An absence of quantitative analysis that provides convincing evidence makes decision-making difficult (Government of Australia, 2016).

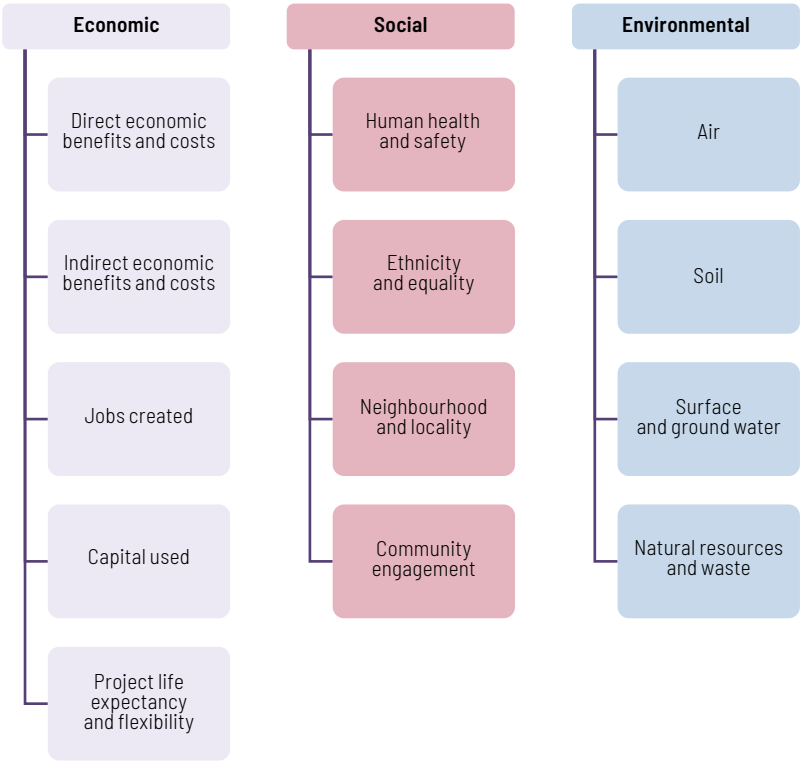
In assessing the sustainable remediation of contaminated sites, performance indicators must be (Coffey, 2018; Government of Australia, 2016):

- Site-specific and relevant to the remediation strategy under evaluation (for example, they must examine both abiotic and biotic factors).
- Balanced across all three dimensions (in other words, the same number of indicators must be used for economic, social and environmental aspects).
- Agreed on with stakeholders from the outset.

Since indicators entail a commitment of public resources, they are an integral part of national programmes for the remediation of mining environmental legacies. Only a good selection of performance indicators ensures that efficiency and effectiveness are measured in a clear and transparent manner (see diagram VII.2).

[1] The document produced by the Government of Australia (2016) refers to rehabilitation, which is covered by the concept of sustainable remediation as used throughout this handbook (see chapters I and II).

■ Diagram VII.2
Dimensions of elements to be evaluated, with some examples within sustainable remediation indicators



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Coffey, "Incorporating sustainability into contaminated land management", 2018 [online] https://www.eianz.org/document/item/4720.

In selecting the indicators for monitoring a project, consideration should be given to the type of project, its location and the goals set. Once these factors have been defined, the next step is to apply specific criteria that address the three dimensions of sustainable development and include the stakeholders (see table VII.2). This can be further refined in individual cases and supplemented during the follow-up process (Government of Australia, 2016; CEPEP/SHCP, 2019).

Monitoring indicators must be selected carefully, and sufficient resources must be allocated to ensure useful long-term monitoring and evaluation. A remediation project typically monitors a range of factors including water content and quality, soil stability and erosion, air quality and gas emissions, and changes in flora and fauna. The techniques used to collect that information include sampling campaigns, estimates of vegetation cover and densities, and species inventories and counts (Government of Australia, 2016).

■ Table VII.2
Example of an indicator selection matrix

Criteria	Indicators to be applied
C1: Do one or more communities stand to benefit from the remediation project?	If the answer to C1 is in the affirmative, then the indicators for remediation and the indicators for social issues can be used.
C2: Will a reuse project be viable for the site once it is remediated, and can the community be included in it?	If the answers to C1 and C2 are in the affirmative, the social sustainability indicators may also be used.
C3: Can the remediation and reuse of the site be carried out in accordance with criteria of sustainability?	If the answers to all three criteria are in the affirmative, all four types of indicators can be used: remediation indicators, social indicators, social sustainability indicators and contamination indicators.
C4: Is the party responsible for the remediation a private or public (government) entity?	When the party responsible for the remediation is a private entity, the general indicators related to spending will not apply. When the government is responsible for the remediation, the following indicators will be used: - Spending - Contracting - Studies performed - Feasibility studies - Ecosystem indicators

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit (CEPEP/SHCP), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City, 2019 [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

1. Sustainability indicators

The site's sustainability assessment and conceptual model (see chapter IV) enable remediation practitioners to identify the activities at a site that are linked to significant impacts on sustainability. Remediation is deemed successful if its objectives are achieved and the environmental criteria are met.

Song and others (2017) recommend checking that concentrations are below a maximum permissible limit, ensuring that the soil maintains ecosystem services to the extent that is possible, and ensuring that risks to ecological and human receptors are kept at acceptable levels. The contaminant content, soil characteristics and ecological and human health risk assessments are therefore taken into account (see table VII.3).

Once the indicators to be evaluated have been selected, their characteristics are defined, including such aspects as the metrics to be used (see table VII.4). These are measurable values that correlate with one of the parameters under evaluation, such as carbon dioxide emissions (in tons of CO_2), groundwater contamination (in mg/L of pollutant), energy use (in kWh), local workers trained (in number of workers per unit of time) or local suppliers used. In a project, the metrics are selected according to the sustainability considerations used.

■ Table VII.3
Relevant indicators for the management and sustainable remediation of mining environmental legacies

Aspect to be monitored	Indicator	Name and description
Remediation of environmental mining legacies	Remediation indicator 1	Number of abandoned mines, waste dumps and tailings generated in the mining system, recorded for a given period and unit of analysis.
	Remediation indicator 2	Number of claims per source of mining contamination (abandoned mines, waste and tailings dumps) occurring in the area under investigation, recorded for a given period and unit of analysis.
	Remediation indicator 3	Number of agreements per mining activity.
	Remediation indicator 4	Number of abandoned mines and waste and tailings dumps remediated and endorsed by the national environmental authority.
Social problems resulting from contamination	Social aspects indicator 1	Number of measures of satisfaction implemented for abandoned mines and waste and tailings dumps. The number of public apologies or acknowledgements of the harm offered by the party that caused the damage, plus the sanctions imposed by local or national authorities or international agencies on account of the presence of abandoned mines and waste and tailings dumps in the mining system.
	Social aspects indicator 2	Percentage of social problems detected in the community and addressed during period i related to the mining environmental legacy's contamination.
	Social aspects indicator 3	Number of services that the site will provide for the community once remediation has been carried out or a reuse project has been implemented.
	Social aspects indicator 4	Community participation in the site management after remediation, indicated by the number of activities undertaken by the community at the site. This depends on the existence and characteristics of a reuse project.
Sustainability of site remediation and future use	Contamination indicator 1	Amount of fossil fuels consumed during remediation for each specific measure of the remediation alternatives.
	Contamination indicator 2	Amount of greenhouse gas emissions in tons of carbon dioxide equivalent emitted.
	Contamination indicator 3	Amount of greenhouse gas emissions owing to future site use for each type of source (for example, services provided on site or maintenance of facilities or buildings). Revegetation of the site can reduce emissions.
	Contamination indicator 4	Amount of particulate matter emitted into the environment. Broken down by type and pathways.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of G. Gálvez, "Generación de indicadores de pasivos ambientales y sociales para el SIPAS del Programa de Reparación Ambiental y Social del Ministerio del Ambiente del Ecuador aplicado a las actividades hidrocarburíferas y mineras a nivel nacional", Quito, Central University of Ecuador (UCE), 2015.

■ Table VII.4
Environmental legacy indicators for mining activities

Indicators in the Ecuadorian System of Indicators for Environmental and Social Liabilities	
Indicator name:	Number of abandoned mines and waste and tailings dumps.
Definition:	The number of abandoned mines and waste and tailings dumps generated in the mining system, recorded for a given period and unit of analysis.
Calculation formula:	***Number of abandoned mines and waste and tailings dumps =*** Σ ***abandoned mines***$_i$ ***+ waste dumps***$_i$ ***+ tailings dumps***$_i$
Indicator name:	Number of claims by source of mining contamination.
Definition:	The number of claims by contamination source (abandoned mines, waste dumps and tailings dumps) occurring in the area under investigation, recorded for a given period and unit of analysis.
Calculation formula:	***Number of claims =*** Σ ***complaint/claim***$_i$ ***+ public report***$_i$ ***+ national judical proceedings***$_i$ ***+ international judical proceedings***$_i$
Indicator name:	Number of measures of satisfaction implemented for abandoned mines and waste and tailings dumps.
Definition:	The number of public apologies or acknowledgements of harm offered by the party that caused the damage, plus the sanctions imposed by local or national authorities or international agencies on account of the presence of abandoned mines and waste and tailings dumps in the mining system.
Calculation formula:	***Number of measures of satisfaction =*** Σ ***number of apologies and public acknowledgements of contamination impacts***$_i$ ***+ number of penalties imposed for contamination***$_i$
Indicator:	Number of agreements per mining activity.
Definition:	Agreements are the legal instruments in which the different parties involved in resolving a problem set out their obligations and the expected benefits.
Calculation formula:	***Number of agreements =*** Σ ***mining projects carried out***$_i$ ***+ contingency/accidents***$_i$ ***+ renegotiation***$_i$ ***+ others***$_i$
Indicator name:	Number of abandoned mines and waste and tailings dumps remediated and endorsed by the national environmental authority.
Definition:	The number of abandoned mines and waste and tailings dumps remediated and endorsed by the national environmental authority.
Calculation formula:	***Number of remediated spills, pools and pits endorsed =*** Σ ***abandoned mines rehabilitated***$_i$ ***+ waste dumps remediated***$_i$ ***+ tailings dumps remediated***$_i$
Proposed environmental liability indicators for mining activities for estimating remediation project sustainability	
Indicator name:	Fossil fuel consumption during remediation.
Definition:	The amount of fossil fuels consumed in the implementation of each specific measure of the remediation alternatives.
Calculation formula:	***Fuel: total kilograms of fuel i in vehicle j during the remediation period.***
Indicator name:	Greenhouse gas emissions.

Indicators in the Ecuadorian System of Indicators for Environmental and Social Liabilities	
Definition:	The volume of greenhouse gas emissions in tons of carbon dioxide equivalent generated by each remediation alternative considered.
Calculation formula:	***Total emissions from the use of fuel i in vehicle j during the remediation period + use of electrical energy + energy consumption per kilogram of material used during civil construction works.***
Indicator name:	Greenhouse gas emissions from future site use.
Definition:	The volume of greenhouse gas emissions that will be generated from the site's future use as a result of services provided at the site, facility and building maintenance, emission sinks from variable renewable energy systems or revegetation, and so on.
Calculation formula:	***Volume of emissions = fuel consumption + energy consumption + emission sinks.***

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of G. Gálvez, "Generación de indicadores de pasivos ambientales y sociales para el SIPAS del Programa de Reparación Ambiental y Social del Ministerio del Ambiente del Ecuador aplicado a las actividades hidrocarburíferas y mineras a nivel nacional", Quito, Central University of Ecuador (UCE), 2015.

At the same time, the budgetary indicators cover the financial variables (see chapter VI). Their main purpose is to show that financial resources have been used or committed in a reasonable, effective and efficient manner (see table VII.5).

■ Table VII.5
Examples of budget indicators for the sustainable management and remediation of a mining environmental legacy

Indicator type	Name and description
Pre-investment	Preparation of technical data sheets and cost-benefit analyses justifying the need to resolve a contamination problem
	Infrastructure feasibility studies authorized for advancing to the execution stage
	Contracting of infrastructure feasibility studies
	Number of infrastructure feasibility studies conducted during the year
	Approved resources
Investment	Modified resources
	Paid-in resources
Follow-up	Percentage of community committees that remain operational two years after receiving investment support
	Percentage of people with effective employment in the communities
Cross-cutting	Percentage of priority hectares submitted to systemic restoration actions
	Percentage of priority species for which recovery actions have been undertaken

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Ministry of Finance and Public Credit of Mexico (SHCP), "Sistema de evaluación del desempeño" [online] https://www.transparenciapresupuestaria.gob.mx/Sistema-Evaluacion-Desempeno.

It is also possible to synthesize the information from the indicators through the use of indices. The various methods that exist to generate such indices include multi-criteria analysis (see chapter III), direct measurement of indicator components with weights

implicit in the model and principal component analysis. In this way, the objective of bringing together all the dimensions of environmental debt into a single global index is achieved.

C. Use of indicators in the follow-up or monitoring stage

Follow-up (or monitoring) is carried out by means of performance indicators and focuses on the use of the resources allocated. The selection of the criteria and indicators, as well as the type of monitoring to be implemented, will depend on the party responsible for the remediation. That task is generally performed by the project's executing agency, and it should be considered in the planning phase to ensure timely and cost-effective solutions throughout the life cycle of the project (Government of Australia, 2016).

If the monitoring is the responsibility of a private entity, it is agreed upon as part of the authorization of the remediation plan. If the legal obligation to conduct monitoring with indicators does not exist, the authorities may not request that a private individual generate information for the indicators, nor may it request that such information be provided to it. Therefore, in order to make progress in this area, due account must be taken of the legal frameworks.

The existence of a legal basis would encourage the implementation of a monitoring, reporting and verification system, which aims to provide clarity and predictability and is currently only valid when a public government entity is responsible for remediation. The existence of a legal basis requiring the responsible parties to prepare monitoring reports would lead to its observance by both public and private entities. As an alternative, and more immediately, the powers of the supervisory authority can be brought into play and the authorization of the remediation plan or programme can state that the authority has to agree with the responsible party on methods for monitoring (supervising) issues arising from the remediation process.[2]

The monitoring, reporting and verification system must be compatible with the results-based indicator matrices that are used in the progress reports of government budgetary programmes. The monitoring, reporting and verification system for the remediation of mining environmental mining legacies under government responsibility is created by assigning roles, tasks and obligations to each party involved and by defining rules for coordination and reporting (see diagram VII.3).

[2] The Latin American Network for Environmental Enforcement and Compliance (REDLAFICA), the mission of which is to improve environmental oversight and compliance throughout the region, is notable in this regard. The network consists of Argentina, Brazil, Colombia, Costa Rica, Chile, the Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Panama, Paraguay, Peru and the Plurinational State of Bolivia.

■ Diagram VII.3
Stages in the implementation of an indicator monitoring system

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Climate Change Secretariat, *Handbook on Measurement, Reporting and Verification for Developing Country Parties*, Bonn, 2014.

Similarly, a framework of legal provisions should be established for the generation and presentation of timely information and data management. In the absence of provisions, a coordination agreement should be signed between the various stakeholders involved, including the environmental, financial, local and oversight authorities, the parties responsible for carrying out the studies and the project's beneficiary communities.

Performance indicator sheets are used to monitor the performance of indicators during a project's life. Typically, there are three strategies for monitoring performance indicators (Government of Australia, 2016):

(i) Direct comparison: measurements are made against the site's reference data.

(ii) Attribute analysis: statistics and information on comparable indicators are compared with the remediation objectives and closure criteria.

(iii) Path analysis: trends in the structure and function of the ecosystems under study are examined.

A number of techniques exist that can be used to monitor performance indicators: (i) landscape function analysis, which determines the functional status of the remediated area, (ii) remote sensing, such as aerial photography, satellites, and aerial and terrestrial laser scans (see Gholizadeh and others, 2018), and (iii) monitoring fauna and flora inventories (Government of Australia, 2016).

Once a monitoring programme is in place and remediation has been completed, absolute or relative measurements of its success —which can include statistical considerations— can be established. This issue will be discussed in more detail in the following section.

D. Use of indicators in the evaluation stage

Upon completion of the remediation activities, project performance is evaluated and the achievement of project objectives is assessed using indicators structured into a matrix of performance indicators (see table VII.6). The evaluation may include semi-quantitative criteria that associate a value to the degree of progress with the indicator (for example, low, medium or high, or unsatisfactory, satisfactory, good or excellent).

■ Table VII.6
Example of an indicator evaluation matrix

Evaluation stage	Indicator	Indicator target for period i	Evaluation
Consistency and results	Remediation indicator 1 Number of abandoned mines and waste and tailings dumps	50	30 mining environmental legacies have been registered 30/50 = 0.6 Medium compliance
	Remediation indicator 4 Number of abandoned mines and waste and tailings dumps remediated and endorsed by the national environmental authority	3	1 mining environmental legacy remediated 1/3 = 0.33 Low compliance
	Social aspects indicator 2 Percentage of detected community social problems attended to in period i	10	7 of the problems detected in the remediated mining environmental legacy have been resolved 7/10 = 0.7 High compliance
	Contamination indicator 1 Fossil fuel consumption during remediation	30% reduction in fuel consumption compared to vehicles in poor condition or more than 10 years old	25% reduction 0.25/0.30 = 0.83 High compliance

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of L. Alvarado and E. Morín, "Guía para la preparación de proyectos por fases (PPF), 2018", Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP), 2018; Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit (CEPEP/SHCP), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City, 2019 [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

Absolute and relative measurements exist to evaluate the success of remediation operations. Examples of absolute measurements include verifying whether the contaminant's concentration in soil has decreased to a maximum allowable limit value or whether a predetermined volume of a product has been extracted from an aquifer. It is essential to assess whether remediation actually protects human health or the ecological environment in addition to improving environmental conditions (through removal of contaminants). In that context, the use of a risk approach must be considered (adapted from EPA, 1992b). Absolute measurements present more compliance challenges for those responsible for remediation, as the maximum allowable limits are often fixed generic values, which may be difficult to achieve with the available technology.

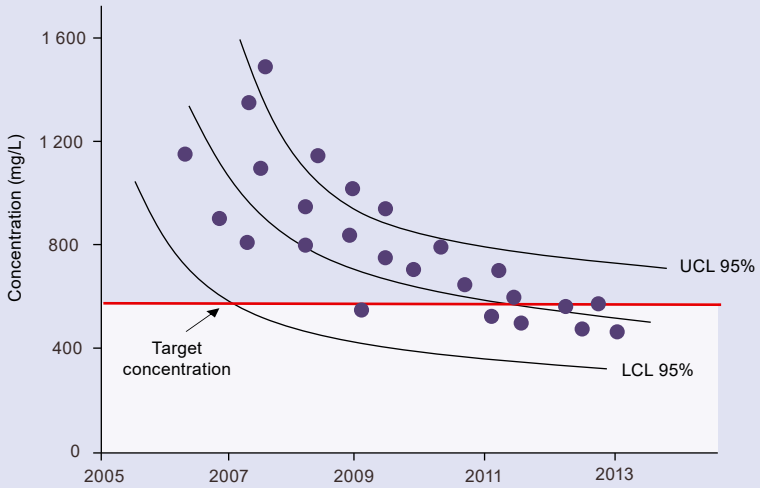
In contrast, relative measurements include a specification of the efficiency of the removal technology (for example, an 80% reduction in the contaminant). This type of measurement can result in reduced risk to human health and the environment.

Regardless of the measurement used, determining whether the remediation actually achieved its objectives requires conducting multiple sampling campaigns to ensure the permanence of the remediation's effects. Measuring the characteristics to be monitored by means of a single campaign is insufficient to determine the conclusion (release) of a contaminated site, especially with regard to soil. As it is a non-standardized medium, data values inevitably vary between sampling campaigns. The results of each campaign therefore cannot be evaluated rigorously. Sampling frequency tends to decrease with time (see box VII.2).

■ Box VII.2
Statistical verification of remediation results

EPA (1992a) recommends that in groundwater remediation using the pump-and-treat technique, post-remediation sampling should be a continuation of the sampling conducted during remediation monitoring. It also suggests that a statistical monitoring of concentrations be carried out, indicating the contaminant's concentration over time. Subsequently, a multiple or non-linear regression line is fitted to the plotted values (see figure).

Plot of concentration over time and multiple regression curve indicating continued concentration reduction



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), *General Methods for Remedial Operation Performance Evaluations*, Ada, 1992.
Note: UCL 95% = upper confidence limit of 95%.
LCL 95% = lower confidence limit of 95%.

Remediation can be deemed complete when contaminant concentrations have stabilized. In this case, the regression line has a slope equal to zero at a point where the average contaminant concentration is equal to or less than the target concentration, or a negative slope, and the

concentrations are below the target concentration. A statistical test (e.g. Student's t distribution) should always be performed to determine that the slope of the fitted regression line is no greater than zero at a 95% confidence level.

Regression plots should be updated with data obtained during sampling. The reactivation of the remedial actions or a reassessment of the need to reapply remedial technology may be indicated when the slope is no longer statistically equal to or less than zero, or when two or more successive data values are above the upper limit of the 95% confidence interval of the regression line.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of United States Environmental Protection Agency (EPA), *General Methods for Remedial Operation Performance Evaluations*, Ada, 1992.

In conclusion, the indicator-based monitoring and evaluation of a project is useful in: (i) identifying areas for improvement during execution and making the required adjustments, (ii) determining the success of the remediation actions, and (iii) determining the socioenvironmental impact in the post-remediation phase.

In view of the above, choosing timely and relevant performance indicators is essential, and consideration should be given to their selection at the project planning stage. They also require monitoring during both the implementation and post-remediation phases.

Chapter VIII
Final thoughts

Although countries have adopted rules requiring companies to take charge of their closure processes to prevent the emergence of new environmental legacies, many contaminated sites still exist where remediation or management remains an urgent task. However, the scarcity of public resources and other economic and social challenges force governments to choose and execute those projects that promise the best performance. The management and remediation of mining environmental legacies require a methodology that allows investment projects to be prioritized in accordance with a broad vision of sustainability. Along with taking into account health and environmental risks and evaluating different technological options, meaningful participation by all stakeholders must be encouraged.

This handbook provides guidelines, information and methodologies for the parties responsible for designing or implementing public policies related to the prioritization of remediation investments. The prioritization that the handbook recommends for mining environmental legacies is based on a series of steps that begin with risk analysis and their subsequent prioritization. For each remediation option, a comprehensive evaluation should be conducted: in other words, one that addresses the environmental, financial, economic and social dimensions.

Environmental evaluations are intended to remediate and rehabilitate the site, to reduce and mitigate risk, to consider the emissions and recycling options of each alternative, and to assess whether future site use can provide services to offset the mining environmental legacy's impacts. Financial evaluations examine the financial outflows of the remediation, as well as its potential revenues. The economic evaluation expands on the financial evaluation to include the costs and benefits to society as a whole from implementing the remediation alternative. Finally, the social evaluation complements the economic evaluation by analysing economic results with a view to social equality.

Beyond the remediation of existing legacies, progress must be made with the development and strengthening of regulatory and institutional frameworks to avoid the creation of environmental mining legacies in the future.

Bibliography

"Access to information from mine site certifications" Working Group (2022), "Recommendations to improve local governance through mining certifications", Stilleweg, Deutsche Gesellschaft für Internationale Zusammenarbeit/Federal Institute for Geosciences and Natural Resources/Natural Resource Governance Institute (GIZ/BGR/NRGI).

Adler, M. (2016), "Benefit-cost analysis and distributional weights: an overview", *Review of Environmental Economics and Policy*, vol. 10, No. 2, Oxford, Oxford University Press.

Alberruche, M. and others (2014), *Manual para la evaluación de riesgos de instalaciones de residuos de industrias extractivas cerradas o abandonadas*, Madrid, Ministry of Agriculture, Food and Environment/Geological and Mining Institute of Spain.

Alvarado, L. and E. Morín (2018), "Guía para la preparación de proyectos por fases (PPF), 2018", Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP).

Arancibia, V. (2017), *Inventariación, Caracterización y Evaluación de Riesgos por Pasivos Ambientales Minero Metalúrgicos y su Influencia en el Recurso Hídrico: Reserva Nacional de Fauna Andina Eduardo Avaroa*, Lima, United Nations Development Programme (UNDP).

Arranz-González, J. and others (2022), "Polluting potential from mining wastes: proposal for application a global contamination index", *Environmental Monitoring and Assessment*, vol. 194, Berlin, Springer.

___(2020a), *Glosario técnico en materia de gestión de pasivos ambientales mineros*, Madrid, Association of Iberoamerican Geological and Mining Surveys (ASGMI).

___(2020b), *Manual para el inventario de minas abandonadas o paralizadas*, Madrid, Association of Iberoamerican Geological and Mining Surveys (ASGMI).

___(2019), *Guía para la rehabilitación de instalaciones abandonadas de residuos mineros*, Madrid, Ministry for Ecological Transition.

Arrow, K. and others (2014), "Should governments use a declining discount rate in project analysis?", *Review of Environmental Economics and Policy*, vol. 8, No. 2, Chicago, University of Chicago Press.

___(1993), "Report of the NOAA Panel on Contingent Valuation", Washington, D.C., National Oceanic and Atmospheric Administration (NOAA).

ATAP (Australian Transport Assessment and Planning) (2022), *Australian Transport Assessment and Planning Guidelines: T2 Cost Benefit Analysis*, Canberra.
Atkinson, G. and S. Mourato (2008), "Environmental cost-benefit analysis", *Annual Review of Environment and Resources*, vol. 33, San Mateo, Annual Reviews.
Australia, Government of (2016), *Mine Rehabilitation: Leading Practice Sustainable Development Program for the Mining Industry*, Canberra.
Azqueta, D. (1994), *Valoración económica de la calidad ambiental*, Madrid, McGraw-Hill.
Barba-Romero, S. (1996), *Manual para la toma de decisiones multicriterio* (LC/IP/L.122), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
Barros, E. (2010), *Tratado de responsabilidad extracontractual*, Santiago, Editorial Jurídica de Chile.
Baum, S. (2012), "Value typology in cost-benefit analysis", *Environmental Values*, vol. 21, No. 4, Thousand Oaks, Sage Publications.
Berger, A. (2007), "Arboles de decisión", Buenos Aires, CEMA University (UCEMA) [online] https://ucema.edu.ar/~aberger/Arboles/Arboles.pdf.
Bezama, A. and others (2007), "Application of a balanced scorecard system for supporting decision-making in contaminated sites remediation", *Water, Air, and Soil Pollution*, vol. 181, Berlin, Springer.
BGR/SERNAGEOMIN (Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile) (2008), *Manual de evaluación de riesgos de faenas mineras abandonadas o paralizadas FMA/P*, Santiago.
Biddix, J. (2018), *Research Methods and Applications for Student Affairs*, Hoboken, Wiley.
Boardman, A. and others (2018), *Cost-Benefit Analysis: Concepts and Practice*, Cambridge, Cambridge University Press.
Bongaerts, E., E. Casals and H. Domsch (2018), "Estudio comparativo de experiencias positivas en la gestión de sitios contaminados", *Informe*, No. 1, Santiago, Deutsche Gesellschaft für Internationale Zusammenarbeit/Federal Institute for Geosciences and Natural Resources/Economic Commission for Latin America and the Caribbean (GIZ/BGR/CEPAL).
Bonner, S. (2022), *Social Cost Benefit Analysis and Economic Evaluation*, Brisbane, University of Queensland.
Bourne, L. (2016), *Stakeholder Relationship Management: A Maturity Model for Organisational Implementation*, London, Routledge.
Brent, R. (2008), *Applied Cost-Benefit Analysis*, Cheltenham, Edward Elgar Publishing.
Brusseau, M. (2019), "Sustainable development and other solutions to pollution and global change", *Environmental and Pollution Science*, M. Brusseau, I. Pepper and C. Gerba (eds.), Cambridge, Academic Press.
Cabanillas, A. (1996), *La reparación de los daños al medio ambiente*, Pamplona, Editorial Aranzadi.
Castellanos, L. (2015), "Árboles y tablas de decisiones: guía de estudio", Maracaibo [online] https://luiscastellanos.files.wordpress.com/2015/02/arboles-y-tablas-decisiones-luis-castellanos.pdf.
Cavanillas, S. (1996), "Tendencias en materia de responsabilidad civil", *Responsabilidad civil del empresario*, F. Mckay (ed.), Santiago, University of the Andes.

CCME (Canadian Council of Ministers of the Environment) (2024), "Canadian Environmental Quality Guidelines" [online] https://ccme.ca/en/current-activities/canadian-environmental-quality-guidelines.

CDC (Centers for Disease Control and Prevention) (2023), "Cómo prevenir la exposición de los niños al plomo", Atlanta [online] https://www.cdc.gov/spanish/nceh/especiales/envenenamientoporplomo/index.html.

CEPEP/SHCP (Study Center for the Preparation and Socioeconomic Evaluation of Projects/Ministry of Finance and Public Credit) (2019), "Diplomado Evaluación de Políticas y Programas Públicos 2023", Mexico City [online] https://mexicox.gob.mx/courses/course-v1:SHCP+EDPY23095X+2023_09/about.

CETESB (Environmental Company of the State of São Paulo) (2023), "Relação de áreas contaminadas", São Paulo [online] https://cetesb.sp.gov.br/areas-contaminadas/relacao-de-areas-contaminadas/.

Chappuis, M. (2020), "Remediación y activación de pasivos ambientales mineros (PAM) en el Perú", *Environment and Development series*, No. 168 (LC/TS.2019/126), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Cinelli, M. and others (2021), "Supporting contaminated sites management with Multiple Criteria Decision Analysis: demonstration of a regulation-consistent approach", *Journal of Cleaner Production*, vol. 316, Amsterdam, Elsevier.

CL:AIRE (Contaminated Land: Applications in Real Environments) (2020), *Supplementary Report 1 of the SuRF-UK Framework: A General Approach to Sustainability Assessment for Use in Achieving Sustainable Remediation*, Haddenham.

___(2010), *A Framework for Assessing the Sustainability of Soil and Groundwater Remediation*, London.

Clerc, J. (2022), "Mecanismos de financiamiento para la remediación de PAMs", Santiago, E2BIZ/Economic Commission for Latin America and the Caribbean (ECLAC) [online] https://www.cepal.org/sites/default/files/news/files/jacques_clerc.pdf.

Climate Change Secretariat (2014), *Handbook on Measurement, Reporting and Verification for Developing Country Parties*, Bonn.

Coffey (2018), "Incorporating sustainability into contaminated land management" [online] https://www.eianz.org/document/item/4720.

Collinao, M. P. and others (2015), "Guía metodológica: medición del gasto en protección ambiental del gobierno general", *Project Documents* (LC/W.653), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

CONAMA (National Environment Commission of Chile) (1997), *Análisis y Desarrollo de Metodologías de Evaluación Económica para Planes de Descontaminación y Normas de Calidad Ambiental*, Santiago.

Congress of the Republic of Colombia (2023), *Ley 2327 de 2023 (Septiembre 13) por medio de la cual se establece la definición de pasivo ambiental, se fijan lineamientos para su gestión y se dictan otras disposiciones*, Bogotá.

Congress of the Republic of Peru (2017), "Aprueban criterios para la gestión de sitios contaminados: decreto supremo N° 012-2017-MINAM", *El Peruano*, Lima, 2 December.

___(2014), "Aprueban disposiciones complementarias para la aplicación de los Estándares de Calidad Ambiental (ECA) para Suelo: decreto supremo N° 002-2014-MINAM", *El Peruano*, Lima, 24 March.
___(2005), "Ley Nº 28611: Ley General del Ambiente", *El Peruano*, Lima, 15 October.
___(2004), *Ley N° 28271, Ley que regula los pasivos ambientales de la actividad minera*, Lima.
Contreras, E. (2018), "Precios sociales: marco teórico para el cálculo de tasa social de descuento, divisa y mano de obra", *Documento de Trabajo*, Santiago, University of Chile, unpublished.
___(2004), "Evaluación social de inversiones públicas: enfoques alternativos y su aplicabilidad para Latinoamérica", *Manuals series*, No. 37 (LC/L.2210-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
Contreras, E. and C. Diez (2015), *Diseño y evaluación de proyectos: un enfoque integrado*, Santiago, JC Sáez Editor.
Corral, H. (2011), *Lecciones de responsabilidad civil extracontractual*, Santiago, Editorial Jurídica de Chile.
CrcCARE (Cooperative Research Centre for Contamination Assessment and Remediation of the Environment) (2019), *Remediation Action Plan Development: Guideline on Performing Cost-benefit and Sustainability Analysis*, Newcastle.
Crespo, R. (2008), "La responsabilidad objetiva por daños ambientales y la inversión de la carga de la prueba en la nueva constitución", *Letras Verdes*, No. 2, Quito, Latin American Faculty of Social Sciences (FLACSO).
Cross, F. (1989), "Natural resource damage valuation", *Vanderbilt Law Review*, vol. 42, No. 2, Nashville, Vanderbilt University.
Cuadros, J. and others (2012), "Elementos conceptuales y aplicaciones de microeconomía para la evaluación de proyectos", *Manuals series*, No. 77 (LC/L.3511), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
DCLG (Department for Communities and Local Government) (2009), *Multi-criteria Analysis: A Manual*, London.
Dean, M. (2022), *A Practical Guide to Multi-Criteria Analysis*, London, University College London.
De las Casas, J. (2019), "Participación del sector privado para la remediación de los pasivos ambientales mineros bajo administración del estado", Lima, University of Lima.
De Miguel, C. and M. Pereira (2019), "Pasivos ambientales mineros: retos para la sostenibilidad", *La bonanza de los recursos naturales para el desarrollo: dilemas de gobernanza*, ECLAC Books, No. 157 (LC/PUB.2019/13-P), R. Sánchez (ed.), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
DEQ (Montana Department of Environmental Quality) (2020), *Montana Limestone Resources Environmental Assessment*, Drummond.
Doroni, G. (2015), "Responsabilidad por pasivos ambientales mineros y cierre de minas: breve análisis de los marcos normativos de Bolivia, Chile y Perú", *Anuario del Centro de Investigaciones Jurídicas y Sociales*, No. 12, Córdoba, National University of Córdoba.
Dufey, A. and P. Zamorano (2023), "Estándares y certificaciones internacionales voluntarias en materia de minería sostenible en los países andinos", *Environment and Development series*, No. 175 (LC/TS.2023/67), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Dupuit, J. (1995), "De la mesure de l'utilité des travaux publics", *Revue française d'économie*, vol. 10, No. 2, Lyon, Persée.

Earley III, D. (2020), *In Situ Recovery & Remediation of Metals*, Englewood, Society for Mining, Metallurgy & Exploration (SME).

ECLAC (Economic Commission for Latin America and the Caribbean) (2023a), *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean: implementation guide* (LC/TS.2021/221/Rev.2), Santiago.

___(2023b), *Social Panorama of Latin America and the Caribbean, 2023* (LC/PUB.2023/18-P/Rev.1), Santiago.

___(2022a), *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean* (LC/PUB.2018/8/Rev.1), Santiago.

___(2022b), *Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean. Implementation guide* (LC/TS.2021/221/Rev.2), Santiago.

___(2022c), *Social Panorama of Latin America and the Caribbean, 2022* (LC/PUB.2022/15-P), Santiago.

___(2021), "Nuevo contenido sobre inversión pública y red SNIP", Santiago, 4 February [online] https://observatorioplanificacion.cepal.org/es/news/nuevo-contenido-sobre-inversion-publica-y-red-snip.

___(2018), *The Inefficiency of Inequality* (LC/SES.37/3-P), Santiago.

Ecuadorian Constituent Assembly (2008), *Constitución de la República del Ecuador*, Quito.

Edwards, G. (2014), "Estimación de la tasa social de descuento de largo plazo en el marco del sistema nacional de inversiones", Santiago, Ministry of Social Development.

Efroymson, R., J. Nicolette and G. Suter (2004), "A framework for net environmental benefit analysis for remediation or restoration of contaminated sites", *Environmental Management*, vol. 34, Berlin, Springer.

Environmental Protection Scotland (2017), "Introduction to land contamination and development management. Guidance for assessing and addressing land contamination issues to meet the requirements of local planning authorities in Scotland", Glasgow.

EPA (United States Environmental Protection Agency) (2024), "Risk Assessment Guidance for Superfund (RAGS): part A", Washington, D.C. [online] https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part.

___(2023), "Superfund soil screening guidance", Washington, D.C. [online] https://www.epa.gov/superfund/superfund-soil-screening-guidance#user.

___(2022), "Risk assessment guidance: EPA guidance", Washington, D.C. [online] https://www.epa.gov/risk/risk-assessment-guidance.

___(2020), *Superfund Community Involvement Handbook*, Washington, D.C.

___(2018), *Proteger a los niños de la exposición al plomo*, Washington, D.C.

___(2014), *Framework for Human Health Risk Assessment to Inform Decision Making*, Washington, D.C.

___(2012), "Green remediation best management practices: mining sites", Washington, D.C.

___(2008), *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*, Cincinnati.

___(2000), *Abandoned Mine Site Characterization and Cleanup Handbook*, Seattle.
___(1992a), *General Methods for Remedial Operation Performance Evaluations*, Ada.
___(1992b), *Guidelines for Exposure Assessment*, Washington, D.C.
___(1989), "The feasibility study: development and screening of remedial action alternatives", Washington, D.C. [online] https://semspub.epa.gov/work/HQ/174411.pdf.
European Commission (2015), "Presentación detallada", Brussels [online] https://europa.eu/capacity4dev/evaluation_guidelines/wiki/presentacion-detallada-9.
___(2010), "Common Implementation Strategy for the Water Framework Directive (2000/60/EC)", *Guidance Document*, No. 26, Luxembourg.
___(2006), "Life Cycle Assessment (LCA) as a decision support tool (DST) for the eco-production of olive oil", Brussels [online] https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=2743&docType=pdf.
European Union (2009), "Commission Decision of 30 April 2009 completing the definition of inert waste in implementation of Article 22(1)(f) of Directive 2006/21/EC of the European Parliament and the Council concerning the management of waste from extractive industries", *Official Journal of the European Union*, Luxembourg, 1 May.
Farmer, A. (1993), "The effects of dust on vegetation – a review", *Environmental Pollution*, vol. 79, No. 1, Amsterdam, Elsevier.
Farrow, S. and M. Toman (1998), "Using environmental benefit-cost analysis to improve government performance", *Discussion Paper*, No. 99-11, Washington, D.C., Resources for the Future.
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of Germany (2002), *German Federal Government Soil Protection Report*, Bonn.
FIO/ECLAC/GIZ (Ibero-American Federation of Ombudsman/Economic Commission for Latin America and the Caribbean/Deutsche Gesellschaft für Internationale Zusammenarbeit) (2020), "Recomendaciones para la incorporación del enfoque de derechos humanos en la evaluación de impacto ambiental de proyectos mineros", *Project Documents* (LC/TS.2020/97), Santiago.
Fortuna, M., I. Simion and M. Gavrilescu (2011), "Sustainability in environmental remediation", *Environmental Engineering and Management Journal*, vol. 10, No. 12, Iași, Gheorghe Asachi Technical University of Iaşi.
Fundación Chile (2015), *Manual de tecnologías de remediación de sitios contaminados*, Santiago.
Galindo, L. and others (2017), "Portafolio de políticas públicas de adaptación al cambio climático y mitigación de sus efectos con beneficios adicionales o 'sin arrepentimiento' en América Latina", *Project Documents* (LC/TS.2017/127), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
Gálvez, G. (2015), "Generación de indicadores de pasivos ambientales y sociales para el SIPAS del Programa de Reparación Ambiental y Social del Ministerio del Ambiente del Ecuador aplicado a las actividades hidrocarburíferas y mineras a nivel nacional", Quito, Central University of Ecuador (UCE).
Garbarino, E. and others (2018), *Best Available Techniques (BAT): Reference Document for the Management of Waste from Extractive Industries in accordance with Directive 2006/21/EC*, Luxembourg, European Commission.

Garber, A. and C. Phelps (1997), "Economic foundations of cost-effectiveness analysis", *Journal of Health Economics*, vol. 16, No. 1, Amsterdam, Elsevier.

GEF (Global Environment Facility) (2019), "Celebrating women's contribution to global environmental sustainability", Washington, D.C., 8 March [online] https://www.thegef.org/blog/celebrating-womens-contribution-global-environmental-sustainability.

Gholizadeh, A. and others (2018), "Monitoring of selected soil contaminants using proximal and remote sensing techniques: background, state-of-the-art and future perspectives", *Critical Reviews in Environmental Science and Technology*, vol. 48, Milton Park, Taylor & Francis.

Government of the State of Mexico (2014), *Estudio costo beneficio para el proyecto: Puente Fresnos – Río Córdoba (segunda etapa) y conexión a la autopista: México – Querétaro*, Toluca de Lerdo.

Gómez, C. (1998), "Profundizando y renovando las bases de la economía marginalista", Madrid, University of Alcalá [en línea] https://econ.web.uah.es/hpeweb/marg2/HPE9811.htm.

___(1994), "El análisis costo-beneficio y el medio ambiente", *Project Documents* (LC/IP/L.101), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Green, R. (1979), *Sampling Design and Statistical Methods for Environmental Biologists*, New York, Wiley.

Holland, K. and others (2011), "Framework for integrating sustainability into remediation projects", *Remediation*, vol. 21, No. 3, Hoboken, Wiley.

IAEA (International Atomic Energy Agency) (2009), "Decision making process for remediation activities", *IAEA Safety Report Series*, No. 792, Vienna.

IDB (Inter-American Development Bank) (2020), *Marco de Política Ambiental y Social*, Washington, D.C.

Iglesias, D. (2007), "Costos económicos por la generación y manejo de residuos sólidos en el municipio de Toluca, Estado de México", *Equilibrio Económico*, vol. 3, No. 2, Saltillo, Autonomous University of Coahuila (UAdeC).

ILO (International Labour Organization) (1989), *Indigenous and Tribal Peoples Convention, 1989 (No. 169)*, Geneva.

INEI (National Institute of Statistics and Informatics) (2016), *Clasificador Nacional de Ocupaciones 2015*, Lima.

ISO (International Organization for Standardization) (2023a), *Mine closure and reclamation – Managing mining legacies — Part 1: requirements and recommendations*, Geneva.

___(2023b), *Mine closure and reclamation – Managing mining legacies — Part 2: case studies and bibliography*, Geneva.

ITRC (Interstate Technology Regulatory Council) (2010), "Technology overview as part of a web-based technical and regulatory guidance: re-use and reprocess (R2) technologies", Washington, D.C. [online] https://projects.itrcweb.org/miningwaste-guidance/to_reuse.htm.

Iturbe, R. and R. Flores (2014), "Evaluación de riesgo ambiental", *Suelos y acuíferos contaminados: evaluación y limpieza*, R. Iturbe (ed.), Mexico City, Trillas.

Jenkins, G., K. Chun-Yan and A. Harberger (2011), "The integrated analysis of investment projects", *Cost-Benefit Analysis for Investment Decisions*, Kingston, Queen's University.

Jiliberto Herrera, R. J. and M. Bonilla Madriñán (2009), "Guía de evaluación ambiental estratégica", *Project Documents* (LC/W.287), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Jouini, M. and others (2020), "Performances of stabilization/solidification process of acid mine drainage passive treatment residues: assessment of the environmental and mechanical behaviors", *Journal of Environmental Management*, vol. 269, No. 1, Amsterdam, Elsevier.

Karaca, O., C. Cameselle and K. Reddy (2018), "Mine tailing disposal sites: contamination problems, remedial options and phytocaps for sustainable remediation", *Reviews in Environmental Science and Bio/Technology*, vol. 17, Berlin, Springer.

Kendrick, T. (2010), *Project Management Tool Kit: 100 Tips and Techniques for Getting the Job Done Right*, Nashville, AMACOM.

Knoke, T., E. Gosling and C. Paul (2020), "Use and misuse of the net present value in environmental studies", *Ecological Economics*, vol. 174, Amsterdam, Elsevier.

Legg, C. and L. Nagy (2006), "Why most conservation monitoring is, but need not be, a waste of time", *Journal of Environmental Management*, vol. 78, No. 2, Amsterdam, Elsevier.

Le Tourneau, P. (2004), *La responsabilidad civil*, Bogotá, Legis Editores.

Lewis, L. and T. Tietenberg (2020), *Environmental Economics and Policy*, London, Routledge.

Limón, B. and M. Herrejón (2013), "Remediación y revitalización del predio de Peñoles, Compañía Minera, Fundidora y Afinadora Monterrey, S. A. y su conversión en el Paseo de Santa Lucía, 2ª etapa, en Monterrey, Nuevo León", *Remediación y revitalización de sitios contaminados: casos exitosos en México*, W. Schmidt, R. Flores and U. Ruiz (eds.), Eschborn, Deutsche Gesellschaft für Internationale Zusammenarbeit/Secretariat of the Environment and Natural Resources (GIZ/SEMARNAT).

Lindell, A. (2009), *Revitalización urbana de sitios contaminados a través de ejemplos en México*, Mexico City, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Lindenmayer, D. and G. Likens (2010), *Effective Ecological Monitoring*, Clayton, CSIRO Publishing.

Liñán, J. and T. Rötting (2013), "Estudio mineralógico y geoquímico de la optimización de un sistema de tratamiento pasivo de drenaje ácido de mina con alta carga metálica", doctorate thesis in geology, Huelva, Huelva University.

Livermore, M. (2012), "Can cost-benefit analysis of environmental policy go global?", *New York University Environmental Law Journal*, vol. 19, No. 1, New York, New York University.

López, P. and others (2003), "La minería y su pasivo ambiental", *Análisis de Políticas Públicas*, No. 24, Santiago, Fundación Terram.

Maastricht University/RIVM/Trimbos Institute (Maastricht University/National Institute of Public Health and the Environment/Netherlands Institute of Mental Health and Addiction) (2016), *Social Cost-benefit Analysis of Tobacco Control Policies in the Netherlands*, Maastricht.

Manning, C. (2023), "Technology readiness levels", Washington, D.C., National Aeronautics and Space Administration (NASA), 27 September [online] https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level.

Martínez-Alier, J. and M. O'Connor (1996), "Ecological and economic distribution conflicts", *Getting Down to Earth: Practical Application of Ecological Economics*, R. Costanza, O. Segura and J. Martínez-Alier (eds.), Washington, D.C., Island Press.

McSweeney, B. (2006), "Net present value: the illusion of certainty", *Strategic Change*, vol. 15, Hoboken, Wiley.
Meixueiro, J. and others (2015), "Guía general para la presentación de estudios de evaluación socioeconómica de programas y proyectos de inversión: análisis costo-beneficio. Actualización 2015", Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP).
Meixueiro, J. and M. Pérez (2008), *Metodología general para la evaluación de proyectos*, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP).
MIDEPLAN (Ministry of National Planning and Economic Policy of Costa Rica) (2010), *Guía metodológica general para la identificación, formulación y evaluación de proyectos de inversión pública*, San José.
MINEM (Ministry of Energy and Mining of Peru) (2023), "Inventario de Pasivos Ambientales Mineros", Lima [online] https://www.gob.pe/institucion/minem/colecciones/24670-inventario-de-pasivos-ambientales-mineros.
___ (2018), "La intervención del Estado en la remediación de pasivos ambientales mineros", *Informativo Minero*, No. 12, Lima.
___ (2015), *Remediación de pasivos ambientales mineros en el Perú*, Lima.
___ (2006), *Guía para la elaboración de planes de cierre de minas*, Lima.
Minería Chilena (2013), "PAM: ideando mecanismos de financiamiento", Santiago, March.
Ministry of Environment, Water and Ecological Transition of Ecuador (2024), "Programa de Reparación Ambiental y Social (PRAS)", Quito [online] http://pras.ambiente.gob.ec/web/siesap/informacion-em.
___ (2020), *Guía metodológica de peritaje ambiental: herramienta para la reparación integral de daños ambientales*, Quito.
___ (2004), "Ley de Gestión Ambiental, codificación", Quito [online] https://www.ambiente.gob.ec/wp-content/uploads/downloads/2012/09/LEY-DE-GESTION-AMBIENTAL.pdf.
Ministry of Health of Costa Rica/Ministry of Environment and Energy of Costa Rica (2018), *Reglamento General para la Clasificación y Manejo de Residuos Peligrosos*, San José.
Ministry of Social Development and Family of Chile (2023), *Informe Precios Sociales 2023*, Santiago.
___ (2017), *Metodología formulación y evaluación de proyectos de evacuación y drenaje de aguas lluvias*, Santiago.
Mishan, E. and E. Quah (2021), *Cost-Benefit Analysis*, Abington, Routledge.
Mitchell, R. and R. Carson (1989), *Using Surveys to Value Public Goods: The Contingent Valuation Method*, London, Routledge.
MMA (Ministry of the Environment of Chile) (2013a), *Guía metodológica para la elaboración de un análisis general de impacto económico y social (AGIES) para instrumentos de gestión de calidad del aire*, Santiago.
___ (2013b), *Resolución Exenta N° 406/2013. Aprueba Guía Metodológica para la Gestión de Suelos con Potencial Presencia de Contaminantes y sus Anexos, y deja sin efecto resolución que indica*, Santiago.
Morales, A. (2023), "Complemento de la guía metodológica de cierre de minas", *Project Documents* (LC/TS.2023/139), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Morales, A. and M. Hantke (2020), "Guía metodológica de cierre de minas", *Project Documents* (LC/TS.2020/166), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Morín, E. (2018), *Guía general para la presentación de evaluaciones costo y beneficio de programas y proyectos de inversión, 2018*, Mexico City, Study Center for the Preparation and Socioeconomic Evaluation of Projects (CEPEP).

Nas, T. (2016), *Cost-Benefit Analysis: Theory and Application*, Lanham, Lexington Books.

National Assembly of the Republic of Ecuador (2017), "Código Orgánico del Ambiente", *Registro Oficial*, No. 983, Quito, 12 April.

National Congress of Chile (2012), "Proyecto de ley de la remediación de pasivos ambientales mineros", Santiago.

___(2011), *Ley núm. 20.551. Regula el Cierre de Faenas e Instalaciones Mineras*, Santiago.

Niroshika, K. and others (2020), "Soil amendments for immobilization of potentially toxic elements in contaminated soils: a critical review", *Environment International*, vol. 134, Amsterdam, Elsevier.

Nyborg, K. (2012), *The Ethics and Politics of Environmental Cost-Benefit Analysis*, New York, Routledge.

Nyborg, K. and I. Spangen (2000), "Cost-benefit analysis and the democratic ideal", *Nordic Journal of Political Economy*, vol. 26, Cambridge, Cambridge University Press.

Oblasser, A. (2016), "Estudio sobre lineamientos, incentivos y regulación para el manejo de los Pasivos Ambientales Mineros (PAM), incluyendo cierre de faenas mineras: Bolivia (Estado Plurinacional de), Chile, Colombia y el Perú", *Environment and Development series*, No. 163 (LC/L.4208), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

OECD (Organisation for Economic Co-operation and Development) (2023), *Glossary of Key Terms in Evaluation and Results-Based Management for Sustainable Development*, Paris.

___(2018), *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use*, Paris.

OECD/IDB (Organisation for Economic Co-operation and Development/Inter-American Development Bank) (2016), *Panorama de las Administraciones Públicas: América Latina y el Caribe 2017*, Paris.

OHCHR (Office of the United Nations High Commissioner for Human Rights) (2022), *Remedy in Development Finance: Guidance and Practice*, New York.

OLACEFS (Organization of Latin American and Caribbean Supreme Audit Institutions) (2021), *Auditoría coordinada sobre estructuras de gobernanza para el manejo integral de los pasivos ambientales mineros*, Santiago.

O'Mahony, T. (2021), "Cost-benefit analysis and the environment: the time horizon is of the essence", *Environmental Impact Assessment Review*, vol. 89, Amsterdam, Elsevier.

Ortegón, E., J. Pacheco and H. Roura (2005), "Metodología general de identificación, preparación y evaluación de proyectos de inversión pública", *Manuals series*, No. 39 (LC/L.2326-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

OSWER (Office of Solid Waste and Emergency Response) (2012a), "Green remediation best management practices: mining sites" [online] https://clu-in.org/greenremediation/docs/GR_factsheet_miningsites.pdf.

___(2012b), "Guía comunitaria sobre la cobertura" [online] https://clu-in.org/download/citizens/EPA-542-F-12-004S_guia_del_ciudadano_sobre_el_recubrimiento.pdf.
Oxfam Intermón (2020), "Definición de sostenibilidad: ¿sabes qué es y sobre qué trata?", Barcelona [online] https://blog.oxfamintermon.org/definicion-de-sostenibilidad-sabes-que-es-y-sobre-que-trata/.
Pacheco, J. and E. Contreras (2008), "Manual metodológico de evaluación multicriterio para programas y proyectos", *Manuals series*, No. 58 (LC/L.2957-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
Palma, J. and others (2007), "Estabilización de taludes de tranques de relaves afectados por la erosión eólica", document presented at the VI Chilean Geotechnics Congress, Valparaíso, Chilean Geotechnical Society (SOCHIGE), 28–30 November.
Pantaleón, C., M. Pereira and C. de Miguel (2015), "Guía metodológica: instrumentos económicos para la gestión ambiental", *Project Documents* (LC/W.651), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
Peru, Government of (2021), "Corea apoyará a Perú en proyecto de remediación de pasivos ambientales mineros", Lima, 2 July [online] https://www.gob.pe/institucion/apci/noticias/503960-corea-apoyara-a-peru-en-proyecto-de-remediacion-de-pasivos-ambientales-mineros.
Petek, G. (2020), *Improving California's Response to the Environmental and Safety Hazards Caused by Abandoned Mines*, Sacramento, Legislative Analyst's Office (LAO).
PIRAMID Consortium (2003), *Engineering Guidelines for the Passive Remediation of Acidic and/or Metalliferous Mine Drainage and Similar Wastewaters*, Newcastle upon Tyne, Newcastle University.
Polackova, H. (2000), "Government contingent liabilities: a hidden risk to fiscal stability", Washington, D.C., World Bank.
Posner, E. and M. Adler (1999), "Rethinking cost-benefit analysis", *Yale Law Journal*, vol. 109, New Haven, Yale University.
Presidency of the Republic of Mexico (2024), *Constitución Política de los Estados Unidos Mexicanos que reforma la de 5 de Febrero de 1857*, Mexico City.
___(2016), "Ley General de Asentamientos Humanos, Ordenamiento Territorial y Desarrollo Urbano", *Diario Oficial de la Federación*, Mexico City, 28 November.
___(2013), "Ley Federal de Responsabilidad Ambiental", *Diario Oficial de la Federación*, Mexico City, 7 June.
___(2006), *Reglamento de la Ley General para la Prevención y Gestión Integral de los Residuos*, Mexico City.
Prieto, L. and others (2004), "Análisis coste-efectividad en la evaluación económica de intervenciones sanitarias", *Medicina Clínica*, vol. 122, No. 13, Amsterdam, Elsevier.
r3 Environmental Technology (2017), *Estrategias para la rehabilitación de tierras mineras contaminadas con mercurio para su reutilización en energía renovable y otras estrategias de reutilización autosostenibles. Producto 1: un plan de pruebas de campo in situ de técnicas que prometen ser replicables a otros sitios contaminados de manera similar, con base en evaluaciones de tecnología y trabajo de pruebas a escala de laboratorio*, Bogotá.
___(2014), "Remediación sostenible", Bogotá [online] http://www.r3environmental.com.co/es/servicios/remedacion-sostenible.html.

Revesz, R. and M. Livermore (2023), *Retaking rationality: How Cost-benefit Analysis Can Better Protect the Environment and Our Health*, Oxford, Oxford University Press.

Rico, M. and others (2008), "Reported tailings dam failures: a review of the European incidents in the worldwide context", *Journal of Hazardous Materials*, vol. 152, No. 2, Amsterdam, Elsevier.

Robison, L., P. Barry and R. Myers (2015), "Consistent IRR and NPV rankings", *Agricultural Finance Review*, vol. 75, No. 4, Bradford, Emerald Publishing.

Roseke, H. (2019), "How to develop a stakeholder engagement plan", Calgary, ProjectEngineer, 18 March [online] https://www.projectengineer.net/how-to-develop-a-stakeholder-engagement-plan/.

Ruíz, U. (2006), *Guía técnica para orientar la elaboración de estudios de evaluación de riesgo ambiental de sitios contaminados*, Mexico City, Secretariat of the Environment and Natural Resources (SEMARNAT).

Sánchez, R. (ed.) (2019), *La bonanza de los recursos naturales para el desarrollo: dilemas de gobernanza*, ECLAC Books, No. 157 (LC/PUB.2019/13-P), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Sánchez-Pedraza, R., O. Gamboa and J. Díaz (2008), "Modelos empleados para la toma de decisiones en el cuidado de la salud", *Revista de Salud Pública*, vol. 10, No. 1, Bogotá, National University of Colombia.

Santé, I. and R. Crecente (2005), "Evaluación de métodos para la obtención de mapas continuos de aptitud para usos agroforestales", GeoFocus, No. 5, Barcelona, Autonomous University of Barcelona.

Sapag, N., R. Sapag and J. Sapag (2014), *Preparación y evaluación de proyectos*, Mexico City, McGraw-Hill.

Schmidt, W., R. Flores and U. Ruiz (eds.) (2013), *Remediación y revitalización de sitios contaminados: casos exitosos en México*, Eschborn, Deutsche Gesellschaft für Internationale Zusammenarbeit/Secretariat of the Environment and Natural Resources (GIZ/SEMARNAT).

Schuschny, A. and H. Soto (2009), "Guía metodológica: diseño de indicadores compuestos de desarrollo sostenible", *Project Documents* (LC/W.255), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Schuyler, J. (1994), "Decision analysis in projects: modeling techniques", *PM Network*, vol. 8, No. 7, Pennsylvania, Project Management Institute (PMI).

SCJN (Supreme Court of Justice of the Nation) (2020), "Amparo en revisión 640/2019", Mexico City, 15 January.

SEMARNAT (Secretariat of the Environment and Natural Resources) (2017), "Procedimiento de identificación y caracterización de sitios contaminados", Mexico City [online] https://www.gob.mx/cms/uploads/attachment/file/249157/4._Procedimiento_de_caracterizacio_n_de_sitios_contaminados.pdf.

___(2008), "Guía de llenado para la ficha del sistema informático de sitios contaminados", Mexico City, unpublished.

___(2007), "Norma oficial mexicana NOM-147-SEMARNAT/SSA1-2004, que establece criterios para determinar las concentraciones de remediación de suelos contaminados por arsénico, bario, berilio, cadmio, cromo hexavalente, mercurio, níquel, plata, plomo, selenio, talio y/o vanadio", *Diario Oficial de la Federación*, Mexico City, 2 March.

___(2006), *Guía técnica para orientar la elaboración de estudios de evaluación de riesgo ambiental de sitios contaminados*, Mexico City.

Sen, A. (2000), "The discipline of cost-benefit analysis", *Journal of Legal Studies*, vol. 29, Chicago, University of Chicago Press.

SENER/FSUE/FIDE (Secretariat of Energy/Universal Electric Service Fund/Trust Fund for Electric Energy Savings) (2017), "Sección F: análisis de mecanismos de sostenibilidad y corresponsabilidad de proyectos de electrificación con sistemas aislados", Mexico City [online] http://fsueconvocatoriaaislados.fide.org.mx/manuales/Anexo9-Analisis-Mecanismos-Sostenibilidad.pdf.

SERNAGEOMIN (National Geology and Mining Service of Chile) (2019), "Catastro de Faenas Abandonadas Actualizado a 2019", Santiago [online] https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.sernageomin.cl%2Fwp-content%2Fuploads%2F2020%2F09%2FCatastro-de-Faenas-Abandonadas-Actualizado-a-2019.xlsx.

___(2014), *Guía Metodológica de Evaluación de Riesgos para el Cierre de Faenas Mineras*, Santiago.

___(2007), *Catastro de faenas mineras abandonadas o paralizadas y análisis preliminar de riesgo*, Santiago.

SHCP (Ministry of Finance and Public Credit of Mexico) (2024), "Sistema de evaluación del desempeño" [online] https://www.transparenciapresupuestaria.gob.mx/Sistema-Evaluacion-Desempeno.

___(2018), "Clasificador por objeto del gasto para la Administración Pública Federal", *Diario Oficial de la Federación*, Mexico City, 26 June.

Silva, M. and G. Suazo (2020), "Metodologías para el uso de factores de emisión: material particulado en depósitos de relaves abandonados", *Environment and Development series*, No. 170 (LC/TS.2020/92), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Song, B. and others (2017), "Evaluation methods for assessing effectiveness of in situ remediation of soil and sediment contaminated with organic pollutants and heavy metals", *Environment International*, vol. 105, Amsterdam, Elsevier.

Squire, L. and H. van der Tak (1975), *Economic Analysis of Projects*, Baltimore, The Johns Hopkins University Press.

Stefanovic, M. and I. Stefanovic (2005), "Decisions, decisions", Pennsylvania, Project Management Institute (PMI) [online] https://www.pmi.org/learning/library/decisions-quantitative-making-process-7466.

Stiglitz, J. and J. Rosengard (2015), *Economics of the Public Sector*, New York, W. W. Norton & Company.

SURF (Sustainable Remediation Forum) (2009), "Sustainable remediation white paper—integrating sustainable principles, practices, and metrics into remediation projects", *Remediation*, vol. 19, No. 3, Hoboken, Wiley.

Taylor, A. and others (2019), "Five-step approach to stakeholder engagement", *Reports*, San Francisco, Business for Social Responsibility (BSR), 29 April.

Terán, L. (2017), "Memoria. Proyecto 'Gestión de Pasivos Ambientales en Áreas Protegidas y su Influencia en el Recurso Hídrico'", La Paz, United Nations Development Programme (UNDP).

The Economist (2014), "Why doing a cost-benefit analysis is harder than it looks", London, 24 April [online] https://www.economist.com/the-economist-explains/2014/04/23/why-doing-a-cost-benefit-analysis-is-harder-than-it-looks.

Torche, A. and others (2009), "La inversión pública: su impacto en crecimiento y bienestar", *Camino al bicentenario: propuestas para Chile*, Santiago, Pontifical Catholic University of Chile (PUC) and others.

Toskano, G. (2005), "El proceso de análisis jerárquico (AHP) como herramienta para la toma de decisiones en la selección de proveedores: aplicación en la selección del proveedor para la empresa gráfica comercial MYE S.R.L.", Lima, National University of San Marcos (UNMSM).

Treadwell & Rollo (2011), *Environmental Site Investigation Report. Pier 70 Master Plan Area. San Francisco, California*, San Francisco.

UNESCO (United Nations Educational, Scientific and Cultural Organization) (2009), "Agua y minería en cuencas áridas y semiáridas: guía para la gestión integral", *Documento Técnico del PHI-LAC*, No. 17, Montevideo.

United Nations (2015), *Transforming our World: the 2030 Agenda for Sustainable Development* (A/RES/70/1), New York.

___(1987), *Report of the World Commission on Environment and Development: note by the Secretary-General* (A/42/427), New York.

Velásquez, J. (2012), "Buenas prácticas ambientales y sociales en la minería", Bogotá, PazdelRío [online] http://www.uptc.edu.co/export/sites/default/eventos/2012/cim/documentos/bpracticas.pdf.

Vidal, F. (2001), "La responsabilidad civil", *Derecho PUCP*, No. 54, Lima, Pontifical Catholic University of Peru (PUCP).

Viscusi, W. (1993), "The value of risks to life and death", *Journal of Economic Literature*, vol. 31, No. 4, Nashville, American Economic Association (AEA).

Youmatter (2018), "Stakeholder engagement – meaning, definition & strategies", Paris, 1 October [online] https://youmatter.world/en/definition/stakeholder-engagement-meaning-definition-and-strategies/.

Younger, P., S. Banwart and R. Hedin (2002), *Mine Water: Hydrology, Pollution, Remediation*, New York, Springer.

Yupari, A. (2004), "Pasivos ambientales mineros en Sudamérica", Santiago, Economic Commission for Latin America and the Caribbean/Federal Institute for Geosciences and Natural Resources/National Geology and Mining Service of Chile (ECLAC/BGR/SERNAGEOMIN), unpublished.

Wang, L. and others (2019), "Green remediation of As and Pb contaminated soil using cement-free clay-based stabilization/solidification", *Environment International*, vol. 126, Amsterdam, Elsevier.

Watkins, R., M. Meiers and Y. Visser (2012), *A Guide to Assessing Needs: Essential Tools for Collecting Information, Making Decisions, and Achieving Development Results*, Washington, D.C., World Bank.

Watzlaf, G. and others (2004), *The Passive Treatment of Coal Mine Drainage*, Pittsburgh, National Energy Technology Laboratory (NETL).

WHO (World Health Organization) (2021a), *Guideline for Clinical Management of Exposure to Lead*, Geneva.

___(2021b), *Protecting Health through Urban Redevelopment of Contaminated Sites: Planning Brief*, Copenhagen.

Williams, C. (2007), "Research methods", *Journal of Business & Economic Research*, vol. 5, No. 3, Littleton, Clute Institute.

Wood, C. (1996), "Evaluación de impacto ambiental: un análisis comparativo de ocho sistemas de EIA", *Estudios Públicos*, No. 61, Santiago, Center of Public Studies (CEP).

World Bank (2018), "EAS 5: adquisición de tierras, restricciones sobre el uso de la tierra y reasentamiento involuntario", *Nota de Orientación para los Prestatarios*, Washington, D.C.

___(2015), *¿Qué son los bonos verdes?* , Washington, D.C.

___(2005), *Wealth and Sustainability: The Environmental and Social Dimensions of the Mining Sector in Peru*, Washington, D.C.

___(2001), "Interactive community planning. ZOPP: Goal Oriented Project Planning", Washington, D.C. [online] http://web.mit.edu/urbanupgrading/upgrading/issues-tools/tools/ZOPP.html.

Zuniga, C. and N. Abgar (2011), "Breve aproximación a la técnica de árbol de decisiones" [online] https://niefcz.files.wordpress.com/2011/07/breve-aproximacion-a-la-tecnica-de-arbol-de-decisiones.pdf.

This document contains information, methodologies and guidelines for policymakers and those responsible for implementing public policies aimed at prioritizing investment in environmental remediation projects. It presents an analysis of the concepts of environmental mining legacies and remediation, as well as their most important aspects, taking into account the heterogeneity of the definitions used in the countries of Latin America and the Caribbean. Emphasis is placed on safeguarding human rights, environmental protection, liability for remediation of damage, and economic and financial analysis. It provides common definitions and guiding frameworks to standardize the economic and financial analysis of risk-based environmental management. As a starting point, any remediation project must first control the risk for people and the environment. Subsequent financial, economic and social analyses help to determine the most appropriate projects on the basis of the prevailing conditions. The concepts presented throughout this paper are applied and understood in the framework of public sector economics, environmental economics, welfare economics and the economic and financial spheres.

The *ECLAC Methodologies* collection describes the conceptual principles, technical specifications and applications of the quantitative and qualitative tools developed and used by the Economic Commission for Latin America and the Caribbean (ECLAC). The collection's main aim is to offer better and new policymaking tools, thus contributing to evidence-based public policymaking that fosters sustainable development with equality.

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