MICA
Minerals Intelligence Capacity Analysis

DOC SHEET

Life cycle of a mining project

A complete mining project, from prospection to site remediation, is a long and complex process that stretches over many years.

Scope (conceptual model & main characteristics)

A complete mining project, from exploration to site remediation, is a long and complex process that extends over many years (often up to several decades or more). A complete cycle will involve many fields of expertise and requires large information and financial inputs. In summary, a mining project can be divided into five phases that are closely interconnected and occur in the following chronological order:

Image 1 - Airborne geophysical survey (copyright BRGM, R. Carayol)

1) The exploration phase usually begins with i) research to identify areas that are most favourable for exploration and ii) regional (or 'large scale") studies of these areas. Activities of this phase include desk studies, area selection, exploration permit acquisition, regional studies (geology, geochemistry, geophysics, preliminary community engagement, etc.) The typical land area covered is up to ten-thousands of square kilometers. This stage has minimal environmental impact with airborne geophysical surveys and regional ground

reconnaissance. It may last from 2 to 5 years, typical expenditure is in the order of 0.1 to 10 million € and the expected outcome is the identification of target(s) for subsequent advanced exploration.

2) The advanced exploration phase occurs next and is one where targets, identified in the first phase, are evaluated. This stage requires higher impact activities, such as drilling, trenching, , sampling for metallurgical studies, collection of environmental and social baseline data, community engagement, etc. Fieldwork is conducted on land which more often than not requires a permit, lease or license. The typical land area covered is up to hundreds of square kilometers. This stage has more significant but still moderate environmental and social impacts, and may include road building, traffic, drilling, trenching, etc., that can affect air, flora, fauna, land and/or water, although these can be mitigated. It may last from 3 to 15 years, typical expenditure is up to hundreds of million € (in the order of several million € per project per year) and the usual outcomes, assuming that promising mineral deposit(s) is/are found, are i) a scoping study that includes resource estimates, order-of-magnitude cost estimates and general idea of what a mine might look like, and/or ii) a preliminary feasibility study, more detailed than the scoping study, that includes revised resource estimates, preliminary mine design and engineering, and preliminary cost estimates.

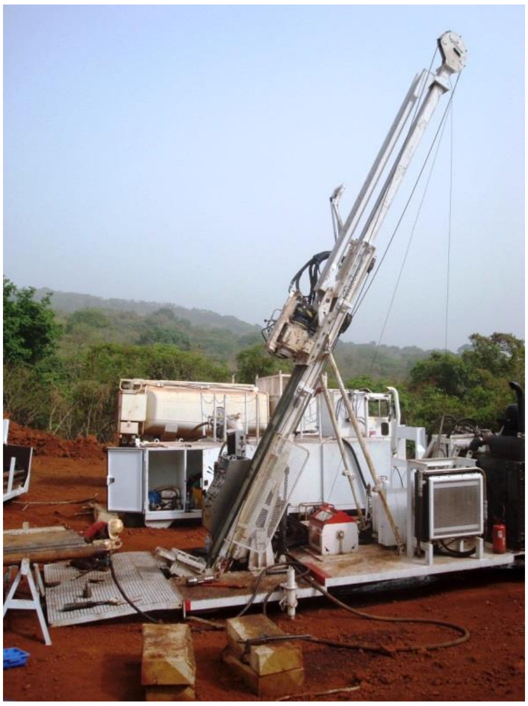

Image 2 - Core drilling exploration campaign (copyright BRGM, G. Bertrand)

3) The development and construction phase happens when a company decides to go ahead with the project based on economic viability. This is the most expensive phase of the mining life cycle as large amounts of capital are needed to construct and develop a mine. The typical land area covered is up to a few tens of square kilometers. This stage usually lasts 3 to 5 years and typical expenditure maybe up to one billion € or more. This phase starts with i) the applications for permits and approvals and ii) an update of the feasibility study that includes reserve estimates, mine and plant design, detailed engineering and cost estimates, full technical and economic assessment and financing. The expected outcome of this phase is, of course, an operating mine.

Image 3 - Mining shovel excavator (copyright BRGM, G. Bertrand)

4) The operation and production phase is the actual mining, milling and processing activity. The duration of a mine activity (the mine life) depends largely (but not only) on the amount (reserves) and quality (grade) of the mineral that is extracted, which are key factors in the profitability of the mine. It is at this stage that companies start to see a return on their investment, although they still have operating costs (wages, energy, equipment, transportation, maintenance, etc.) The development and mining phases have more significant environmental (e.g., mining, processing, waste disposal and tailings) and social (influx of people and significant community changes) impacts, amongst which most can be minimized and controlled, although some change is inevitable.

Image 4 - Underground Mining at Tara, Ireland (copyright Boliden Tara)

5) The closure and reclamation phase actually starts at the beginning of the project, in order to plan well ahead to safeguard the environment when the mine closes. In most countries or regions (e.g. Ireland) a closure and reclamation plan is required, and financial instruments are required in order to set aside the total estimated reclamation costs. In most countries early closure is also catered for in order to deal with the situation where a mine might close earlier than expected for any one of a number of reasons. The closure of a mine and cleaning up of a mine site typically takes two to ten years and costs up to a hundred million € or more, depending on the size of the mine and the nature and extent of any remedial works that may have taken place during the operation of the mine.

Image 5 - Remediation of an old mining site (copyright BRGM, Charbonnages de France)

Most projects do not go through the entire life cycle presented above. As a gross estimation, 500 to 1,000 grassroot exploration projects are needed to identify approximately 100 targets for advanced exploration, which in turn lead to 10 potential development projects and eventually to the construction of 1 mine. The mine life cycle presented above is summarized in Table 1 below.

Phase	1 Exploration		2 Advanced exploration			3 Development and construction				4 Operation and production	5 Closure and reclamation
Tasks	Regional reconnaissance	Testing of showings	Study of occurences	Delineation of mineralized enveloppe	Definition of orebody	Technical feasibility	Economic feasibility	Finance	Construction		
Techniques & methods of evaluation	Strategic exploration - Predictivity mapping - Economic geology - Stream sediments - Geochemistry - Airborne geophysics - Remote sensing	Tactic exploration - Soil/rock geochemistry - Geophysical survey - Geological survey - Typology	Sub-surface works - Pits and trenches - Cuttings - Extrapolation from geological evidences	Development drilling cores - Phase 1 : 1 000-5 000 m of drilling; target study - Phase 2: 5 000-10 000 m of drilling; pre-feasibility ➔ Mineralized envelop	Mine working and drill-holes Certification of continuity of the mineralization (geostatistics, trial tests) ➔ Resouces (in situ reserves) evaluation	- Geostatistics - Pilot plan - Selection of mining method - Grade-tonnage relationships (block model)	- Economic feasibility - Financial evaluation - Bankable report - Social/environmental assessment	- Sales contracts - Audits - Loan agreements	- Detailed engineering - Tenders - Preparatory mine workings - Infrastructure	- Production planning - Production tests - Renewals - Yearly reserve assessment - Ore beneficiation - Product sale	- Mine closure - Site clean-up
Objectives	Detection of anomalies	Identification of targets	Selection of targets	Target study	Report of resource evaluation, preliminary feasibility study	Mining project	Investment decision	Financial and legal package	Mine construction	Mine operation	Site remediation
Typical land area covered	10,000s km2		100s km2			10s km2)					
Typical duration	2 to 5 years		3 to 15 years			3 to 5 years, or more				Several years to several decades	2 to 10 years
Typical expenditure	0.1 to 10 million €		Up to 100s of million €			Up to 1 billion € or more				Operating costs	Up to a hundred million €
Mineral status (indicative)	Resources (mineralization)					Reserves (ore)					
	Speculative	Hypothetical	Inferred	Indicated	Measured						

Table 1 – Overview of a mining project life cycle ; typical land areas, durations and expenditures are indicative and may significantly vary from one project to anothers and/or in different countries.

Contexts of use, application fields	-> contexts (e.g., environmental, economic, social assessment) -> which types of stakeholder questions are concerned? -> link to published studies that implement the method

Involved stakeholders are numerous and include all those who are interested in the mining sector from either an exploration, technical, economical, social or environmental point of view.

Input parameters	-> which parameters are needed to run the method

▶

Type(s) of related input data or knowledge needed and their possible source(s)	-> which types of data are needed to run the method, from which sources could they come… -> could be qualitative data or quantitative data, and also tacit knowledge, hybrid, etc.

▶

Model used (if any, geological mathematical, heuristic…)	-> e.g., geological model for mapping -> e.g., mathematical model such as mass balancing, matrix inversion, can be stepwise such as agent -based models, dynamic including time or quasidynamic specifying time series… -> can also be a scenario

The models required to conduct a mine project through its complete life cycle relate to numerous domains, such as :

- Geology (lithology, tectonic structures, geophysics, geochemistry,…);
- Metallogeny (deposit type, grades,…);
- Economic (supply and demand, future trends, …);
- Environmental (impacts and remediation);
- Social;
- Etc …

System and/or parameters considered	-> **the system can be described by its boundaries**. These can refer to a geographic location, like a country, or a city, the time period involved, products, materials, processes etc. involved, like flows and stocks of copper, or the cradle-to-grave chain of a cell phone, or the car fleet, or the construction sector, or the whole economy… -> **parameters** could possibly refer to geographic co-ordinates, scale, commodities considered, genesis of ore deposits and others…

▶

Time / Space / Resolution /Accuracy / Plausibility…	-> to which spatio-temporal domain it applies, with which resolution and/or accuracy (e.g., near future, EU 28, 1 year, country/regional/local level…) -> for foresight methods can also be plausibility, legitimacy and credibility…

See indicative time and space coverage in Table 1.

Indicators / Outputs / Units	-> this refers to what the method is actually meant for. Units are an important part but that is most of the time not sufficient to express the meaning. For example, **the indicators used in LCA express the cradle-to-grave environmental impacts of a product or service**. This can be expressed in kg CO_2-equivalent. But also in €. Or in millipoints. Or in m^2year land use. -> for foresight methods the outputs are products or processes

Many indicators are required by a mining project, in various domains, such as (but not limited to):

- Geology and metallogeny (volumes, usally in tons; grades, usually in percent, gram per ton or carat);
- Economic (e.g. trading prices, costs, unit costs, profit or loss, …);
- Environment (e.g. carbon balance or footprint, …);
- Etc …

Treatment of uncertainty, verification, validation	-> evaluation of the uncertainty related to this method, how it can be calculated/estimated

▶

Main publications / references	-> e.g. , ILCD handbook on LCA, standards (e.g. , ISO) -> can include reference to websites/pages -> references to be entered with their DOI

Association for Mineral Exploration British Columbia. Mineral exploration life cycle.

Eggert R.G. (2010). Mineral exploration and development: risk and reward. International Conference on Mining, Phnom Penh, Cambodia, 26-27 May 2010

Mineral Development Division, Indian and Northern Affairs Canada. Stages of mineral exploration and development in the NorthWest Territories. ISBN: 978-0-662-45460-1

Related methods	-> List of comparable methods, their particularities… -> link to one or several other existing fact sheet(s)

▶

Some examples of operational tools (CAUTION, this list is not exhaustive)	-> e.g., software… Only give a listing and a reference (publication, website/page…) -> **should be provided only if ALL main actors are properly cited**

▶

Key relevant contacts	-> list of relevant **types** of organisations that could provide further expertise and help with the methods described above.

►