MICA
Minerals Intelligence Capacity Analysis

FACTSHEET

Three-part quantitative assessment method

The three-part method is used in quantitative assessments of undiscovered mineral resources. It produces probabilistic estimates of the amount of metals and ore in undiscovered deposits of selected types.

Scope (conceptual model & main characteristics)

The three-part quantitative assessment method is a method used in the estimation of possibly existing but as yet undiscovered mineral resources (Singer, 1993; Singer and Menzie, 2010). It produces probabilistic estimates of the amounts of metals and ore in undiscovered deposits. The three parts of the method are:

1) Evaluation and selection or construction of a descriptive model and a grade-tonnage model for the deposit type
2) Delineation of areas permitted by the geology for the deposit type (permissive tracts)
3) Estimation of the number of undiscovered deposits of the deposit type within the permissive tracts.

The three-part assessment can only be performed for well-known mineral deposit types, which are documented by deposit models. There are several types of deposits models, but two models are obligatory: A descriptive model and a grade-tonnage model. A descriptive model summarises the geological characteristics of the mineral deposit type. It helps to identify deposits belonging to the type and to distinguish them from other types of deposits. A grade-tonnage model contains data of metal grades and ore tonnages from well-known and totally delineated deposits belonging to the deposit type. Since the grade and tonnage data represent whole deposits, already excavated amounts of ore must be included. The grade-tonnage model is used to estimate the ore grades and metal tonnages in undiscovered deposits belonging to the same type.

The permissive tracts are areas, or more precisely surface projections of volumes of rock, for which geology permits the existence of deposits of a certain type. The permissive volumes are often delineated down to the depth of one kilometer, but other assessment depths can also be used.

The number of undiscovered deposits within a permissive tract is generally estimated in a workshop by a group of geoscientists with expert knowledge concerning the delineated permissive area and the mineral deposit type being assessed. The estimates are carried out independently by the individual experts at several levels of confidence (e.g., at 90%, 50% and 10% confidence). The final estimate is either a consensus estimate reached after a discussion, or consists of averages of the individual experts' estimates.

In a final step of the assessment, the estimated number of deposits for each permissive tract or a group of tracts is combined with the grade and tonnage data from the deposit model to assess the total undiscovered metal endowment. The calculations are carried out using Monte Carlo simulation, which produces probability distributions of metal and ore tonnages in the undiscovered deposits.

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

The method was originally developed in the U.S. Geological Survey to produce unbiased quantitative estimates to support decision-making concerning alternative courses of action with respect land use or mineral resource development. The context of use is usually economic, and the assessments try to answer questions concerning best uses of land possibly containing mineral resources.

Published studies implementing the method include Richter et al. (1975), Singer and Overshine (1979), Drew et al. (1984), Bliss (1989), Brew et al. (1992), Box et al. (1996), U.S. Geological Survey National Mineral Resource Assessment Team (2000), Kilby (2004), Lisitsin et al. (2007, 2014), Cunningham et al. (2008), Hammarstrom et al. (2010, 2013), Mihalasky et al. (2011), Ludington et al. (2012a,b), Sutphin et al. (2013), Zientek et al. (2014a,b), Eilu et al. (2015), Rasilainen et al. (2017). For complete references see Main publications/references section.

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

Grade and tonnage data from well-known and totally delineated deposits, estimated number of undiscovered deposits in delineated areas.

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.

Geological data (maps) of the area under assessment, information on existing mineral deposits within the area (type, location, grade and tonnage if known), and information on exploration history of the area are required to be able to run the method. Additional geophysical, geochemical, geochronological, information is useful. Personal knowledge of experts performing the assessment concerning the geology and mineral deposits within the area is important.

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 estimation of the number of undiscovered deposits as well as the simulation of the amount of undiscovered metals in these deposits, are based on analogy. The number of deposits in well-known areas and the grades and tonnages of well-known deposits are used as the basis for estimations. Monte Carlo simulation is used in the calculation of the undiscovered metal endowment.

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…

The assessments are performed by deposit type, which has to be well known and understood. Permissive areas are defined by a suitable geology that permits the existence of deposits of certain type(s).

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…

The assessment results refer to the time of assessment. With time, new discoveries within the permissive areas might be made, and the estimated undiscovered resources might hence be converted to known resources. The duration between consequtive rounds of assessments within any given area is generally in the order tens of years. The spatial extent of assessments can vary form local (e.g., communality, national park, from tens of square kilometres upwards) to regional (e.g., country-wide, mountain belt, hundreds of thousands of square kilometres or more). The spatial resolution of an assessment depends on the level of detail of the available geological maps. A resolution of 1:1 million is often used. The reliability of the assessment results depends on the amount and quality of information available. The estimated metal tonnages are generally given with two significant digits.

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

The method produces an estimate of the amount of metals in undiscovered deposits within a given area, expressed in metric tons.

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

The uncertainty of the estimates is described by the spread of the calculated probability distributions of undiscovered metal amounts. Validation of the estimates is difficult, as it would require that all the presently undiscovered deposits should be discovered and thoroughly studied.

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

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

Mineral prospectivity mapping aims to delineate areas prospective for selected mineral deposit types. The method is related to the three-part method, but does generally not produce quantitative estimates of undiscovered resources.

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**

Duval, J.S., 2012. Version 3.0 of EMINERS—Economic Mineral Resource Simulator. U.S. Geological Survey, Open-File Report 2004–1344. Available online at http://pubs.usgs.gov/of/2004/1344. (Version 3.0 of EMINERS updates version 2.0, released in 2004 as USGS OFR 2004–1344. Version 2.0 of EMINERS superseded USGS OFR 2002–0380.)

Ellefsen, K.J., 2017, User's guide for MapMark4—An R package for the probability calculations in three-part mineral resource assessments: U.S. Geological Survey Techniques and Methods, book 7, chap. C14, 23 p., https://doi.org/10.3133/tm7C14.

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

U.S. Geological Survey
Geological Survey of Finland
Geologica Survey of Denmark

Glossary of acronyms /abbreviations used	-> Definition