اتاق بازرگانی، صنایع، معادن و کشاورزی کرمانشاه

18 ESFAND 1400

15:00-19:00

ارزیابی پارامترهای فنی و اقتصادی در طراحی معادن روباز

18 ESFAND 1400

Contact

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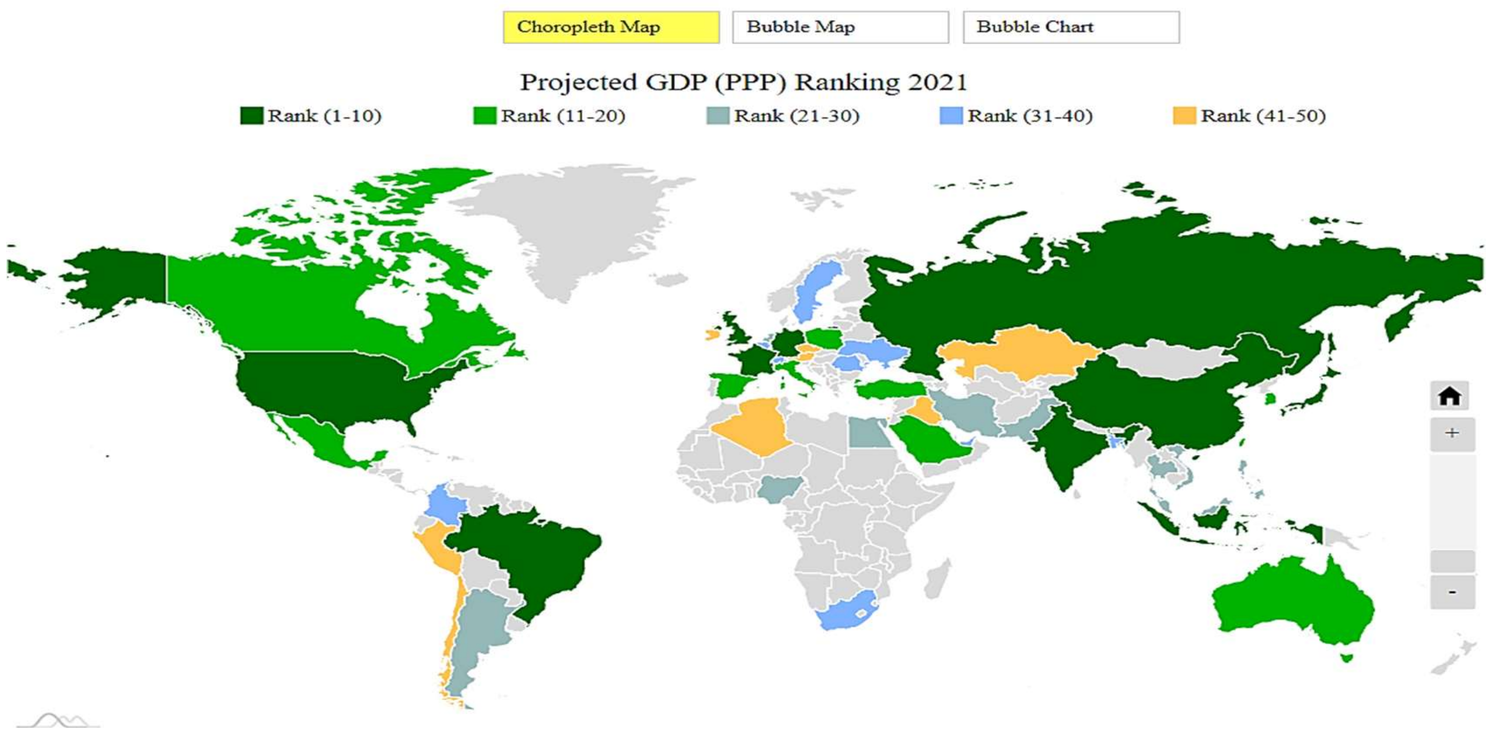
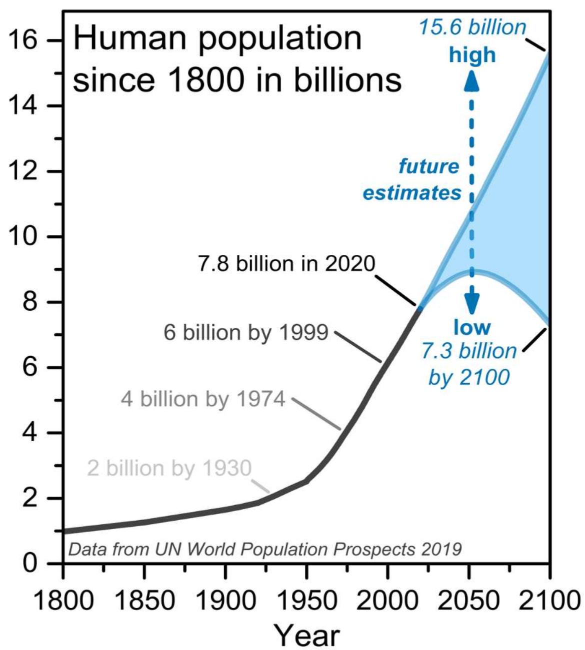
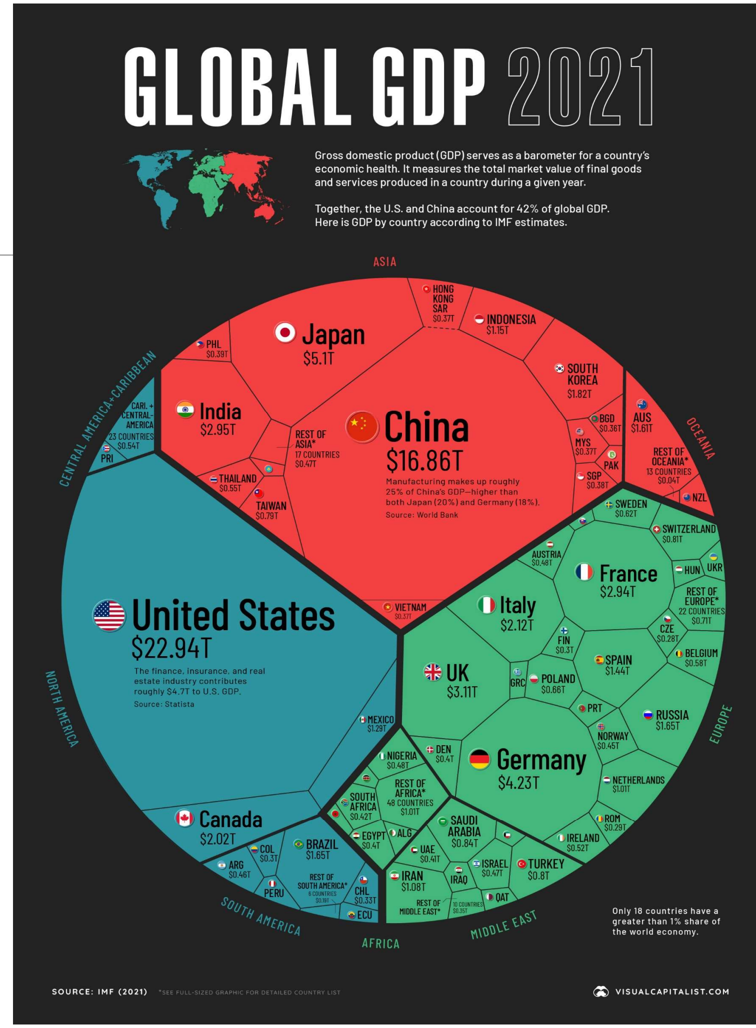
The World Economy



GDP Map 2021

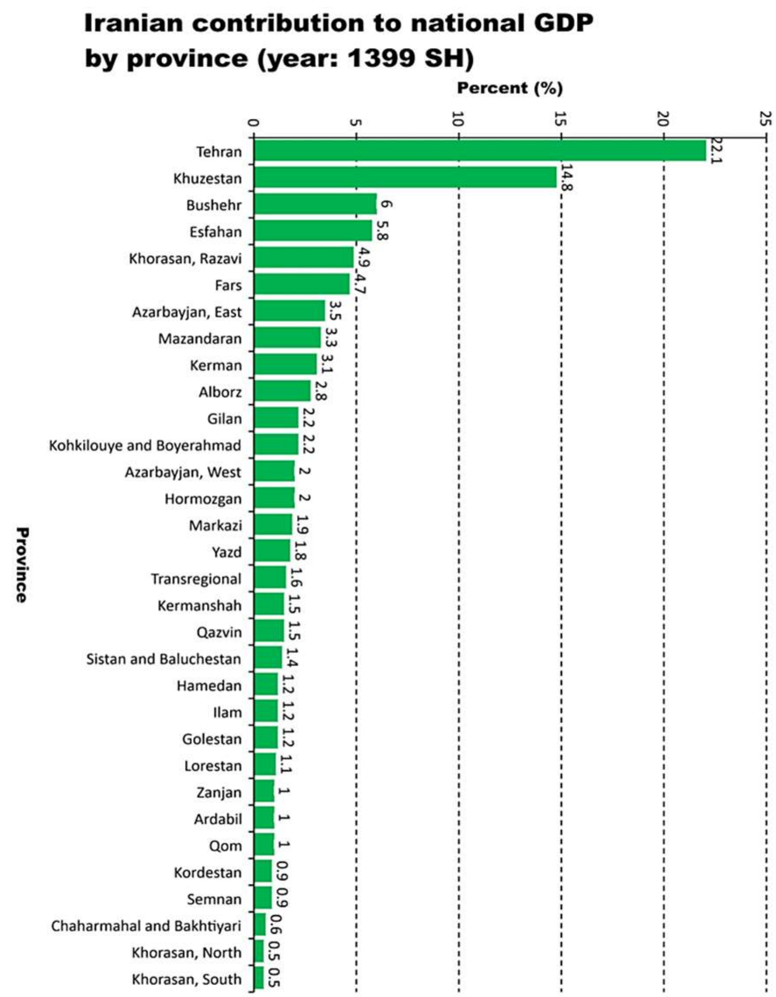
- Iran : $1.08T





Iranian GDP

- Tehran : 22.1%
- Khuzestan : 14.8 %
- Bushehr : 6 %
- Esfahan : 5.8 %
- Khorasan Razavi : 4.9 %
- Fars : 4.7 %
- Azerbaijan, East : 3.5 %
- Mazandaran : 3.3 %
- **Kermanshah** : 1.5 %
- Qazvin : 1.4 %



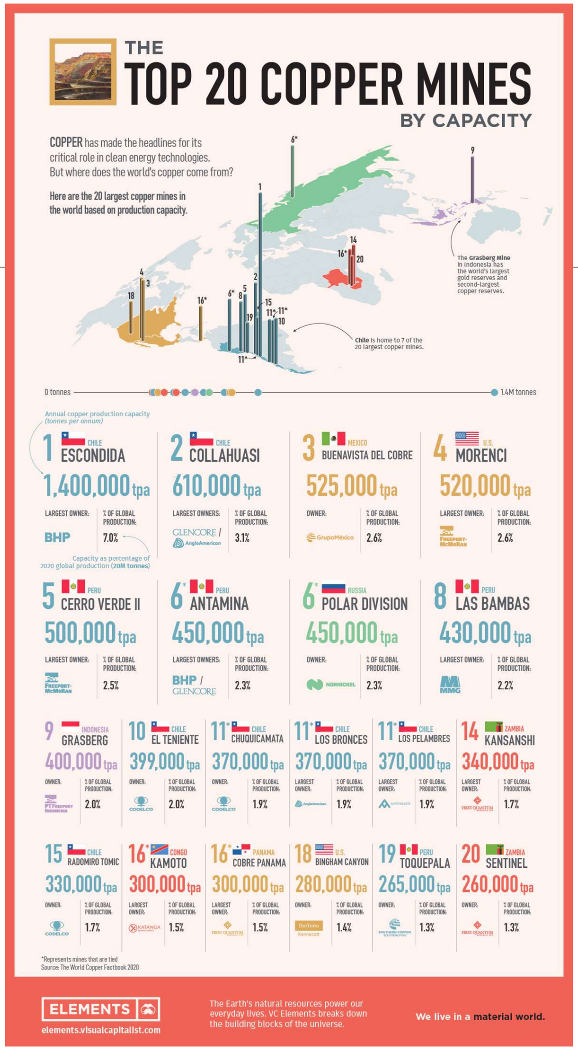
Mining Engineering

Iran – Mines

- نوع ماده معدنی : ۸۱ نوع در ایران
- رتبه معدنی ایران از نظر ذخایر : دهم (با نفت و گاز)
- رتبه معدنی ایران از نظر ارزش : هشتم
- رتبه مس از نظر ذخایر : رتبه هفتم
- رتبه مس از نظر تولید : رتبه پانزدهم
- رتبه روی : رتبه دهم
- رتبه طلا : با تولید ۱۱ تن در سال رتبه سی و نهم جهان
- ۷۰۰۰ معدن فعال در حال حاضر
- ۵۱۰ میلیون تن ماده معدنی
- ۱۶۰۰۰۰ نفر اشتغال زایی در بخش معدن

Copper Mine

Rank	Mine	Country	Annual Production Capacity (tonnes)	Capacity as a % Global Production†
1	Escondida	Chile	1,400,000	7.0%
2	Collahuasi	Chile	610,000	3.1%
3	Buenavista del Cobre	Mexico	525,000	2.6%
4	Morenci	U.S.	520,000	2.6%
5	Cerro Verde II	Peru	500,000	2.5%
6*	Antamina	Peru	450,000	2.3%
6*	Polar Division	Russia	450,000	2.3%
8	Las Bambas	Peru	430,000	2.2%
9	Grasberg	Indonesia	400,000	2.0%
10	El Teniente	Chile	399,000	2.0%



Sarcheshme Complex Copper Mine

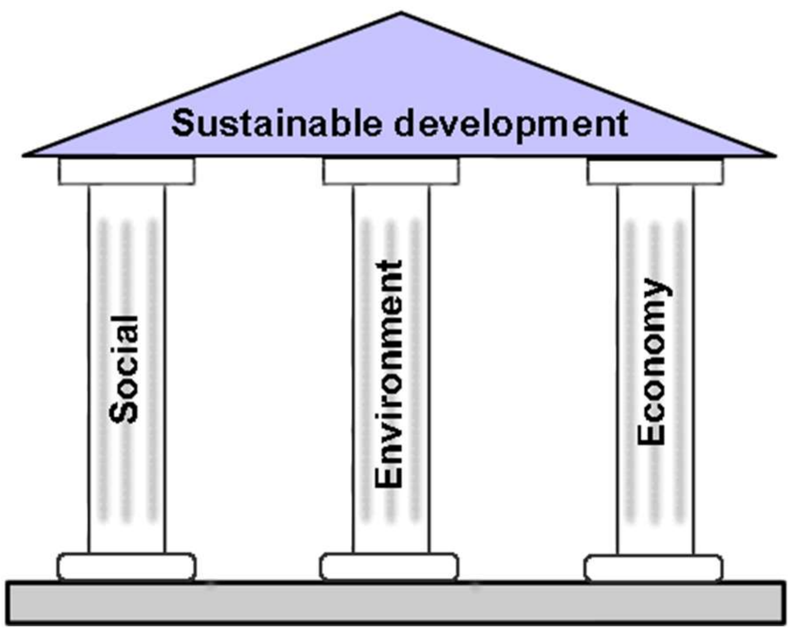
- Production : 220 000 tpd
- Strip Ratio : 1

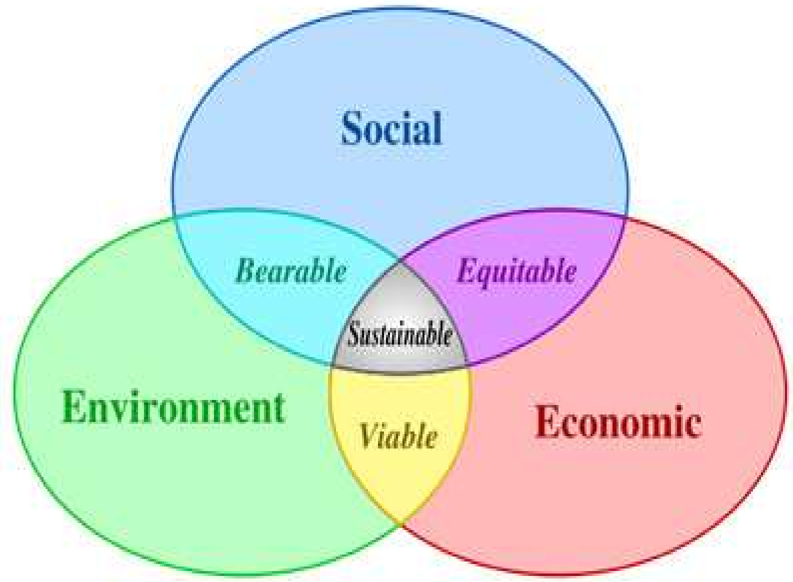
- Drilling :
  - 60 years ; 8 Mm (Iran)
  - 1 Year (2018) ; 11 Mm (Australia)

Mining Engineering

The role of the mining engineer is to define the most efficient way to extract material of economic value from the ground and deliver it to the processing plant. Mining efficiency must take into account the constraints imposed by geology, the requirements of the metallurgical process, capital and operating costs, and safety. Development of a mine plan and the production schedule must satisfy social, environmental, legal, and safety regulations as well as company objectives and values. The three bottom lines—financial, social, and environmental—must be assessed to compare various scenarios. A mine plan cannot be evaluated in isolation.

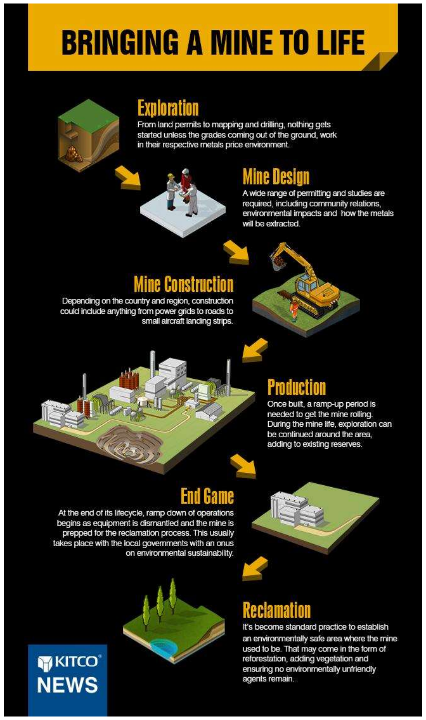
Sustainable Development





Mining engineering

- Geology/Mineralogy
- Mine Environment
- Mine Exploration
- Mine Exploitation
- Rock Mechanics
- Mineral Processing
- Mine Management and Economics
- Mine Closure and Reclamation



Key Point

Open pit planning and design is a decision – making process that leads to a realistic and actionable plan.

Planning time frames : short (next shift) & Long (Life of the mine)

Long term mine planning involves: (Pit design, mine sequence, production rate, process method, ore selection and mining method).

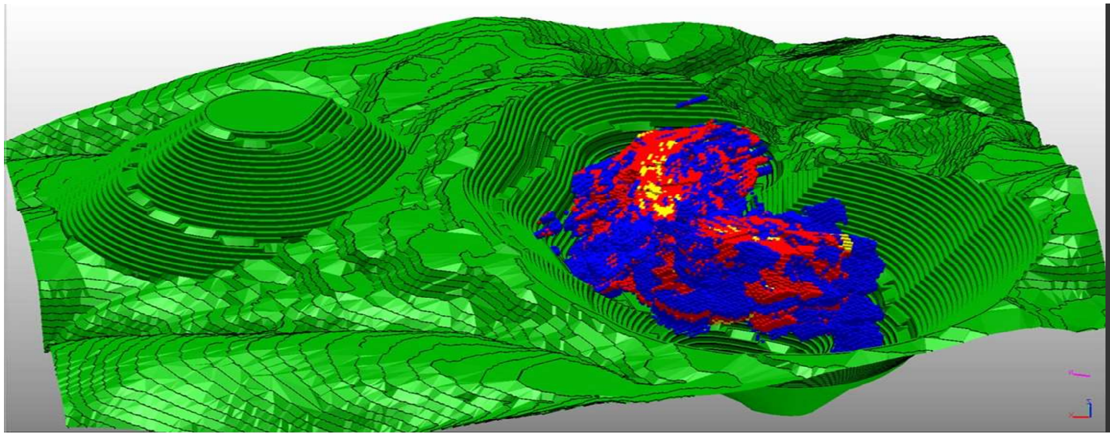
Make a decision under uncertainty

Are the geotechnical conditions well understood? (Seismic and weather conditions)

Make a decision under uncertainty

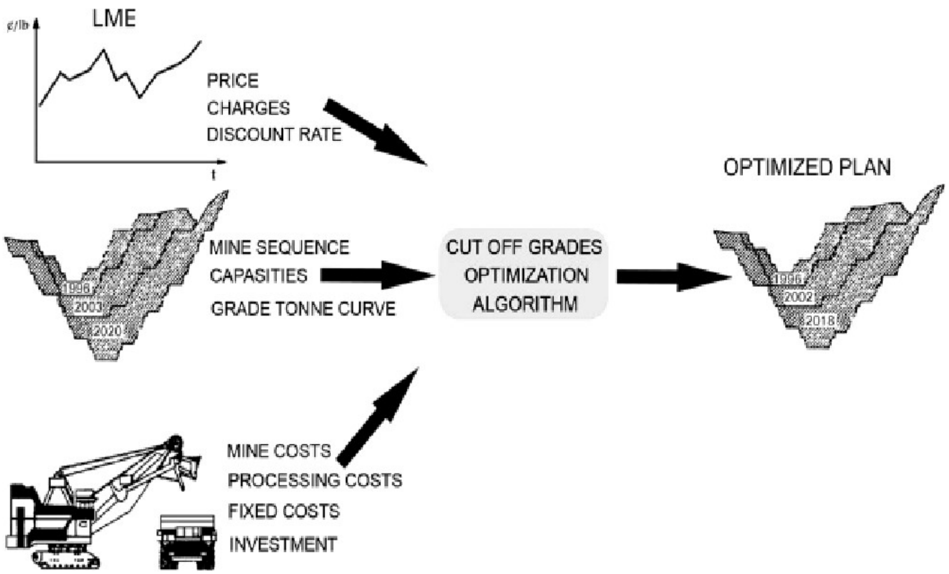
What is the resource under the ground really like?

How much ore is available and how will it respond to the planned processing methods?



Make a decision under uncertainty

What will commodity price and costs be next year ? In 30 years ?



Why Surface Mining

Daily Production Surface Mining

Mine	t/d	Product	Country
CBG Bauxite	32,000	Al	Guinea
Bata Hijau	182,000	Au	Indonesia
Zarafshan Newmont	38,000	Au	Uzbekistan
Goldstrike	32,000	Au	United States
Cripple Creek and Victor	30,000	Au	United States
Rhineland Lignite*	274,000	Coal	Germany
North Antelope Rochelle	251,000	Coal	United States
Black Thunder	250,000	Coal	United States
Cordero Rojo	180,000	Coal	United States
Kaltim Prime	100,000	Coal	Indonesia
Chuquicamata	375,000	Cu	Chile
Escondida	240,000	Cu	Chile
Grasberg	240,000	Cu	Indonesia
Collahuasi	170,000	Cu	Chile
Bingham	150,000	Cu	United States
El Abra	120,000	Cu	Chile
Hamersley Yandacoogina	143,000	Fe	Australia
Carajas	100,000	Fe	Brazil
Alegria	65,000	Fe	Brazil
Samarco	65,000	Fe	Brazil
Mount Wright	62,000	Fe	Canada
Iron Ore Company of Canada	60,000	Fe	Canada
Mt. Keith	32,000	Ni	Australia
Syncrude Oil Sands†	500,000	Oil	Canada

Daily Production Underground Mining

Mine	t/d	Product	Country
El Teniente	100,000	Cu	Chile
Grasberg Underground	50,000	Cu	Indonesia
Olympic Dam	25,000	Cu, U	Australia
Palabora	20,000	Cu	South Africa
Kiruna	40,000	Fe	Sweden
Henderson	32,000	Mo	United States
Norilsk	30,000	Ni	Russia

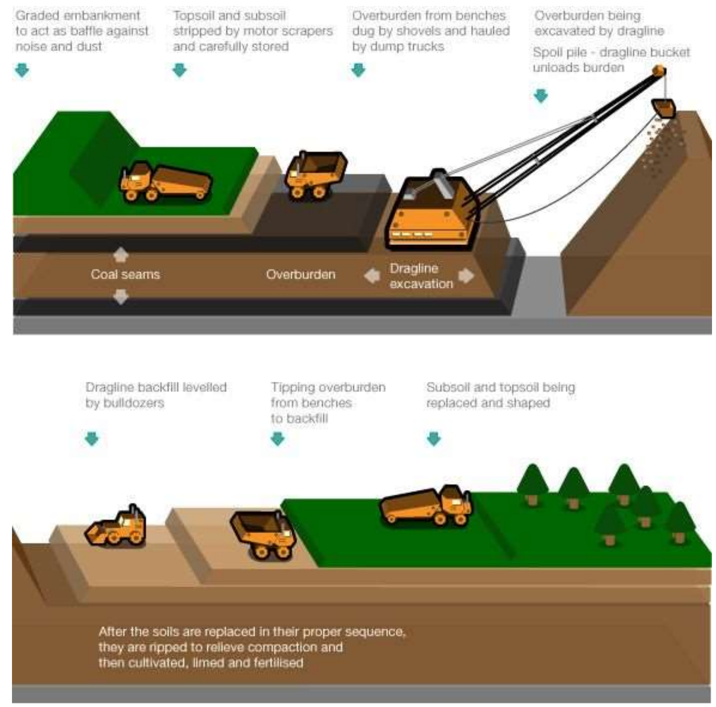
Surface mining

- Strip Mining
- Open pit Mining
- Quarry Mining
- Auger Mining

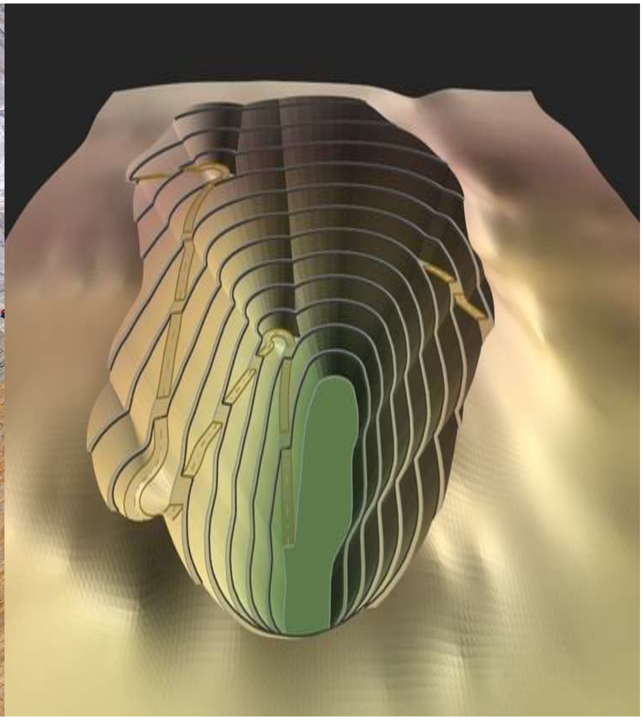
Strip mining

Area Mining (Low Overburden)

Contour Mining (High Overburden)



Open pit mining



Quarry mining

Auger Mining

Mine Operations

Most mine operations have two separate activities:

- mining and
- mineral processing.

The high capital cost and long life of a mining operation necessarily lead to relatively **lower rates** of technological change, broadly shared with other industries with similar characteristics.

The activities currently used in the **mining** and **processing** areas of most mines look similar to those used 25, even 50 years ago.

Drilling and blasting, the use of trucks and shovels, crushing, grinding, flotation, smelting, and refining are all still **core elements** of the industry.

Mine Operations

- In 1970, the average truck purchased for use in an open pit mine was 90 t (metric tons).
- By 2008, the average size of a newly purchased mining truck had doubled to just over 180 t.
- Plant size has followed a similar trend.
- The Escondida mine in Chile has been either the first or the second largest copper mine in the world since it started operating in the late 1980s.

Escondida mine

- Escondida also reflects the general trend in mining toward large open pits.
- At the beginning of the 1990s, more than 90% of mine production was by underground means.
- By the year 2000, 85% of mine production was from open-pit mines.

Metric	1990	2008
Daily ore production, t/d	35,000	240,000 concentrator feed, 60,000 oxide leach feed, 300,000 sulfide leach feed
Total material moved, t/d	280,000	1.4 million
Annual copper production, t/yr	320,000 in concentrate	1.1 million in concentrate, 300,000 million in cathodes
Average copper grade	2.9%	1.5%
Processing technology	Concentrate flotation	Flotation, oxide leach, sulfide leach, electrowinning
Mining technology	Drill, blast, truck, shovel	Drill, blast, truck, shovel, ore conveyors

Open pit Mines – Challenges

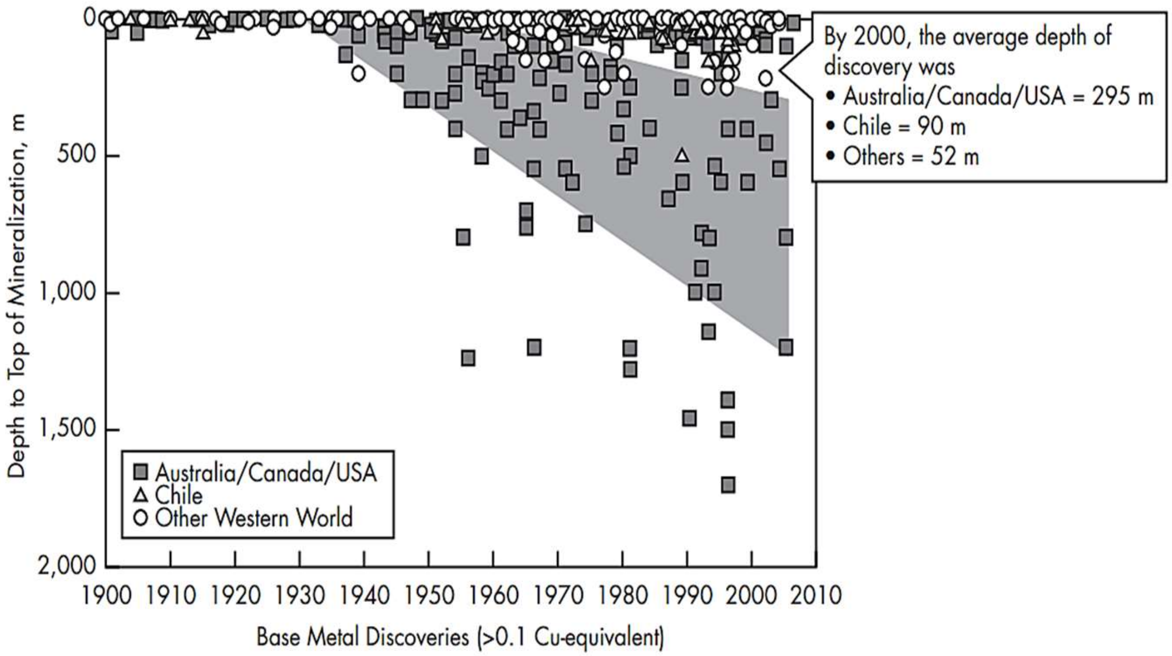
Large open-pit mines create :

- ✓ Big, permanent holes,
- ✓ Leave large piles of waste rock,
- ✓ Use large quantities of water,
- ✓ Produce large amounts of noise and dust, and
- ✓ Consume vast amounts of petroleum to power the mobile equipment.

The tolerance of society for activities such as these is declining.

Open pit mines - Challenges

- At the same time, the ore bodies that remain to be exploited are becoming deeper.
- Between 1930 and 2000, the depth of the average discovery in Australia, Canada, and the United States increased from surface outcropping to 295 m.
- This depth to the top of the ore body requires more pre stripping than any but the largest mines can support.



Remote and Autonomous Operation

The technology shift in mining that merits close monitoring is the increased operation of equipment either remotely or autonomously.

Remote operations, where the operator is not proximate to the equipment, can dramatically improve safety performance.

This method of operation started to become more common in the early 1990s.

By the mid-1990s, equipment suppliers were presenting the potential of autonomous equipment, where no operator was required.

Since then, technology changes, including a high-resolution Global Positioning System, wireless technology, remote sensing, and robust pit management software, are making autonomous operations increasingly viable.

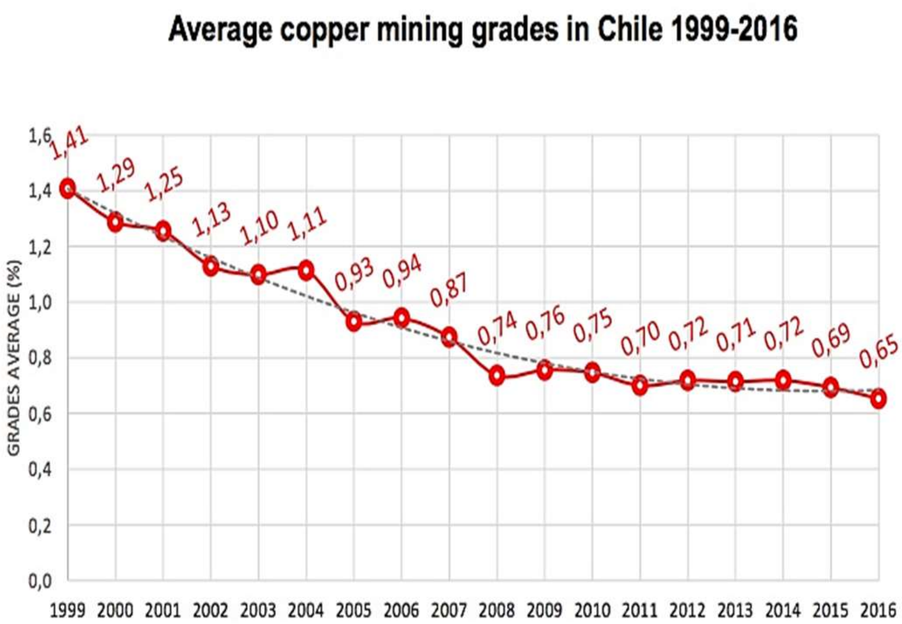
Ex. Comminution and Energy Usage

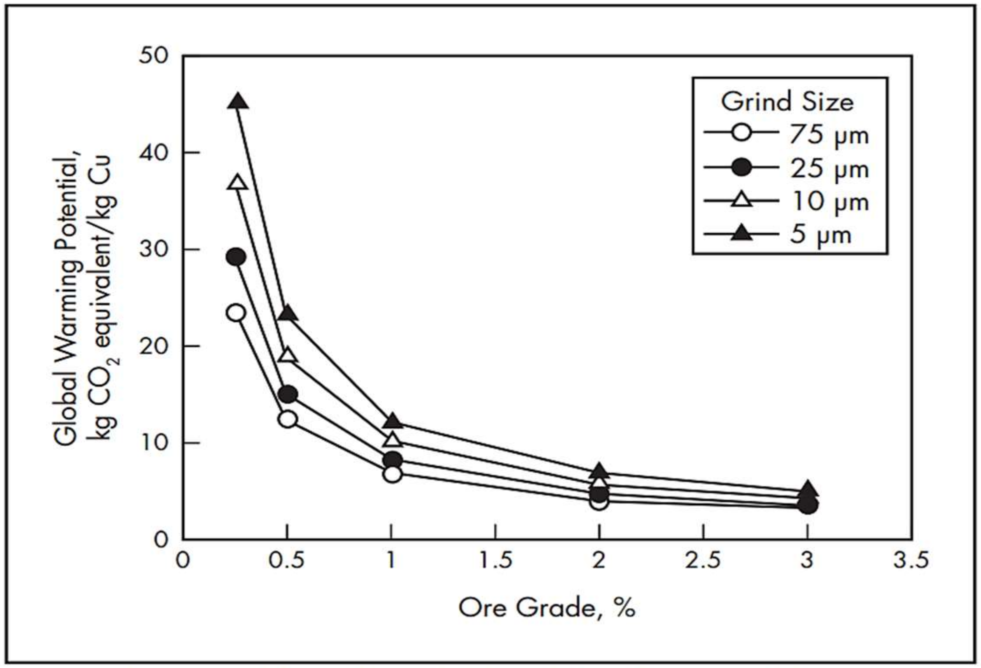
- Large amounts of energy are needed to crush and grind rock finely enough for subsequent separation of the minerals of interest.

- Comminution is the most energy-intensive activity in the current mineral concentration flow sheet, consuming around 30% to 50% of the total energy requirement.

- In the broader perspective, it has been reported that comminution activities in the United States account for as much as 1.5% of U.S. total energy consumption (Charles and Gallagher 1982).

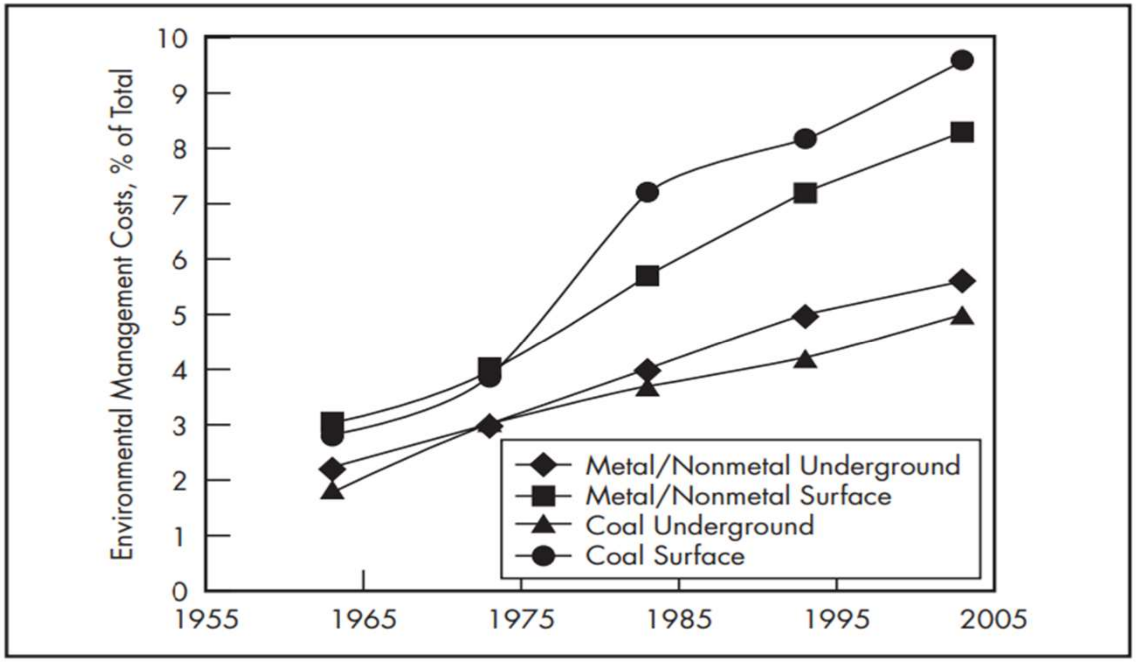
Relationship between ore grade and embodied energy





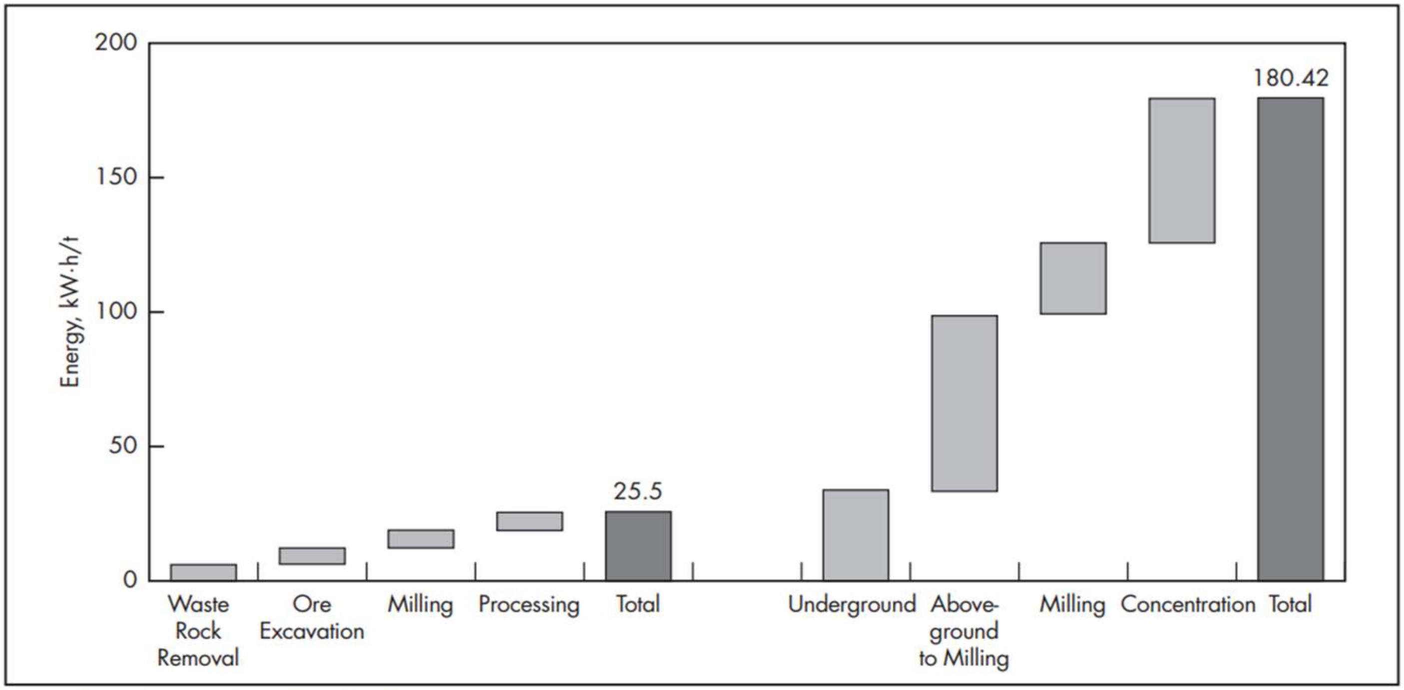
Source: Norgate and Jahanshahi 2007. © CSIRO Australia 2006.

Environmental costs as percentage of total operating costs



Source: Data from Wilson and Dyhr 2004.

Energy consumption in surface and underground mining operations

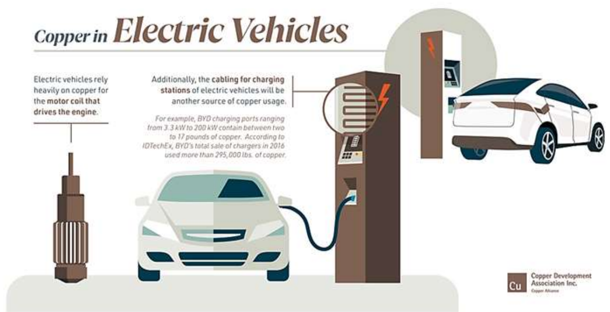


Source: Batterham and Goodes 2007.

Iran – Energy Consumption

- آب کشاورزی : **۸۵** درصد
- آب شرب : ۸ درصد
- آب صنعت : نزدیک به ۳ درصد
- ۰/۲ درصد آب کشور در صنعت فولاد
- ۵ درصد مصرف گاز در صنعت فولاد
- ۹ درصد مصرف برق در صنعت فولاد
- ۵۶ درصد گاز مصرف انرژی و صنعت
- ۲۴ درصد گاز مصرف خانگی
- ۱ درصد گاز مصرف کشاورزی
- ۳ درصد گاز مصرف حمل و نقل

Oil & Electricity Demand



- **نفت :**

سهم نفت در انرژی : ۳۹ درصد (۲۰۲۲)

سهم نفت در انرژی : ۷ درصد (۲۰۵۰)

- **برق :**

سهم برق در انرژی : ۱۹ درصد (۲۰۲۲)

سهم برق در انرژی : ۵۱ درصد (۲۰۵۰)

تولید خودروهای برقی : رشد ۳۵ درصد تا سال ۲۰۳۰

Pit Design

طراحی معادن روباز

Bingham Canyon Copper Mine (USA)

- Located south-west of Salt Lake City in Utah, Bingham Canyon is the world's largest open-pit mine and has been in production since 1906.
- At approximately 4 kilometres wide and 1.2 kilometres deep, it is responsible for the production of around 25% of the copper used in the United States.
- Owned by Rio Tinto and operated under its Kennecott Utah Copper Corp, it employs around 2,400 people.

طراحی معادن روباز

Chuquicamata Copper Mine (Chile)

- "Chuqui" is the second deepest open-pit mine in the world, at a depth in excess of 850 meters.
- It produces around 11% of the world's copper supply, which equates to 350,000 tonnes per annum.
- In August 2019, the underground extraction project was launched at Chuqui, which is estimated to extend the life of the mine by an additional 40 years.
- The mine is owned by Chilean state-owned copper mining company, Codelco.

طراحی معادن روباز

Escondida Copper Mine (Chile)

- Another giant open-pit mine located in Chile, the Escondida site comprises of two mines and is mined to a depth of 645 meters.
- Owned as part of a joint venture, including BHP (57.5%) and Rio Tinto (30%), the mine employs over 2,200 people.
- BHP is projecting an increase in production at Escondida in financial year 2020 between 1,160 and 1,230 metric tonnes (up from 1,135 in 2019).

طراحی معادن روباز

Muruntau Gold Mine (Uzbekistan)

- Discovered in 1958, Muruntau has a current mining depth of 600 metres, with plans to extend this to beyond 1,000 metres.
- It is the world’s largest open-pit gold mine and has estimated production levels of two million ounces per annum.
- Inclusive of historical production, Muruntau has gold ore reserves of an estimated 170 million ounces.

طراحی معادن روباز

Fimiston Gold Mine (Australia)

- in 2016 as Australia's largest gold producing mine by Boddington, it still remains the countries deepest open-pit mine at around 600 meters.

- Also known as the "**Super Pit**" it is located 600 kilometres east of Perth on the south-east edge of the Kalgoorlie-boulder and has a workforce of around 1,100 employees and contractors.

- It is owned by Kalgoorlie Consolidated Gold Mines, a joint venture between Newmont Mining Corporation and Barrick Gold Corporation.

طراحی معادن روباز

Grasberg

- Grasberg mine located in the Papua province of Indonesia currently ranks as the world's seventh deepest open pit operation.

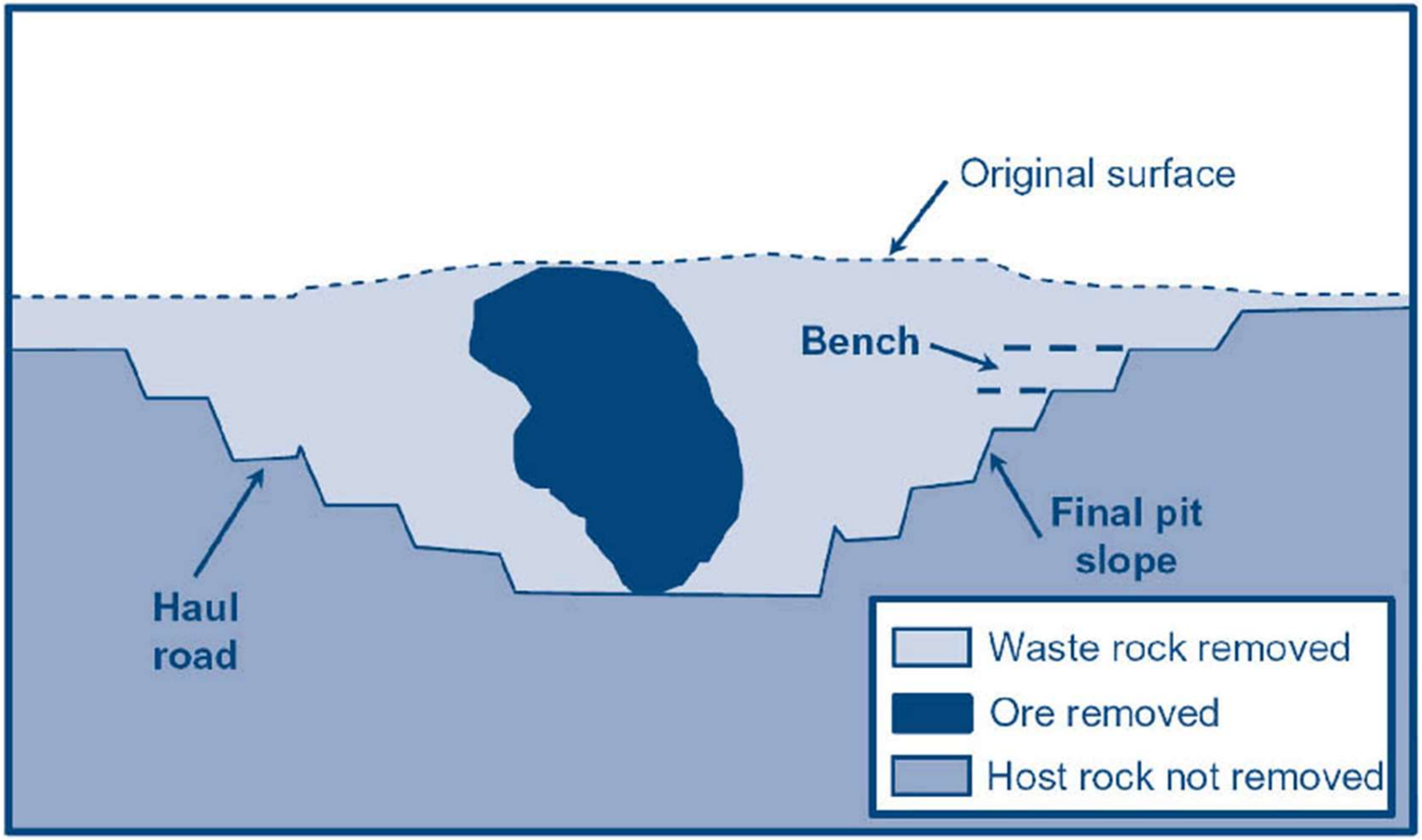
- The miming operation at Grasberg consists of both open pit and underground mines. The Grasberg open pit is more than 550m deep. Grasberg is the largest gold mine in the world.

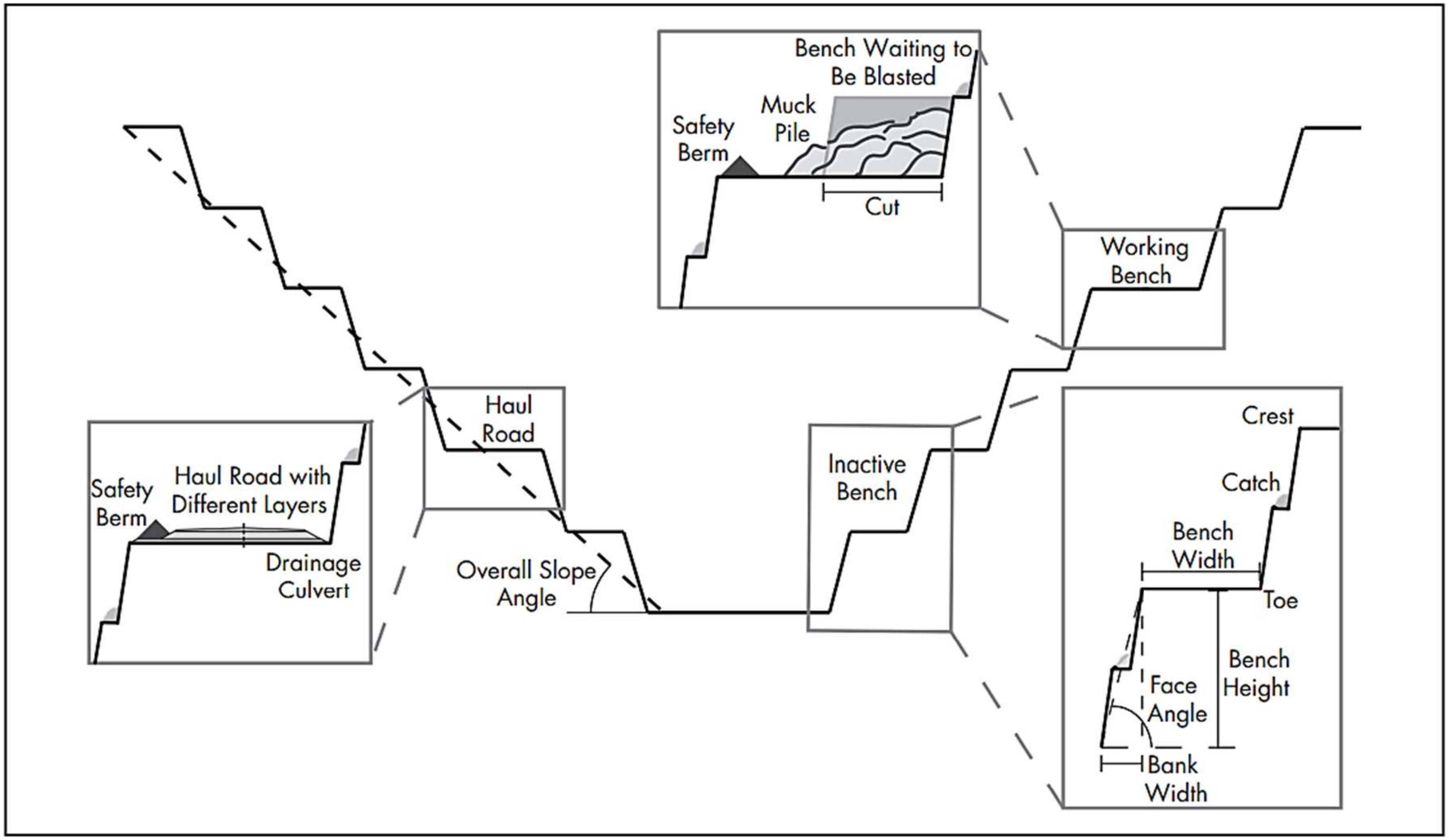
- The mine also produces copper and silver. The Grasberg open pit operation started in 1990 and expected to continue up to 2016. The mine produced 862,000 ounces of gold and 695Mlbs of copper in 2012.

طراحی معادن روباز

Betze-post

- Betze-post pit, a part of Barrick Gold's Goldstrike operation located on the Carlin Trend, Nevada, US, is the eighth deepest open pit mine in the world.
- The gold producing open-pit is about 2.2km long and 1.5km wide. The depth of the pit is well above 500m.
- Betze-Post is a truck-and-shovel operation. Large electric shovels are used for the open-pit mining.


Original surface
Bench
Final pit
slope
Haul
road
Waste rock removed
Ore removed
Host rock not removed


Bench Waiting to Be Blasted
Safety Berm
Muck Pile
Cut
Working Bench
Haul Road
Safety Berm
Haul Road with Different Layers
Drainage Culvert
Overall Slope Angle
Inactive Bench
Crest
Catch
Bench Width
Toe
Bench Height
Face Angle
Bank Width

Pit Design – Challenges

- بر اساس تحقیقاتی که والی در سال ۲۰۰۰ انجام داده است فقط ۶۰ درصد از معادن توانسته اند در سالهای تولید به ۷۰ درصد ظرفیت خود دست پیدا کنند.
- در مطالعه‌ای مشابه که توسط تاتمن در سال ۲۰۰۳ بر روی ۴۱ معدن زیرزمینی انجام شد، ۶۰ درصد ذخایر پیش بینی شده کمتر از میزان مورد انتظار بود.
- در سال ۱۹۹۱، بررسی های انجام شده توسط هارکوآلی نشان می دهد که۵۰ پروژه معدنی در آمریکای شمالی، فقط ۱۰ درصد توانسته‌اند که با ۳۸ درصد شکست در پیش بینی های سالانه خود به اهداف تجاری دست یابند.
- وارد و همکاران در سال ۱۹۹۹ مطالعاتی بر روی ۹ معدن زیرزمینی فلزات پایه در استرالیا انجام دادند که نتایج این مطالعه حاکی از آن است که تنها ۵۰ درصد این پروژه ها در سه سال اولیه به ۵۰ درصد ظرفیت خود رسیده‌اند و ۲۵ درصد پروژه‌ها هرگز به ظرفیت طراحی نرسیدند.
- بررسی‌های انجام شده توسط مک کارتی در سال ۲۰۱۶ نشان می دهد که ۳۲ درصد مشکلات عملیاتی در معادن ناشی از عدم برنامه ریزی تولید بهینه و ۱۷ درصد مشکلات ناشی از عدم قطعیت های زمین شناسی در مدل بلوکی است.

Mining Risk

- **Geologic Component** (location of mineral deposit/the properties of these deposit/Whether they can be mined safely/Whether minerals of economic value can be feasibly extracted.

➢ **Financial Risks :**

- Capital cost of developing the project (initial CC and maintaining production to the end of life(sustaining capital)
- Cost of operations (mining/processing/overhead/etc.) including change in cost of supplies and labor over time.
- Closure and rehabilitation costs, including differences between provisions and actual end-of-life costs.
- The price that will be received for the product sold (gold bullion, copper concentrate)
- Inflation and changes in currency exchange rates.
- Ability to fund a capital – intensive project.

Mining Risk

Technical and Operational Risk :

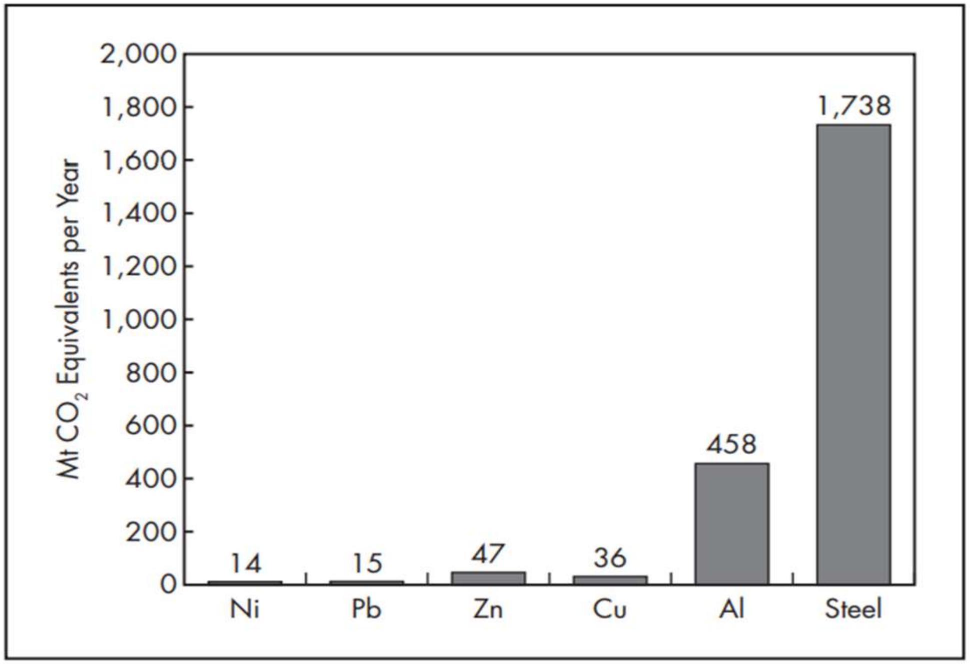
- Reliability of the deposit’s geological model
- Reliability of the metallurgical assumption made in developing the process
- Operating performance of equipment, processes, and facilities(actual Vs. Planned)
- Unexpected operational catastrophes.
- Failure of information technology systems
- Failure or delays in supply lines
- Access to and reliability of power supply, water and consumables.

Mining Risk

Environmental, social and governmental Risks :

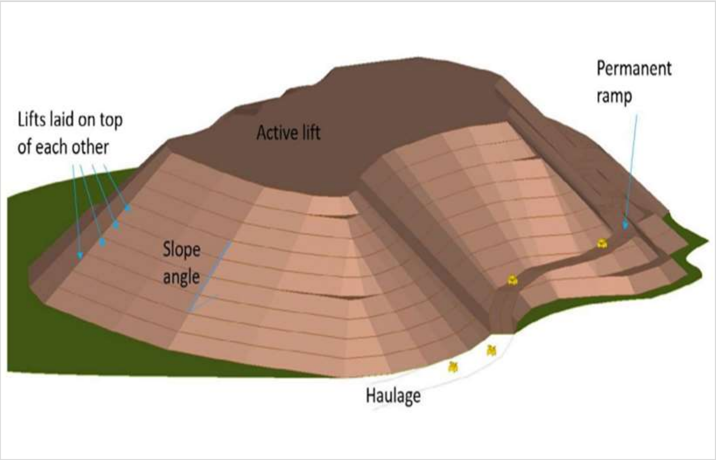
- Security of tenure to land , mineral rights, operating permits and so on.
- Environmental impact and costs of mitigation.
- Safety, health and community impacts.
- Community relations and expectations, including expectation that costs and benefits of operations are fairly distributed.
- Actions from nongovernmental organization
- labor relations
- Timing of approval for necessary governmental permits
- Changes in domestic and foreign laws and regulations
- Changes in tax laws and royalty agreements
- Climate Change, which may impact operations and markets

Global greenhouse gas emissions for selected metals

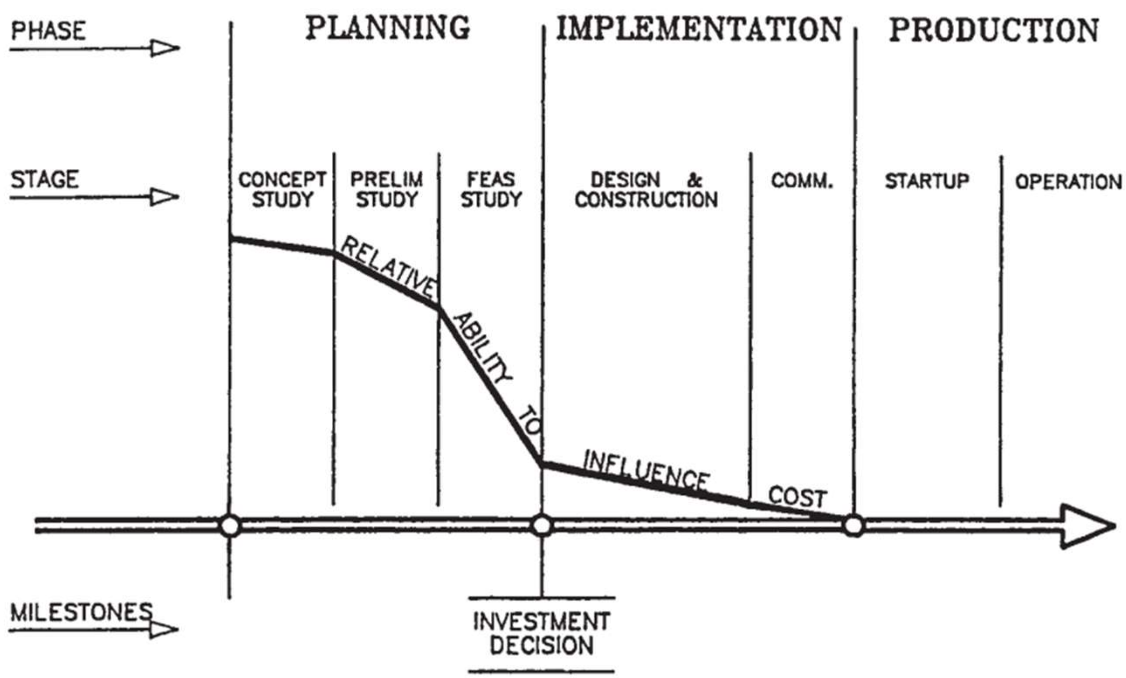


Source: Norgate and Jahanshahi 2006. © CSIRO Australia 2006.

Mining operations



Stages/Phase of Opening



Different types of studies

Type	Purpose	Scope
Concept study	Seek to identify a concept for development or expansion that has a reasonable prospect of creating value	• No constraints on capital or on major changes to the operation • Short- and medium-term (less than 3 years) optimization decisions are not considered • Long-term price forecasts are considered
Prefeasibility study	Examine a wide range of strategic alternatives for development or expansion, and select the single plan that would create the greatest value at an acceptable risk	• Major operational changes are subject to permitting and capital approvals • Focus on value-maximizing optimization decisions • Long- and short-term price forecasts are considered
Feasibility study	Optimize the single plan (output from prefeasibility study) to create an actionable plan that meets company requirements for investment approval	

Conceptual study

The transformation of a project idea into a broad investment proposition.

Capital and operating costs are usually approximate ratio estimates using historical data.

Highlight the principal investment aspects of a possible mining proposition.

The preparation of such a study is normally the work of one or two engineers.

The findings are reported as a preliminary valuation.

Preliminary or pre-feasibility study

An intermediate-level exercise, normally not suitable for an investment decision.

An intermediate stage between a relatively inexpensive conceptual study and a relatively expensive feasibility study.

Some are done by a two or three man team who have access to consultants in various fields others may be multi-group efforts.

Feasibility study

The feasibility study provides a definitive technical, environmental and commercial base for an investment decision.

It uses iterative processes to optimize all critical elements of the project.

It identifies the production capacity, technology, investment and production costs, sales revenues, and return on investment.

PLANNING COSTS

As a percentage of the capital cost of the project:

Conceptual study: 0.1 to 0.3 percent

Preliminary study: 0.2 to 0.8 percent

Feasibility study: 0.5 to 1.5 percent

ACCURACY OF ESTIMATES

Normally acceptable ranges of accuracy are considered to be (Lee, 1984):

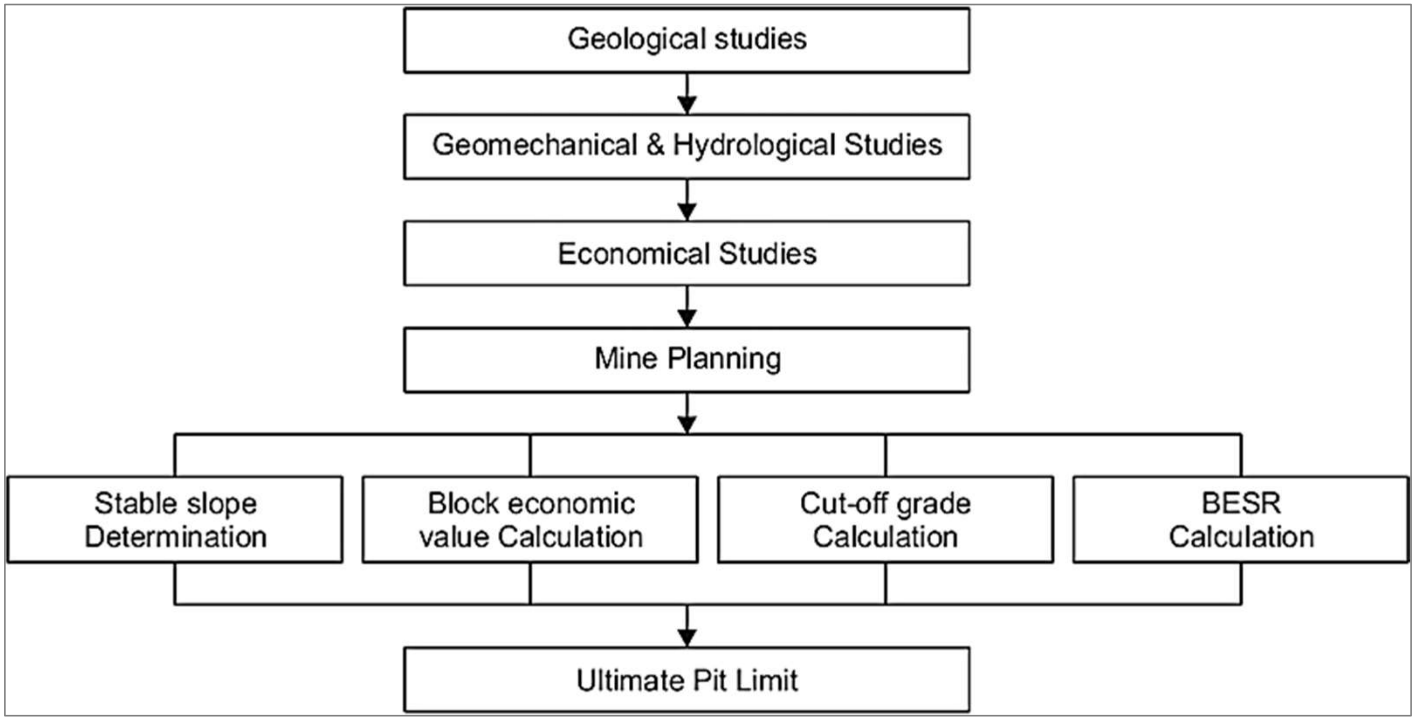
Conceptual study: ±30 percent

Preliminary study: ±20 percent

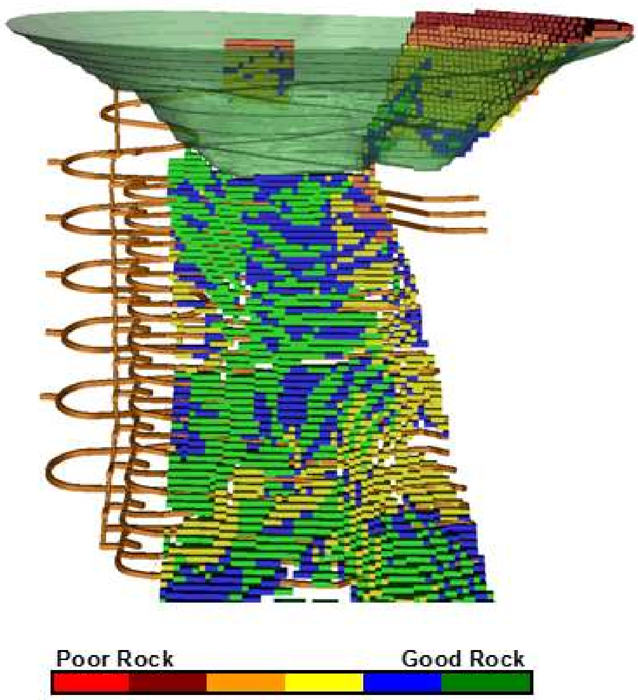
Feasibility study: ±10 percent

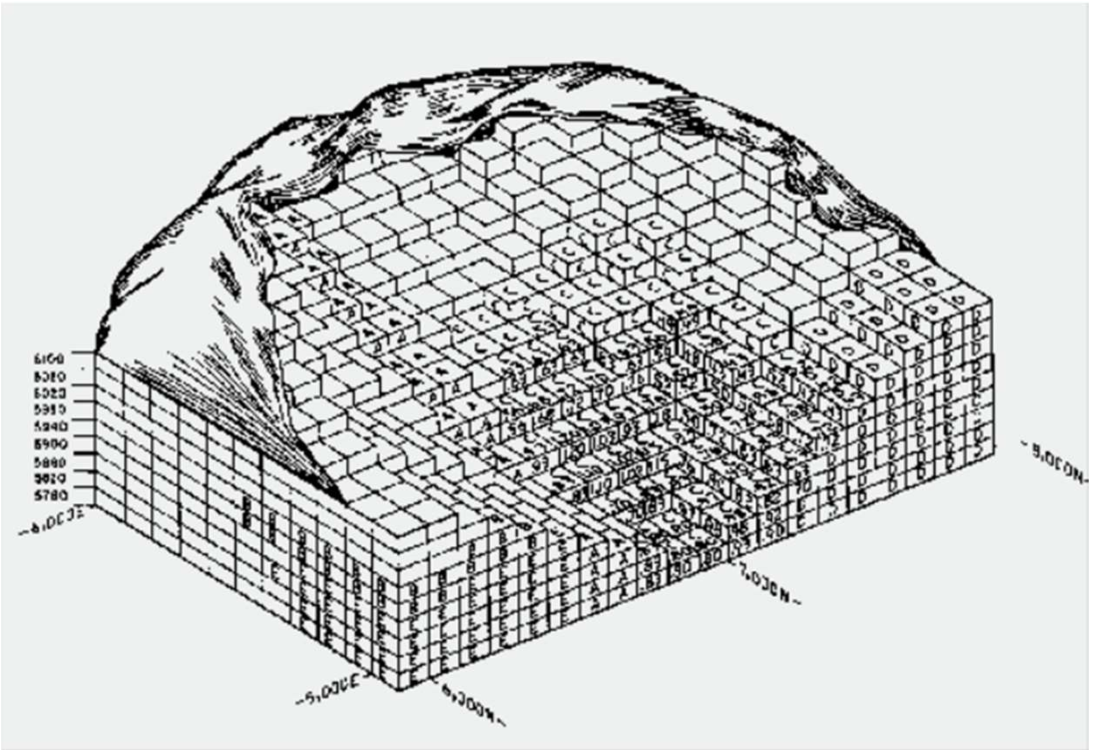
Open pit mine planning

Open Pit Mine Planning

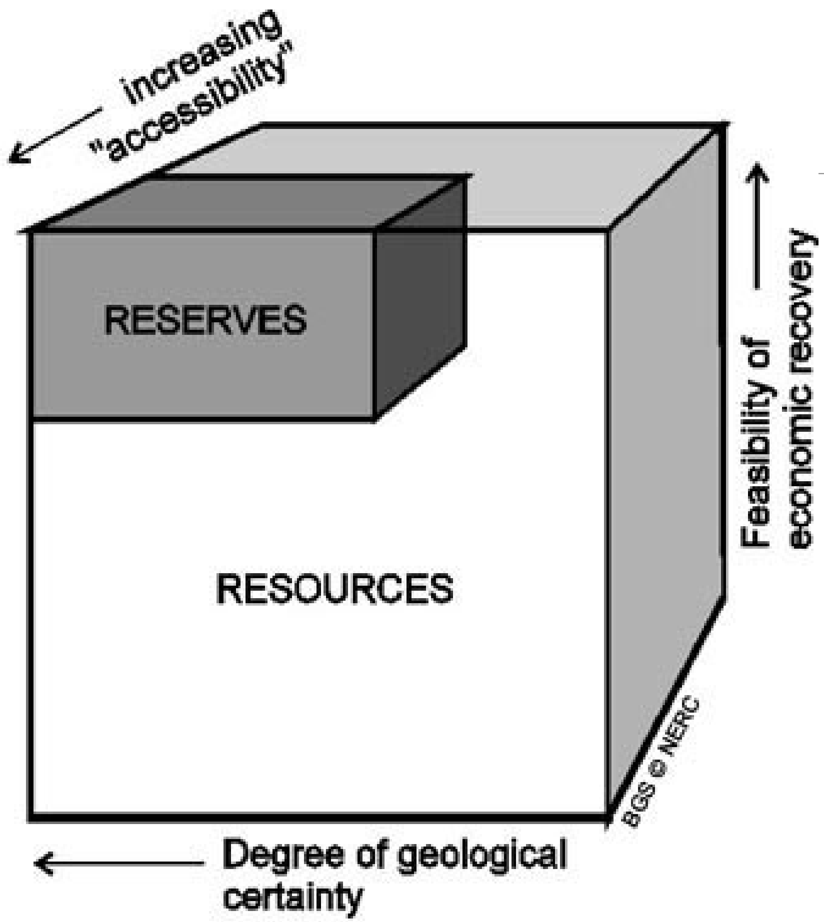


Block Model – Exposure Ore

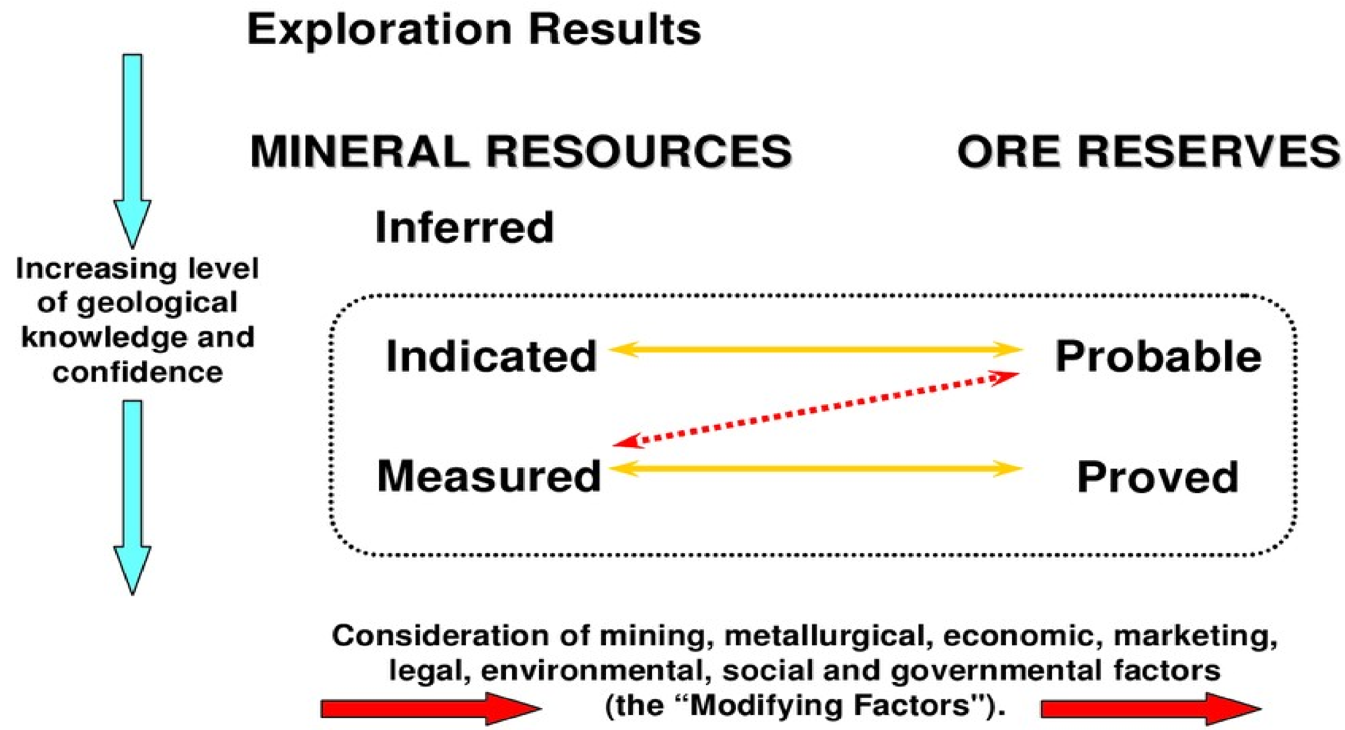




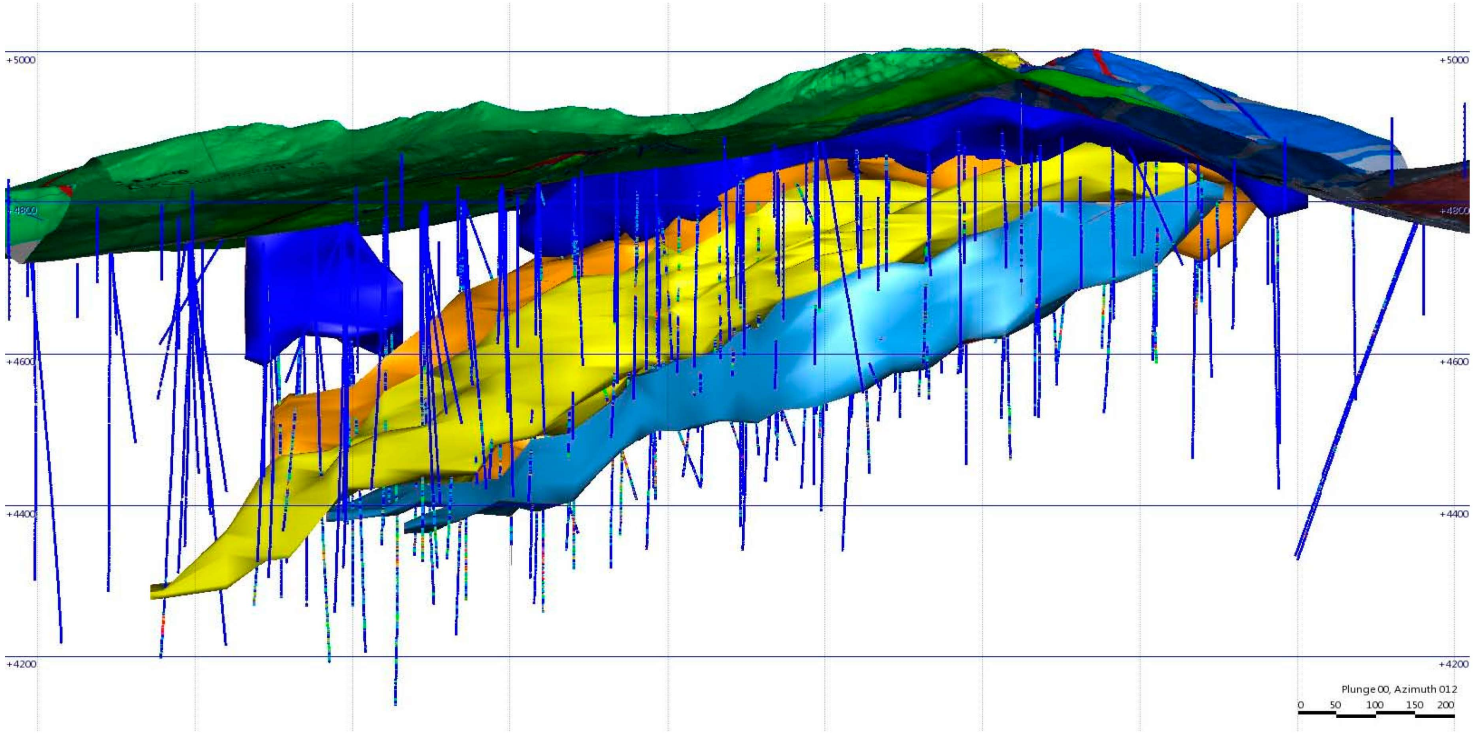
Resource/Reserve



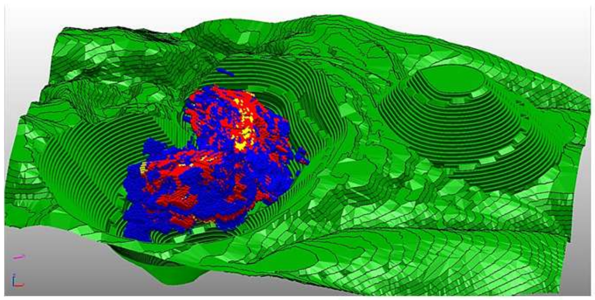
Mineral Resource/Ore Reserve

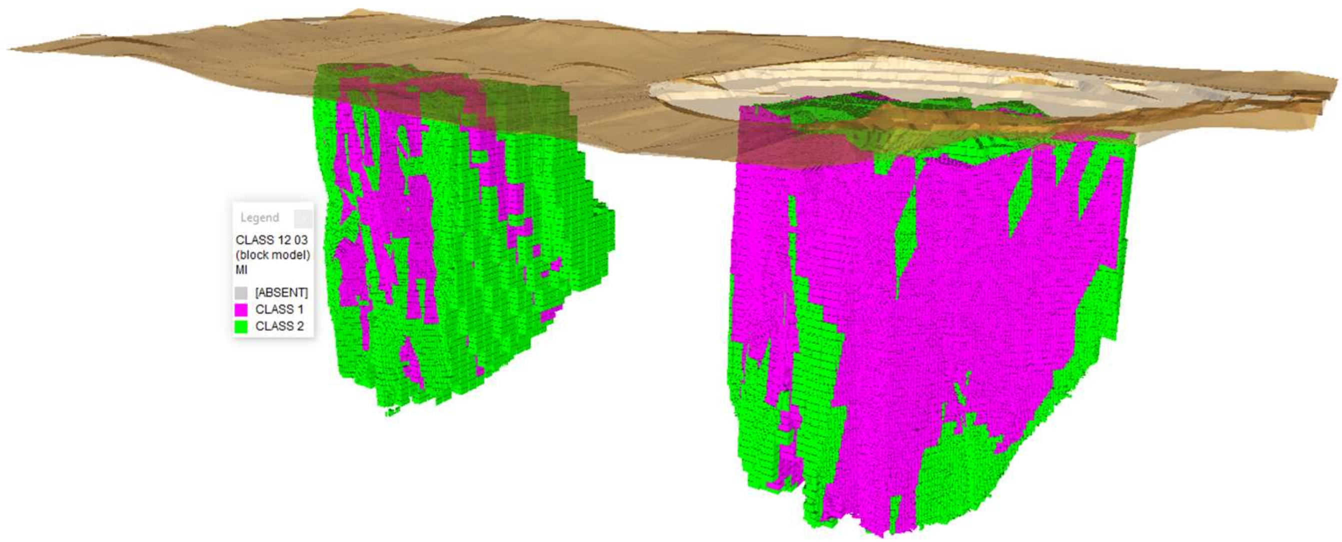


Resource Model

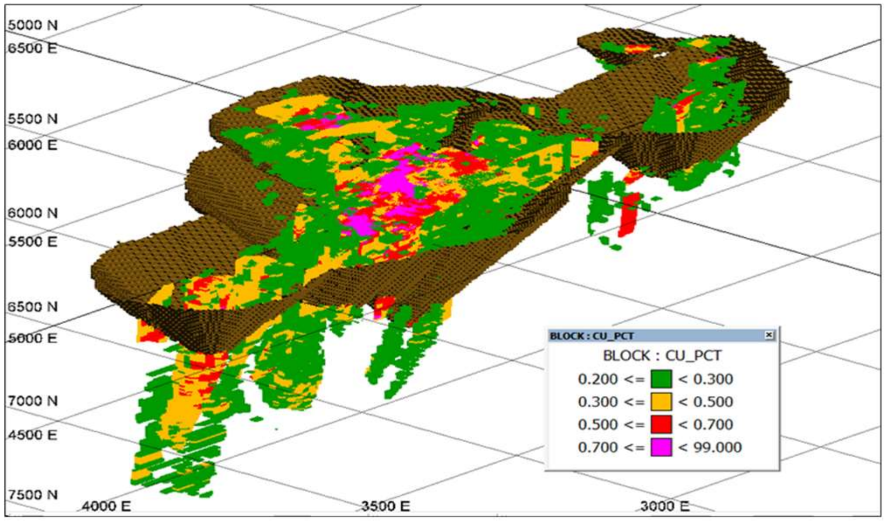


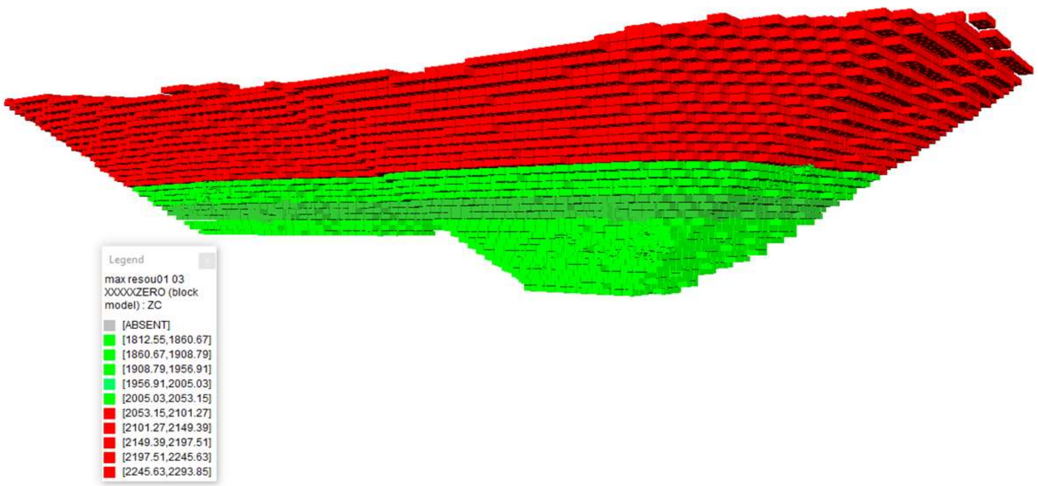
Geological Model





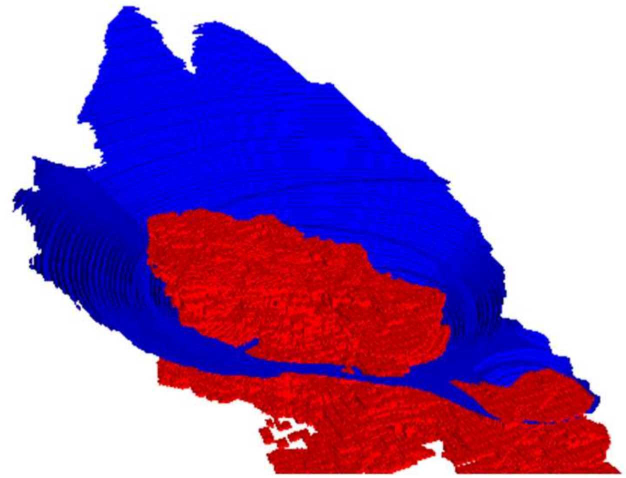
Economic Block Model





Mine Planning Pillars

- Ultimate Pit Limits
- Scheduling
- Mining
- Pushback
- Cut off grade Strategy



What is an Ultimate Pit Limit?

The final pit limits define what is economically mineable from a given deposit.

They identify which blocks should be mined and which ones should be left in the ground.

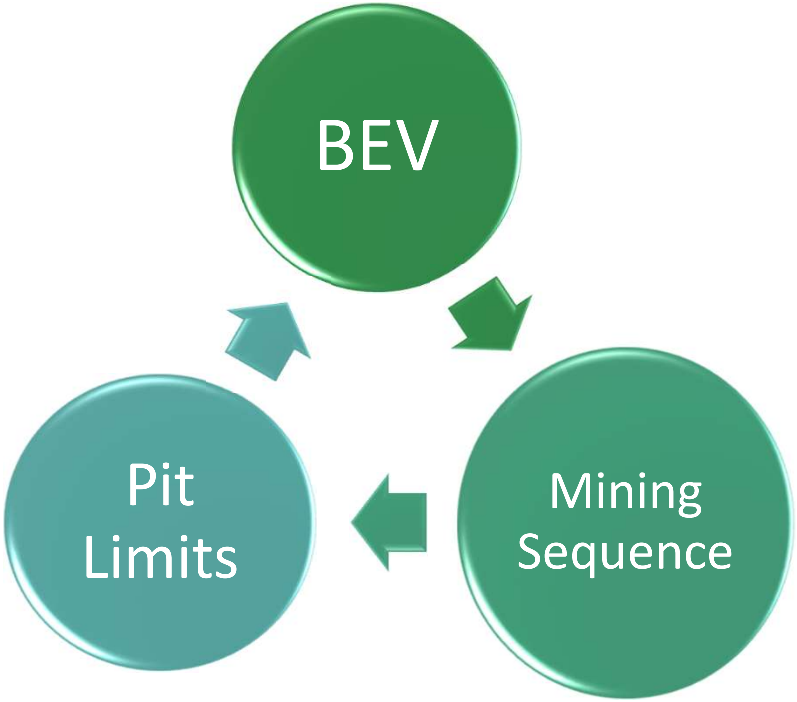
In an effort to identify the blocks to be mined, an economic block model is created from the geologic grade model.

محدوده‌ای است که از بین محدوده‌های ممکن، بیشترین سود یا ارزش را داشته باشد.

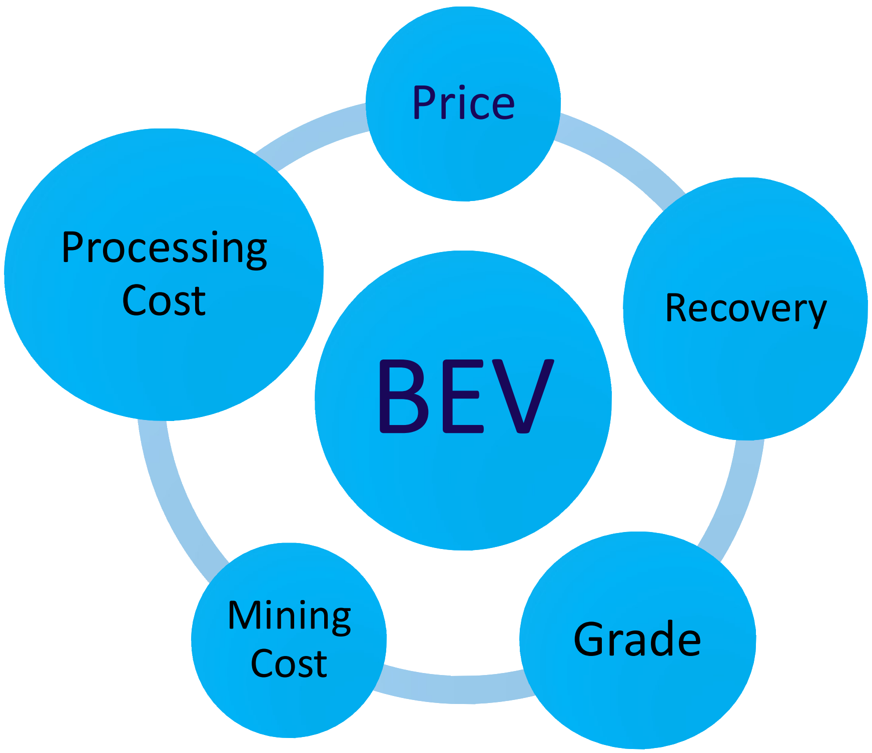
در حقیقت، محدوده‌ای است که اگر همین امروز باطله و کانسنگ داخل آن استخراج شود بیشترین ارزش را داشته باشد.

UPL Problem

- BEV (Block Economic Value)
- Mining Sequence
- Pit Limits



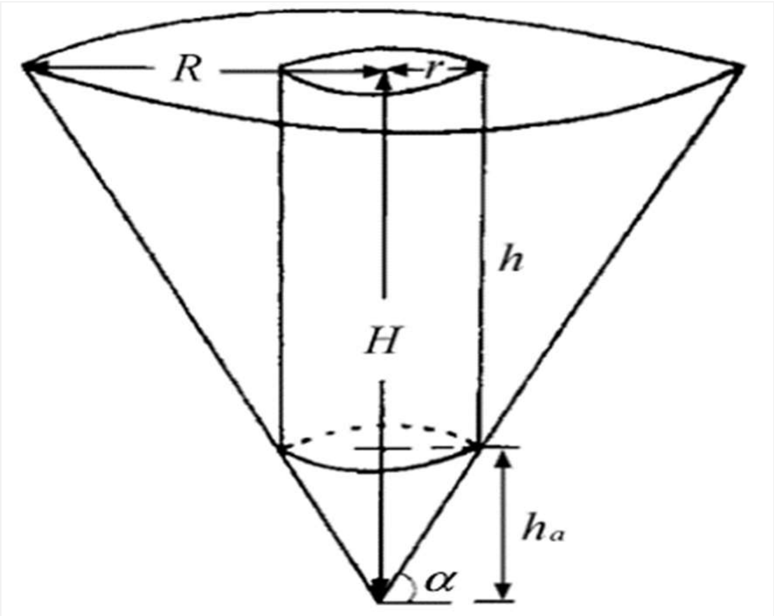
Block Economic Value

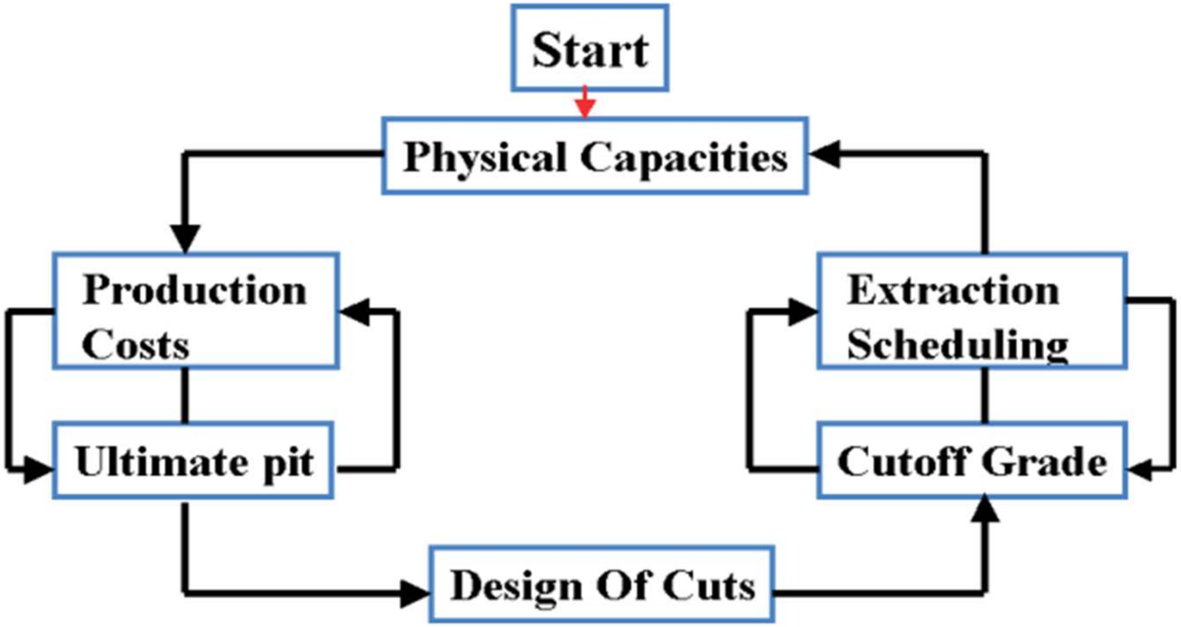


ارزش اقتصادی بلوک شامل :

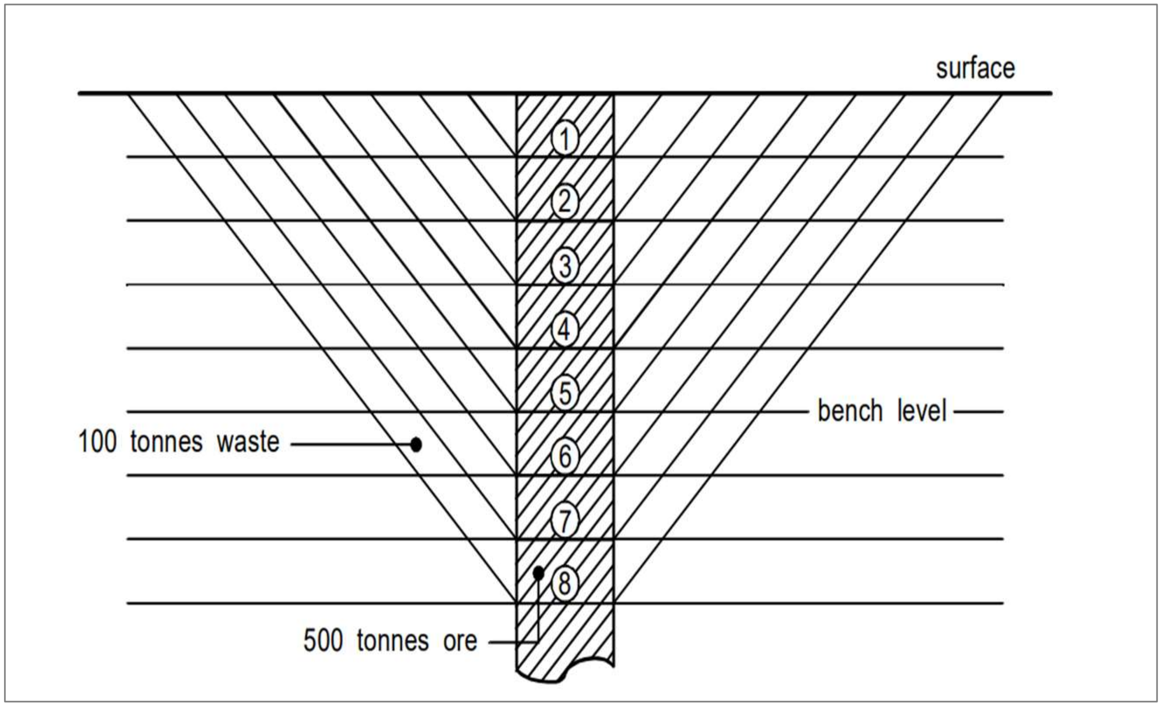
- عیار ماده معدنی
- قیمت محصول نهایی
- بازیابی
- هزینه های استخراج
- هزینه فرآوری
- هزینه های بالاسری
- وزن بلوک

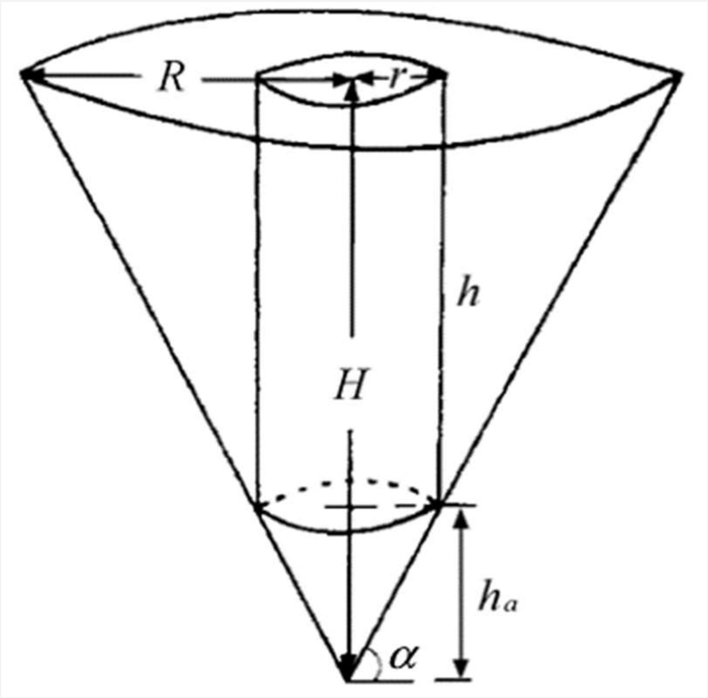
Open pit Mine planning





Ultimate pit limits (upl)



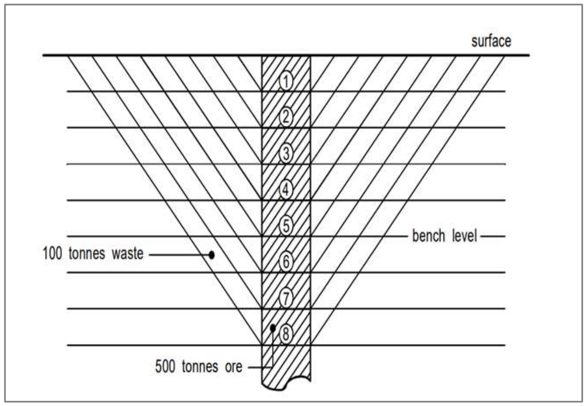


Upl definition

Tonnages for possible outlines

Pit	1	2	3	4	5	6	7	8
Ore	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Waste	100	400	900	1,600	2,500	3,600	4,900	6,400
Total	600	1,400	2,400	3,600	5,000	6,600	8,400	10,400

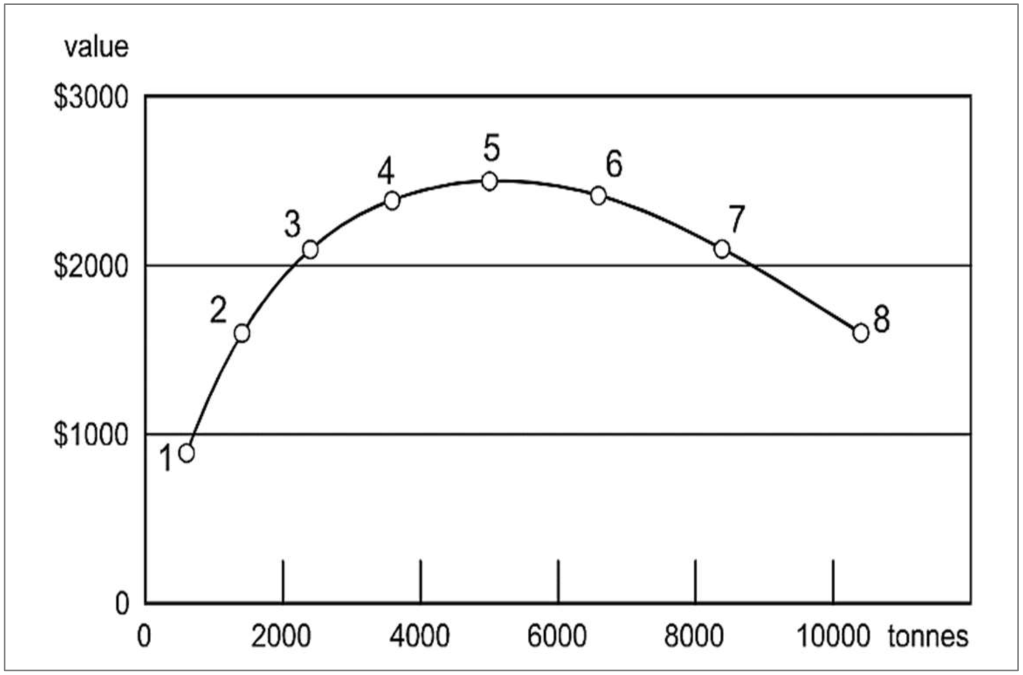
Note that, although the ore tonnage increases linearly with pit number, the waste tonnage increases as the square of the pit number.
If we assume that ore is worth $2.00 per tonne and that waste costs $1.00 per tonne to mine and remove, then the following table shows the value of each pit.

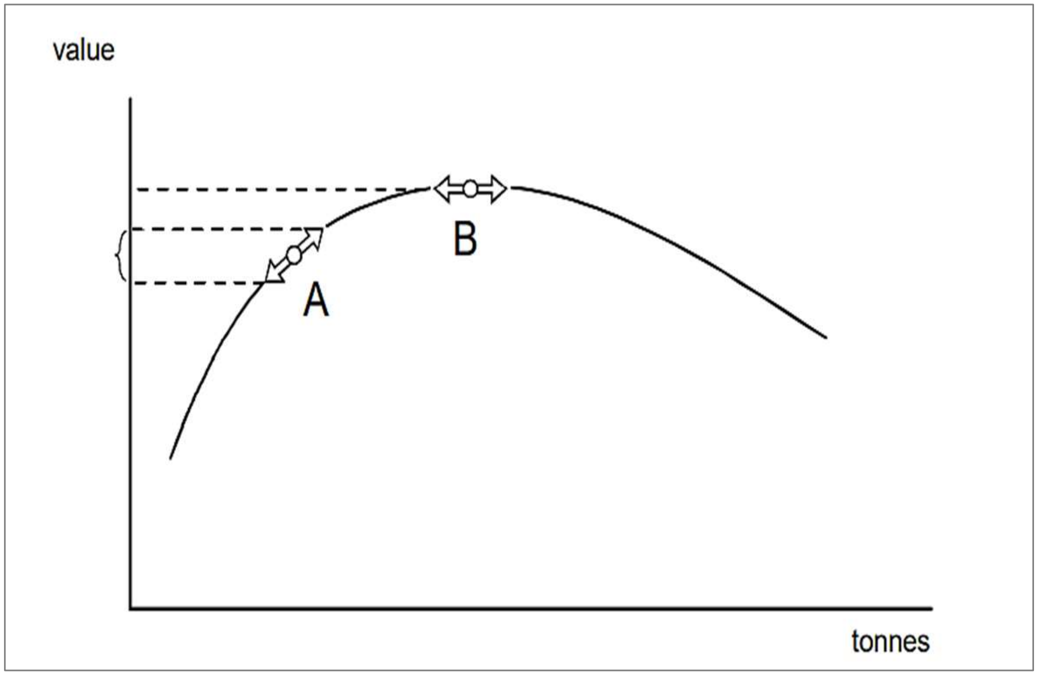


Pit values for ore at $2.00/T and waste at -$1.00/T

Pit	1	2	3	4	5	6	7	8
Value	900	1,600	2,100	2,400	**2,500**	2,400	2,100	1,600

Optimal Pit Selection



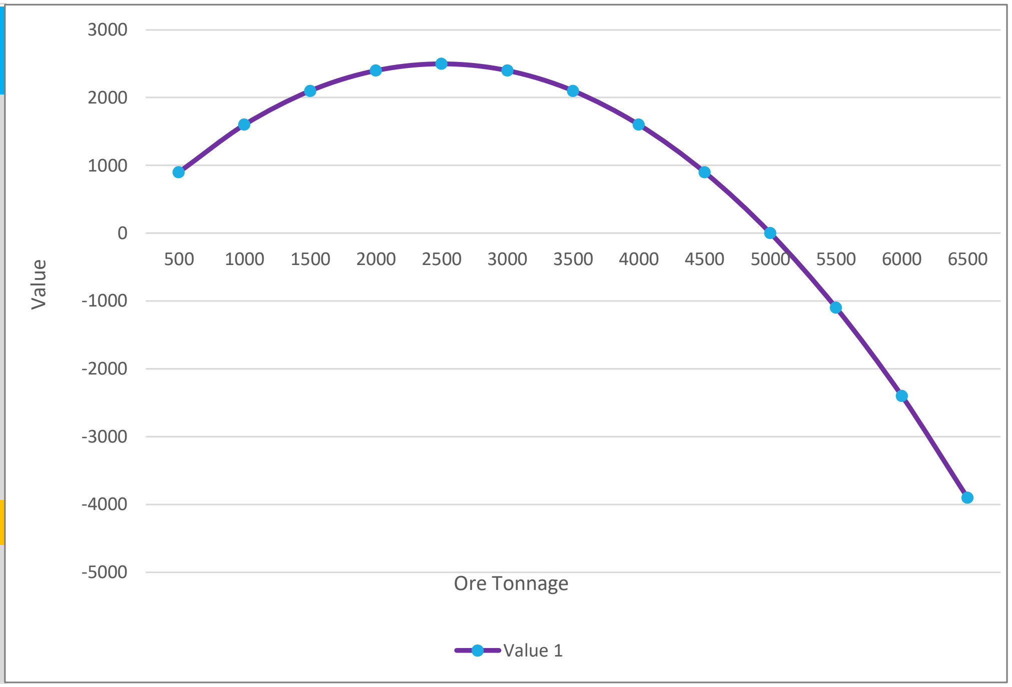


Upl & opl

Pit	Ore Tonnage	Waste Tonnage	Stripping Ratio	Ore Worth / tonne	Waste Cost /tonne	Value 1	Value 2	Value 3	Value 4
1	500	100	0.2	2	1	900	400	1900	2900
2	1000	400	0.4	2	1	1600	600	3600	5600
3	1500	900	0.6	2	1	2100	**600**	5100	8100
4	2000	1600	0.8	2	1	2400	400	6400	10400
5	2500	2500	1	2	1	**2500**	0	7500	12500
6	3000	3600	1.2	2	1	2400	-600	8400	14400
7	3500	4900	1.4	2	1	2100	-1400	9100	16100
8	4000	6400	1.6	2	1	1600	-2400	9600	17600
9	4500	8100	1.8	2	1	900	-3600	9900	18900
10	5000	10000	2	2	1	0	-5000	10000	20000

UPL & OPL

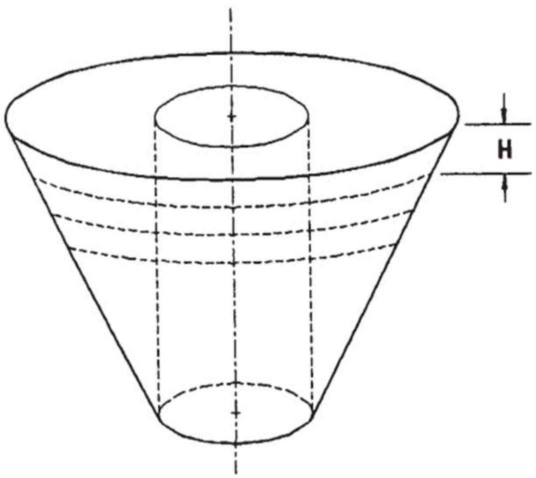
Pit	Ore Tonnage	Waste Tonnage	Stripping Ratio	Ore Worth / tonne	Waste Cost /tonne	Value 1
1	500	100	0.2	2	1	900
2	1000	400	0.4	2	1	1600
3	1500	900	0.6	2	1	2100
4	2000	1600	0.8	2	1	2400
5	2500	2500	1	2	1	2500
6	3000	3600	1.2	2	1	2400
7	3500	4900	1.4	2	1	2100
8	4000	6400	1.6	2	1	1600
9	4500	8100	1.8	2	1	900
10	5000	10000	2	2	1	0
11	5500	12100	2.2	2	1	-1100
12	6000	14400	2.4	2	1	-2400
13	6500	16900	2.6	2	1	-3900

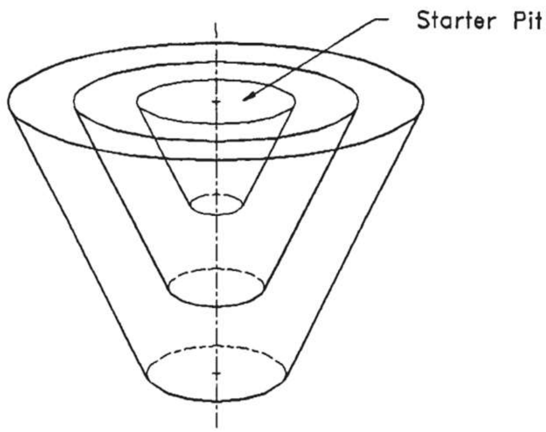


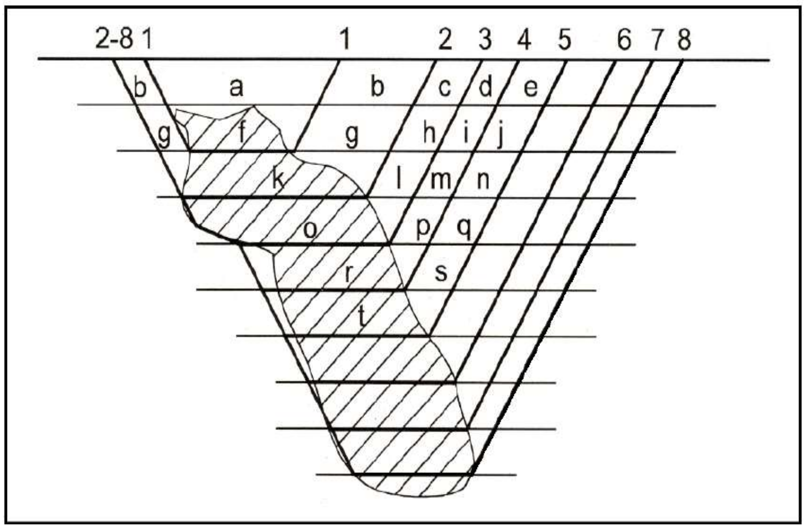
Pushbacks

Once the Ultimate Pit OES has been established, the pushback generation can commence.

چرا روش پوش بک انتخاب و پوش بک طراحی می‌شود؟

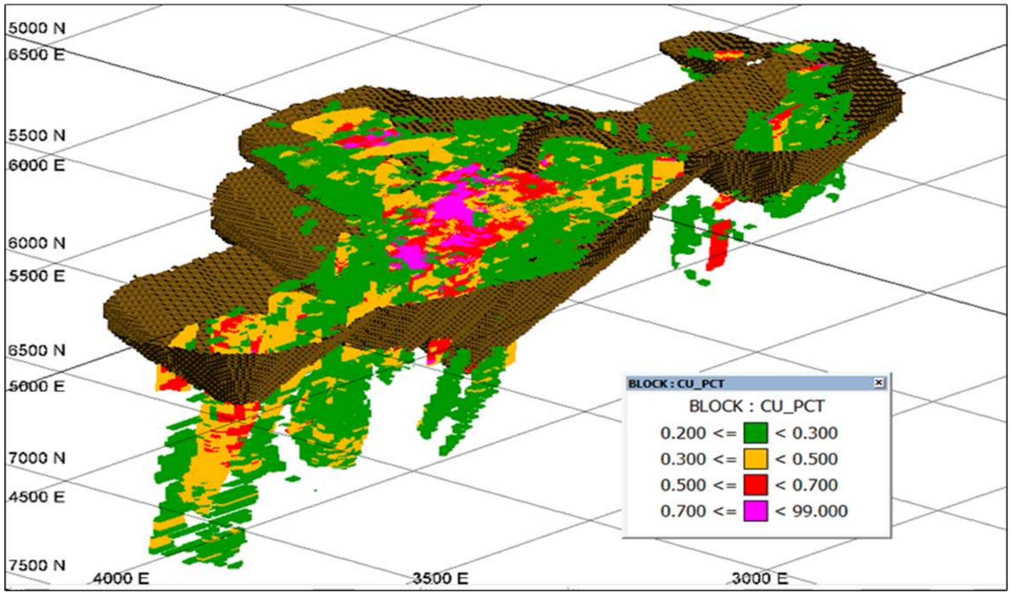






Economic Block Model

$$BEV_{ore} = T_{ore}([(p - s) \times g \times R_{total}] - [C_M + C_P + C_o])$$



What is a Mine Planning?

The open pit design and scheduling problem is a large-scale optimisation problem that has attracted considerable attention over the last 40 years.

The current practice of planning a hard rock open pit mine begins with a ***geologic block model*** and involves determination of:

1. whether a given block in the model should be mined or not;
2. if it is to be mined, when it should be mined; and
3. once it is mined, how it should then be processed.

Targets in Mine Planning

- Which Block?
- When?
- Where ?

$$MaxZ = \sum_{t=1}^{L}\sum_{i=1}^{n}\frac{C_i}{(1+d)^t}\times x_{i,t}$$

s.t.

$$\sum_{i=1}^{n} a_i x_{i,t} \le T_t \quad \forall t \in \{1,2,\ldots.L\}$$

$$x_{i,t} \le x_{\acute{\imath},t} \;\; \forall i \in \{1,2,\ldots.,n\}, \imath \in Prec_{\imath}, t\,\acute{\in}\,\{1,2,\ldots,L\}$$

$$x_{i,t} = 0{,}1 \;\forall i \in \{1,2,\ldots,n\}, t \in \{1,2,\ldots,L\}$$

Mine Planning Horizon

- **برنامه ریزی تولید:** برنامه ریزی برای استخراج و تعیین نحوه استخراج بلوک‌ها در محدوده نهایی معدن است. بر اساس افق زمانی، تقسیم بندی‌های مختلفی ارائه شده است که در اینجا به سه بخش تقسیم شده است.

  براساس افق زمانی سه نوع برنامه ریزی اصلی در معادن روباز بزرگ وجود دارد.

- **برنامه ریزی تولید بلند مدت (Long term):** هدف تهیه پلان‌های استخراج در کل محدوده بهینه است. مهمترین هدف در برنامه ریزی تولید بلند مدت، بیشینه سازی ارزش خالص فعلی است. دوره این برنامه‌ریزی ۳۰ ساله است. بهتر است این برنامه هر ۵ سال بازبینی شود. این برنامه‌ریزی پایه سایر برنامه‌ریزی‌هاست.
- **برنامه ریزی تولید میان مدت (Medium term):** پلی است بین برنامه ریزی تولید بلندمدت و کوتاه مدت. دوره این برنامه‌ریزی تا ۱۰ سال است. هدف از این برنامه‌ریزی، پیش‌بینی‌های آینده لازم است.
- **برنامه ریزی تولید کوتاه مدت (Short term):** زمانبندی تهیه پلان‌های کوتاه مدت تا یکسال است. هدف تامین نیاز کارخانه فرآوری است (عیار و تناژ). نتیجه برنامه‌ریزی‌های بلندمدت و کوتاه مدت در این برنامه نشان داده می‌شود. در ادامه این برنامه، برنامه روزانه است که چگونگی تامین کانسنگ مورد نیاز کارخانه از افق‌ها یا پله‌های مختلف مشخص می‌شود.

Long term Scheduling

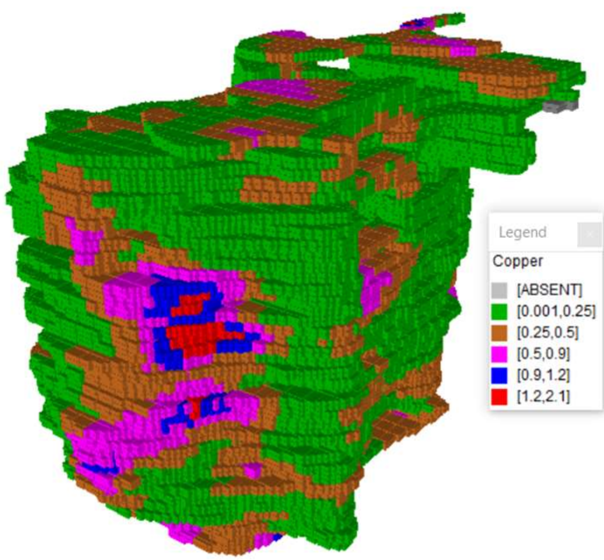
- Taylor Formula

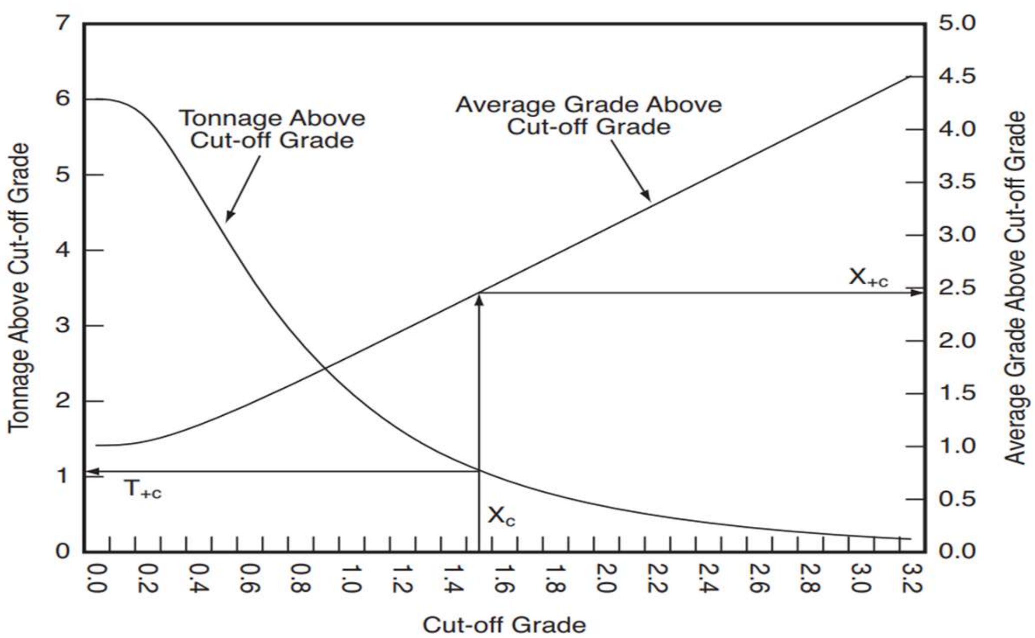
Mine Life: 0.2 * (Mineable ore reserve) ^0.25

Annual ore production rate: 5* (Mineable ore reserve) ^0.75

Year	NPV	sulfide	oxide	total rock	Plant grade
	$	tonnes	tonnes		
1	4,161,209	3,001,201	371,802	11,378,683	0.17
2	32,154,704	7,000,258	1,371,812	26,158,889	0.21
3	61,681,868	12,001,765	3,461,065	43,042,632	0.21
4	87,435,317	17,000,751	4,827,648	56,669,978	0.22
5	113,530,134	22,001,309	6,082,624	69,093,361	0.22
6	132,117,304	27,000,957	6,792,718	81,143,933	0.22
7	147,091,341	32,000,305	7,486,150	94,981,630	0.23
8	161,672,032	37,000,643	8,168,172	104,771,965	0.23
9	174,478,134	42,000,863	8,991,487	114,471,767	0.23
10	185,976,035	47,000,807	9,907,530	122,366,116	0.23
11	195,938,850	52,000,869	11,072,999	131,497,374	0.23
12	203,738,574	57,000,780	11,846,439	138,701,388	0.23
13	209,140,654	62,000,341	12,975,424	147,594,181	0.23
14	214,756,705	67,001,661	14,048,514	155,177,521	0.22
15	220,019,270	72,001,221	15,524,204	162,927,361	0.22
16	225,133,224	77,001,821	18,252,364	171,717,421	0.22
17	228,920,755	82,002,361	23,086,244	183,611,614	0.22
18	233,335,890	87,000,261	34,509,854	201,959,294	0.22
19	235,078,656	90,548,881	42,710,404	215,200,104	0.22

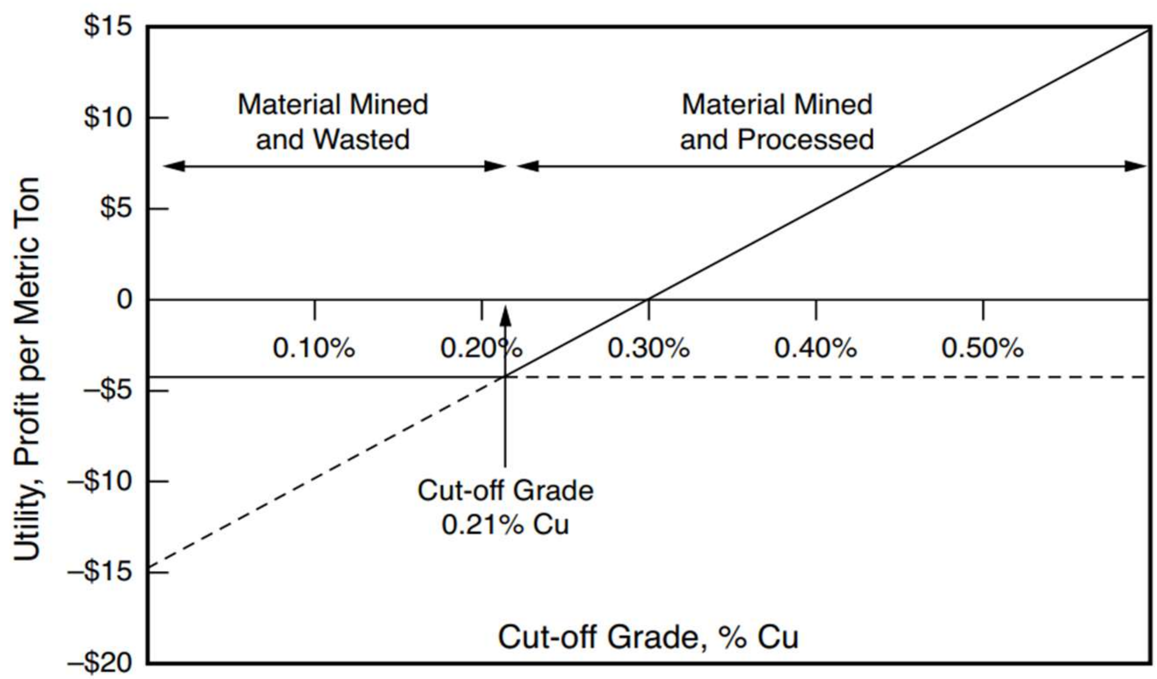
Cut off grade; tonnage grade curve





Internal or mill cut off grade

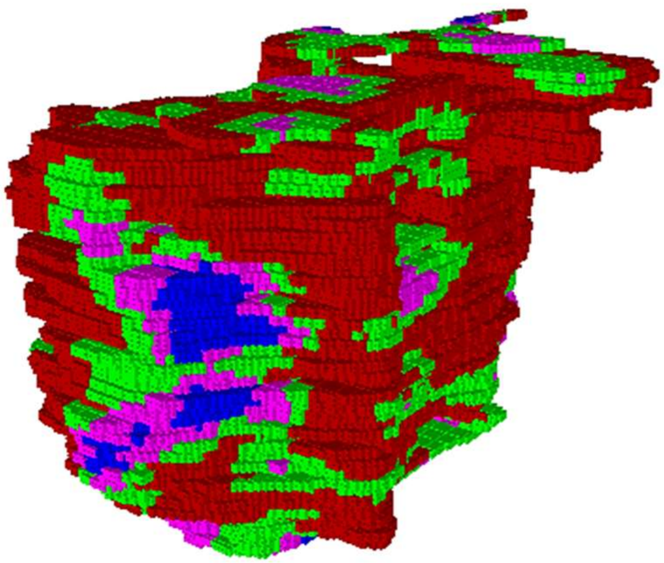
$$g_{c,mill} = \frac{C_P}{10(P - C_S)y}$$



Geology and Economic parameters

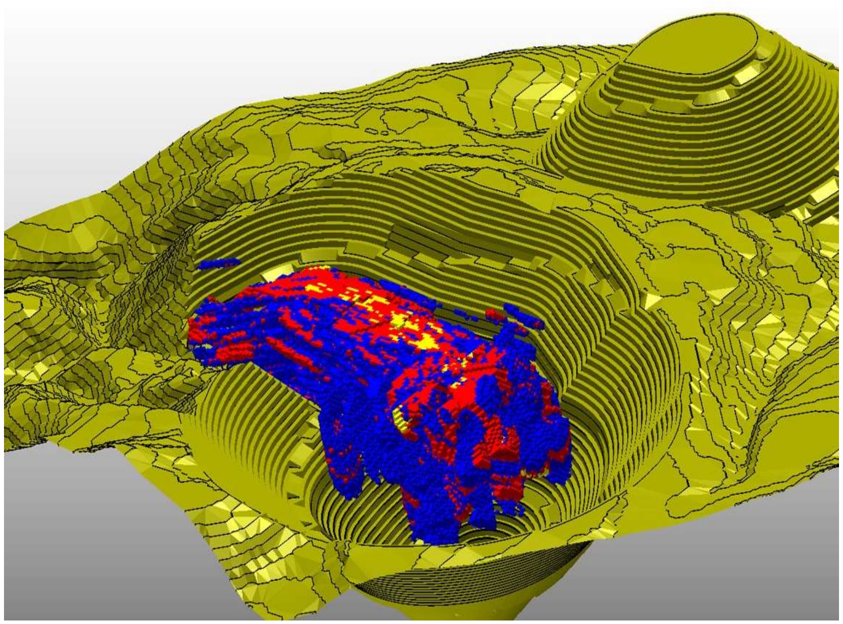
پارامترهای زمین شناسی و اقتصادی

- **پارامترهای زمین شناسی :**
  - عیار و توزیع آن در کانسار (کیفیت کانسنگ)
  - ذخیره (کمیت کانسنگ)
  - شکل کانسار و توپوگرافی
  - هیدرولوژی کانسنگ
  - درصد بازیابی کانسنگ
  - عیار عناصر آلاینده و همراه
  - کانی شناسی و خصوصیات آن در فرآوری کانسنگ



پارامترهای زمین شناسی و اقتصادی

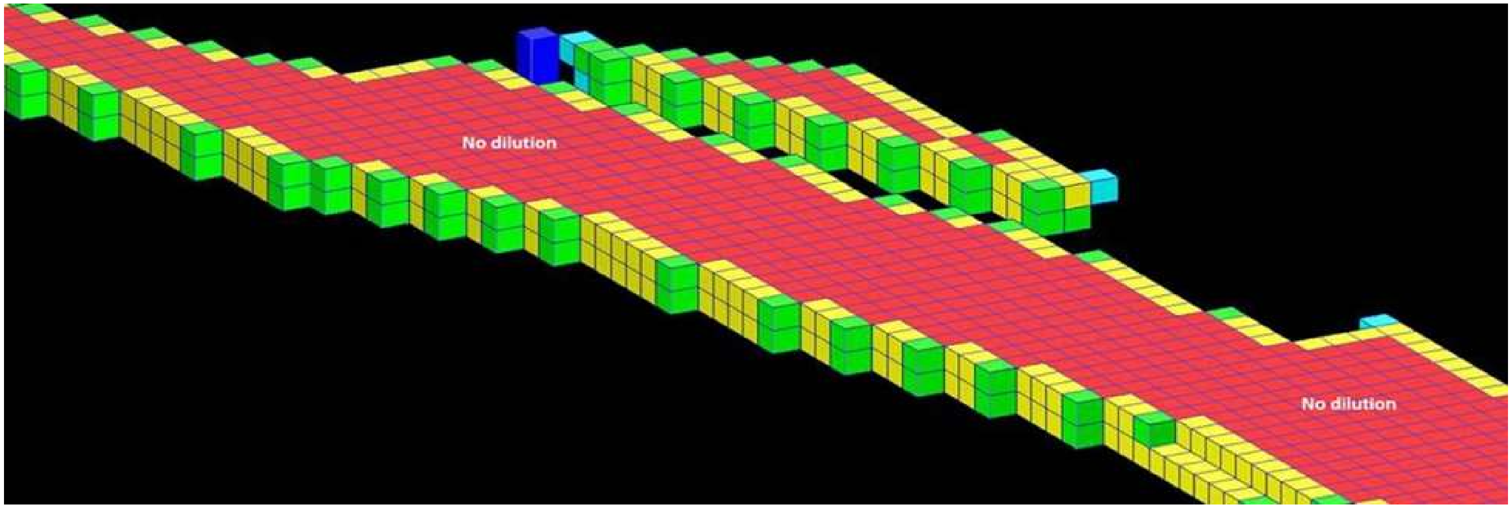
- **پارامترهای اقتصادی:**
  - قیمت محصول نهایی
  - عیار حد اقتصادی
  - هزینه استخراج بلوک کانسنگ
  - هزینه باطله برداری
  - هزینه فرآوری بلوک کانسنگ
  - موقعیت قرارگیری بلوک استخراجی
  - ارزش عناصر مفید همراه
  - هزینه های تولید محصول نهایی



Geo/Eco Parameters

- Ore body shape
- Grade / Cut off Grade / Grade Distribution
- Ore body Thickness
- Ore body Depth
- Ore body dip
- Mine life
- Mining Limits
- Dilution
- Recovery
- Price and mining costs

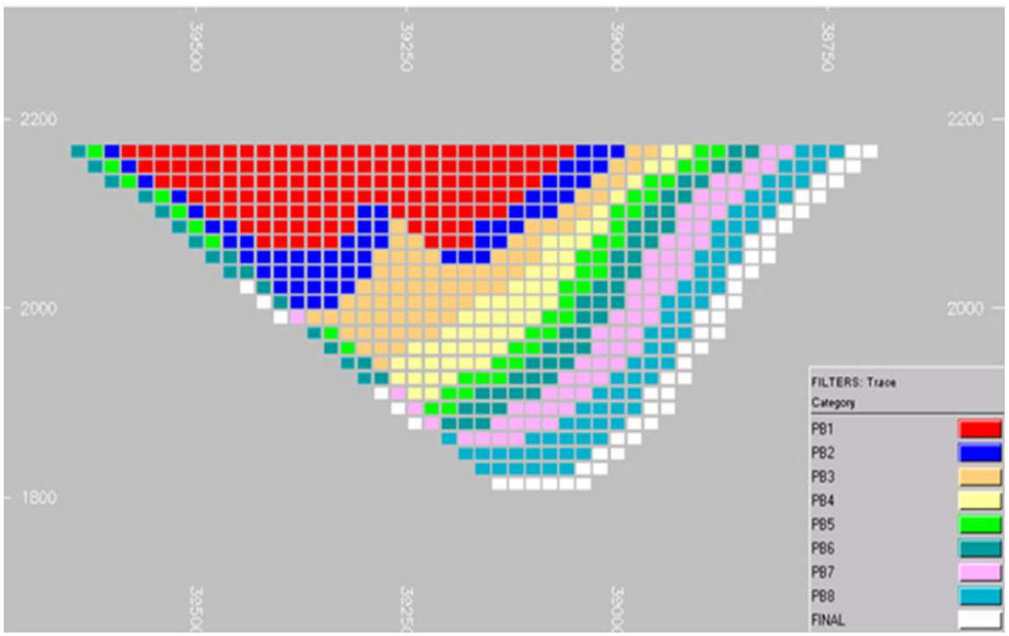
Dilution / Ore Loss



Dilution

- Mining dilution affects the economy of mining projects in many ways.
- A common approach to estimating mining dilution is to apply a fixed factor to the entire block model.
- The fixed dilution factor is usually driven by assumptions that are made based on experience and general knowledge.
- Instead of quantifying dilution in mining studies it is common to assume a general dilution such as 5% for massive deposits and 10% for tabular shape deposits.
- Dilution increases the operating costs in the mill by increasing the tonnage of material to be milled. In addition to its direct impact on short term income of a mine, dilution causes significant changes in other factors that on the long term reduce the overall value of the project.
- Dilution also increases the cut-off grade which in turn reduces the overall ore utilization of a mine.

Block Location



$$\mathrm{Pcost} = \left(\frac{g_{ore} \times R_p}{g_p} \times C_{Tc/Rc} + \left(C_p + C_L\right)\right) \times \mathrm{mass} \times R_m$$

$$\mathrm{Mcost} = (C_m + C_L) \times \mathrm{Mass}$$

Info/data/Software

https://data.worldbank.org/

https://www.mining-technology.com/features/feature-top-ten-deepest-open-pit-mines-world/

https://epi.yale.edu/epi-results/2020/country/irn

Datamien Studio

NPV-Scheduler

Reference

[1] SME 2011

[2] SME Handbook 2021


Thank You!
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