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# A Mining Method Selection Model Using a Numerical Approach by UBC for Laila Underground Coal Mine

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## Abstract

*This research concentrates on selecting the most appropriate underground mining system for the Laila coal deposit, which is situated in the Darah-i-Souf region of Samangan state. The selection system is based on a holistic evaluation of geotechnical, geometrical, and geological parameters, applying the UBC (University of British Columbia) technique, improved by Nicholas. This numerical technique integrates critical parameters, including the geometrical shape of the ore deposit, Rock Substance Strength (RSS), and Rock Mass Rating (RMR). Data were obtained using laboratory analysis, comparisons with similar mining cases, and geological reports. The seam thickness, mine's depth, rock strength, and inclination angle were input into the UBC technique, which analyzed ten diverse mining systems. As part of these, Sublevel Stoping and the Cut and Fill systems obtained the highest scores. After a precise comparison, the Cut and Fill system was evaluated as the optimal technique due to its suitability for the mine's geological status and its higher safety level and effectiveness. This study gives a fundamental model for future specialized mining performances and planning, sharing the optimal underground mining, saving, and stable mining for the Laila coal mine.*

**Keywords:** Laila Coal Mine, Rock Mass Rating (RMR), Rock Substance Strength (RSS), Underground Mining System, University of British Columbia (UBC) Technique.

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## 1. Introduction

The mining activity includes prospecting surveys, the exploration process, the phase of extraction, processing, and use of high-priced minerals and resources from the depths of the earth. The mining field encompasses conventional methods like underground and open-cast mining to modern methods such as advanced open-pit mining with the use of robots, drone machines, remote sensing applications, and diverse mining software [1]. One of the essential and crucial mining activities belongs to selecting of the most suitable mining methods based on safety and economic issues. Due to the spatial location of irregular geometric shapes of ore deposits based on underground coordinates, the selection of an appropriate mining method is essential for each type of mining activity. These components include economic issues, consideration of the safety process, and optimal exploitation of the mining orebody from the earth's crust. It is necessary to identify the geological, geomechanical, and economic factors to be able to detect spatial characteristics of the deposit. For approaching these goals, there are several systematic methods are existing to compare and rank the most suitable method based on specific conditions [2], [3], [4], [5]. In addition, comparative analyses, such as Stojance Mijalkovski, Dragi Peltechki, Zoran Despodov, Dejan Mirakovski1, Vancho Adjiski, and Nikolinka Doneva have positioned the AHP and PROMETHEE methodology favorably against purely expert-based systems, highlighting its ability to incorporate multiple influencing factors consistently [6]. Hence, the latest studies have shown the versatility of the University of British Columbia (UBC) method across multi-mineral sorting and mining operations. Such as Azadeh, Osanloo, and Ataei [7] point out its effectiveness in evaluating complex geometry and diverse ore thicknesses, while Stojance used it in the lead and zinc mines, confirming its practical applicability and reproducibility [8]. The mentioned methods are relevant to the ore types, geometrical shapes, ore depth, and geological characteristics. Every mining method has its own pros and cons, thus the selection of a suitable mining method is related to various parameters such as feasibility, economic remarks and environmental impacts. In addition, ongoing improvements in mining technology continue to drive innovation in mining methods, leading to more effective and sustainable operations over time [9]. Underground mining methods are applicable when the ore body or mineral deposit is situated in deep locations where open-pit mining becomes unrealistic or unprofitable [10]. According to the underground mining method, the ore body is exploited by shafts and levels (tunnels) with the use of professional equipment and engineering mechanisms. Underground mining needs precise planning, high engineering techniques, and the strict enforcement of safety measures to guarantee the safe mining activity for miners [11].

The Laila mine is located about 17 kilometers southwest of the Dahaneh Tor coal belt, on the left side of Laila valley with the same name known (Laila) in the region. The geological mapping survey of the Laila coal belt was prepared at a scale of 1:200000 in 1963-1964. For the purpose of using new technology in this mine and increasing the production capacity of the Laila coal mine, it is mandatory to utilize an optimal engineering plan. In addition, for evaluating a feasible production plan and design, a preliminary plan is mandatory for the Laila coal mine before the exploitation phase. The

prepared plan must define the general overall layout of the mine, including the number of seams, access points, mining method, and scale of production in a working shift.
The objective of this study is to implement initial investigations to support the pre-design phase. The findings aim to deliver a conceptual skeleton and technical foundation for specialists engaged in subsequent stages of the project, based on the conducted research.

## 2. Materials and Methodology

The UBC method is applied in this research, which is based on a systematic approach for the evaluation and ranking of mining methods in underground mining. The mentioned methodology integrates the geological, geomechanical, and geotechnical parameters to select the most appropriate mining method for the Laila coal mine, which is located in the Darah-i-souf region of Samangan province. The application process of the UBC methodology is illustrated below.

### 2.1. Data Collection and Characterization

The geological mapping survey, geomechanical and geometrical parameters, prospecting reports, laboratory analyses, and archival mining data of the Laila coal mine are gathered in the first step. The mentioned data is as follows:

- **Geometrical parameters**: geometric shape of the deposit, seam thickness, plunge, dip direction of the ore body, and ore grade distribution.
- **Geomechanical parameters**: geomechanical data such as rock mass rating (RMR), rock substance strength (RSS) were achieved via laboratory report and field study.

The geometry of the mine deposit was defined as irregular with intermediate seam thickness within the range of (3-10) meters, the orebody dip over 55 $^{\circ}$, and intermediate ore grade distribution. Thus, the orebody is positioned at a depth of over 600 meters with diverse orebody qualifications. Its rock mass rating is classified as weak to intermediate (RMR 20-40) and strong in hanging wall and footwall (RMR 60-80).
RSS analyses similarly demonstrated weak to moderate strength in the ore zone and intermediate strength in the surrounding host rocks.

### 2.2. Parameter Classification and Scoring

According to the Nicholas UBC approach, twelve crucial parameters were detected and classified:

- Five geometric parameters that identify the spatial shape and structural characteristics of the orebody.
- Six geomechanical parameters reflecting rock quality and strength.

Each variable was then inserted into standard reference tables (Tables 1–2), which assign weighted scores to ten commonly utilized underground mining methods according to the compatibility between orebody characteristics and method requirements. The scoring approach follows the UBC system: higher scores (e.g., 3–4) indicate strong compatibility, while negative scores (e.g., –49) represent non-applicability.

### 2.3. Mining Methods Evaluated

Evaluated mining methods were listed below:

- Cut and Fill
- Sublevel Stoping
- Sublevel Caving
- Block Caving
- Shrinkage Stoping
- Longwall
- Open Pit
- Top Slicing
- Square Set
- Room and Pillar
- Room and Pillar

### 2.4. Numerical Analysis and Ranking

All scores were collected into the eleven parameters to calculate an ultimate result for every method, and then the scores were ranked to a final result. The higher scores indicate the coordination of the orebody with the geological and geomechanical conditions of the Laila coal mine.

## 3. UBC Methodology

The UBC approach, which was expanded at the University of British Columbia, is a systematic and quantitative method for selecting the most appropriate mining method in the field of mining. This methodology was introduced by Miller and his colleagues in 1995 and has become widely known as a useful framework in the field of mining, particularly due to its logical decision-making and its scientific nature [13].

The UBC approach manages its evaluation process based on a specific criterion, such as geological and geotechnical parameters, to be feasible and vital for underground mining operations [14]. Specifically, it considers two main groups of factors:

### 3.1. Deposit Geometry and Grade Distribution

According to Table 1 (Miller and colleagues, 1995), the parameters define the spatial characteristics and grade variability of the orebody:

- *General shape/width*: Categorized as equal-dimensional, platy-tabular, or irregular, reflecting the three-dimensional form of the ore deposit.
- *Ore thickness*: Classified into very narrow (< 3 m), narrow (3–10 m), intermediate (10–30 m), thick (30–100 m), and very thick (> 100 m).
- *Plunge*: Distinguished as flat (< 20º), intermediate (20–55º), or steep (> 55º), which influences the choice of method and mining layout.
- *Depth below surface*: Ranges from shallow (0–100 m), intermediate (100–600 m), to deep (> 600 m).
- *Grade distribution*: Described as uniform, gradational, or erratic, reflecting the consistency and predictability of ore grades within the deposit.

### 3.2. Rock Mechanics Characteristics

As outlined in Table 2, Miller and his colleagues concentrated on the mechanical properties of the surrounding rock mass and the characteristics of the orebody:

- *Rock Mass Rating (RMR)*: A quantitative measure of rock mass quality, classified into very weak (0÷20), weak (20÷40), moderate (40÷60), strong (60÷80), and very strong (80÷100).
- *Rock Substance Strength (RSS)*: Reflects the uniaxial compressive strength of intact rock material, grouped as very weak (< 5 MPa), weak (5÷10 MPa), moderate (10÷15 MPa), and strong (> 15 MPa).

By integrating the above parameters into a weighting and scoring approach, the UBC methodology enables an objective comparison of alternative methods for the mining operations to consider both geometry and rock mechanics. The method's strength lies in its ability to compare qualitative geological information with quantitative analysis, hence improving the reliability and defensibility of the final mining method selection [15], [16]. In this study, the UBC methodology is implemented to methodically evaluate and select the most appropriate underground mining method for the Laila coal mine by considering its geometry and rock mechanics, as shown above.

**Table 1.** Definition of Deposit Geometry and Grade Distribution [14].

| | | |
|---|---|---|
| General shape/width | equi-dimensional | All dimensions are on the same order of magnitude |
| | platy-tabular | Two dimensions are many times the thickness, which does not usually exceed 35 m |
| | irregular | dimensions vary over short distances |
| Ore thickness | very narrow | < 3 m |
| | narrow | 3 ÷ 10 m |
| | intermediate | 10 ÷ 30 m |
| | thick | 30 ÷ 100 m |
| | very thick | > 100 m |
| Plunge | flat | < 20º |
| | intermediate | 20 ÷ 55º |
| | steep | > 55º |
| Depth below surface | shallow | 0 ÷ 100m |
| | intermediate | 100 ÷ 600 m |
| | deep | > 600 m |
| Grade distribution | uniform | The grade at any point in the deposit does not vary significantly from the mean grade for that deposit. |
| | gradational | Grade values have zonal characteristics, and the grades change gradually from one to another. |
| | erratic | grade values change radically over short distances and do not exhibit any discernible pattern in their changes |

**Table 2.** Rock Mechanics Characteristics [14].

| | | |
|---|---|---|
| Rock Mass Rating (RMR) | very weak | 0 ÷ 20 |
| | weak | 20 ÷ 40 |
| | moderate | 40 ÷ 60 |
| | strong | 60 ÷ 80 |
| | very strong | 80 ÷ 100 |
| Rock Substance Strength (RSS) | very weak | < 5 |
| | weak | 5 ÷ 10 |
| | moderate | 10 ÷ 15 |
| | strong | > 15 |

## 4. Results

The application of the UBC (University of British Columbia) mining method selection methodology to the Laila underground coal mine generated a structured, quantitative evaluation of ten prospective underground mining methods. By means of twelve crucial parameters, including both geometry and rock mechanics, this methodology assigned a number of numerical scores to each method to evaluate their suitability for the site-specific conditions of the Laila coal mine. The mineral deposit was described as irregular in shape, with an average seam thickness classified as thick (30–100 m), steep plunge (>55°), and an overall depth greater than 600 m. Rock Mass Rating (RMR) varied from weak to moderate within the coal seam (20–40) and strong (60–80) in the surrounding host rocks, while the Rock Substance Strength (RSS) results similarly indicated weak to moderate strength in the ore zone and stronger values in the adjacent rock mass.

According to these findings, the Cut and Fill method was identified as the most suitable mining method for the Laila coal deposit. Its higher total suitability score reflects its capability to effectively handle complex orebody geometries and variable rock strength while offering controlled exploitation and backfilling to stabilize surrounding rock. Furthermore, its adaptable design aligns with the mine operational goals of ensuring safety, decreasing dilution, and ensuring that the mine production goes ahead well. These results deliver a robust preliminary model to guide subsequent detailed design phases, ensuring that mining operations at the Laila underground coal mine are conducted safely, efficiently, and in harmony with site-specific geological and geotechnical parameters.

## 5. Discussion

The approach, which was applied for the purpose of selecting a mining method for the Laila underground coal mine and employing the numerical approach proposed by Nicholas (University of British Columbia) and implemented through the UBC methodology, provides important information about deposit properties and the suitability of mining methods for the Laila underground coal mine.

Figure 1 demonstrates the main function of the software for inputting the important geological information of the ore deposit in the Laila coal mine, and these parameters show the foundation of a systematic approach for selecting a suitable mining method.

Each category of the input data demonstrates the limitations of geological and economic issues, affecting technical feasibility and safety in underground mining operations. The shape of the ore deposit is categorized as irregular, which demonstrates the vertical and lateral variations in orebody geometry. This variability prefers an adaptable and selective methodology, which corresponds with geological flexibility that is applied in the Cut and Fill and Sublevel Stoping methods.

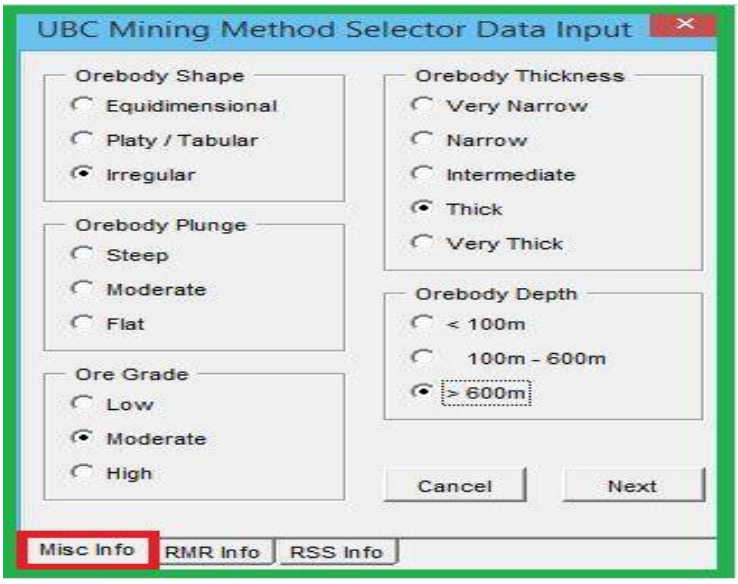



**Fig. 1.** Definition of Deposit Geometry and Grade.

The deposit plunge is categorized as steep, which approximately matches the measured dip angle of 50-55 degrees as previously measured. The orebodies with steep angles are suitable for those kinds of methods that allow gravity-assisted ore flow and safe access on multiple levels. The methods, such as Cut and Fill and Sublevel Stopping, are more applicable in the field of mining. The intermediate ore grade shows a deposit that, while valuable doesn't justify the high-cost techniques generally reserved for very rich ore deposits. Thus, the method should balance between cost-effectiveness and selectivity to optimize economic return. The orebody thickness is classified as thick, and this characteristic increases the economic attractiveness of the Cut and Fill method, however in irregular geometry conditions and highly inclined dip direction, the Sublevel Stopping can be the best option too. Regarding orebody depth, the inputs show a depth greater than 600 meters. At such depths, the mining stress becomes a critical problem, and these conditions demand a suitable mining method to control the mining stress.

Figure 2, explains the classification of rock mass based on the rock mass rating (RMR) procedure across three crucial geological domains: the hanging wall, the ore zone, and the footwall. The RMR procedure, originally formulated by Bieniawski [17], is widely implemented in mining field and geotechnical engineering to evaluate the quality of rock masses and guide design decisions related to excavation stability, support systems, and mining method selection.

- *RMR Hanging Wall:* Rated in the range of 60–80, classified as *Strong* rock.
- *RMR Ore*: Rated in the range of 20–40, classified as *Weak* rock.
- *RMR Footwall:* Also rated in the range of 60–80, classified as *Strong* rock.

The distinction difference in rock mass rating values between the ore zone and the surrounding host rocks (hanging wall and footwall) has important consequences.

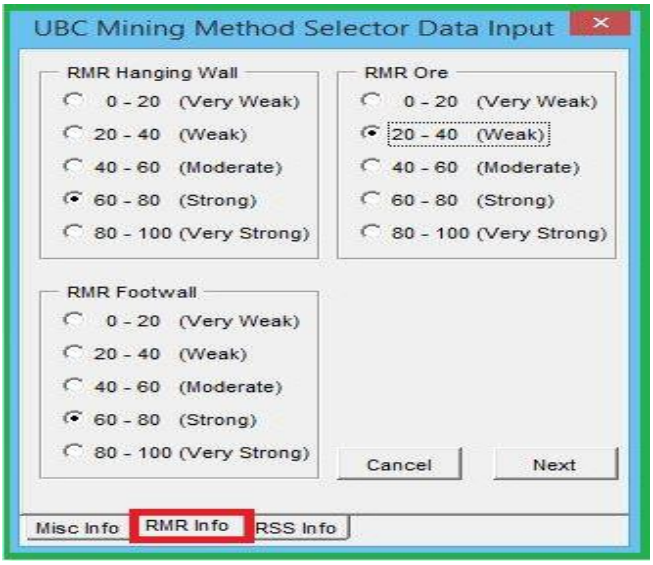



**Fig. 2.** Rock Mechanics Characteristics (RMR).

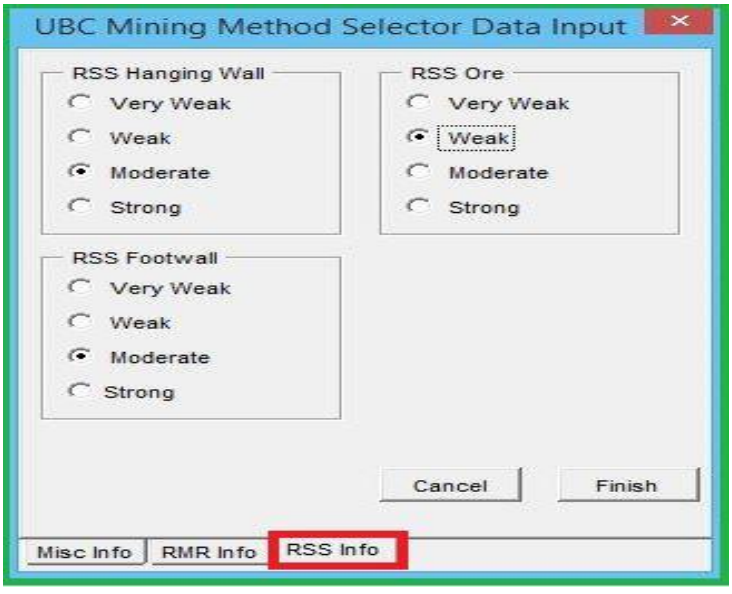



**Fig. 3.** Rock Mechanics Characteristics (RSS).

Figure 3 explains the classifications of rock qualitative strength categories based on rock substance strength (RSS) for three geological domains: the hanging wall, the ore zone, and the footwall. The rock substance strength (RSS), while simpler than the numerical Rock Mass Rating

(RMR) procedure, offers a practical way to classify rock materials based on their relative mechanical competence (Very Weak, Weak, Moderate, and Strong).

- *RSS Hanging Wall:* Classified as *Moderate*.
- *RSS Ore*: Classified as *Weak*.
- *RSS Footwall:* Categorized as *Moderate*.

**Table 3.** Ranking of mining methods.

| Serial number | Mining method | **Total value points** |
|---|---|---|
| 1 | Cut and Fill | 30 |
| 2 | Open Pit | -16 |
| 3 | Longwall | -127 |
| 4 | Shrinkage Stoping | -24 |
| 5 | Square Set | 17 |
| 6 | Top Slicing | 16 |
| 7 | Room and Pillar | -85 |
| 8 | Sublevel Stoping | 30 |
| 9 | Sublevel Caving | 29 |
| **10** | Block Caving | 25 |

The presented Table 3 and Figure 4 reflect a comparative evaluation of underground and surface mining methods according to a numerical approach (UBC). Every method is evaluated according to a number of geological, geometrical, and geomechanical criteria, with an ultimate score defining overall suitability.

### 5.1. Parameters Evaluated

- Geometrical Parameters: Shape, Plunge, Thickness, Grades, Depth
- Geomechanical Parameters: Rock Mass Rating (RMR) and Rock Stress Score (RSS), for Ore Zone, Hanging Wall (HW), and Footwall (FW)

Negative values like -49 are likely placeholders or indicators of non-applicability for certain parameters (e.g., Longwall and Room & Pillar are not suited to particular geometrical conditions).

### 5.2. Highest Ranking Methods

Cut and Fill (30 points) and Sublevel Stoping (30 points) state the highest score, showing a balanced adaptability across ore shape, ground conditions, and structural parameters. Sublevel Caving (29 points) is a close third, sharing high potential in strong geotechnical situations.

### 5.3. Poorly Ranked Methods

Longwall (-127) and Room and Pillar (-85) methods have the highest negative scores; these negative values flow from the geometry of the ore deposit, such as shape parameters, plunge, and ore thickness, likely suggesting incompatibility in the context assessed (possibly hard-rock mining or steep-dipping ore bodies).

Shrinkage Stoping (-24) and Open Pit (-16) rank poorly too, and this ranking results from limitations in rock mechanics or ore control under the specific criteria.

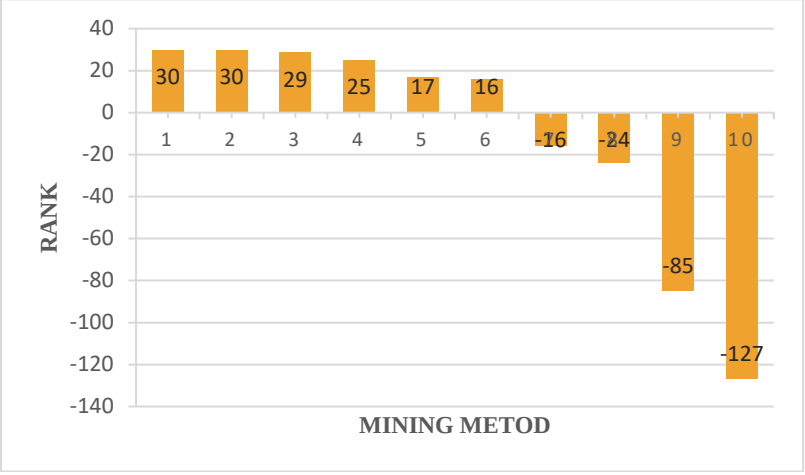



**Fig. 4.** Ranking of mining methods.

## 6. Conclusion

This research utilized the UBC (University of British Columbia) approach, created by Nicholas, to determine the most optimal underground mining method for the Laila Coal mine situated in the Darreh-Souf region of Samangan Province. By methodically incorporating geometrical, geological, and geomechanical data, including ore body configuration, thickness, plunge, depth, rock mass rating (RMR), and rock substance strength (RSS), the UBC approach delivers a structured, quantitative framework for assessing ten potential mining methods.

The results presented that the Cut and Fill and Sublevel Stoping methods obtained the highest aggregate scores, reflecting their compatibility with the Laila deposit's irregularly shaped, steeply dipping, and thick coal seams, as well as the moderate to strong surrounding host rock mass. Among these, the Cut and Fill method was selected as the optimal choice due to its greater adaptability to complex orebody geometries, its capacity to handle variable seam thicknesses, and its inherent pros in providing ground support through backfilling. On the other hand, methods such as Longwall and Room and Pillar obtained substantially lower scores, largely because their application is limited in steep, irregular shapes, and deep deposits such as the Laila mine.

The findings indicate that a systematic approach and data-driven method, such as the University of British Columbia (UBC) system, can substantially enhance decision-making in mining method selection, ensuring technical feasibility, operational safety, and economical efficiency. This conclusion not only supports the initial design and feasibility planning of the Laila underground coal mine but also delivers an applicable methodological outline to similar geological structures. The study emphasizes the

importance of detailed geological and geotechnical studies as a foundation for sustainable and safe resource exploitation in complex underground mining conditions.

## 7. Future Scope

This research delivers an essential model for mining method selection at the Laila underground coal mine by using the UBC technique. In the future, this model can be expanded by integrating additional geological, environmental, and effective factors. Further study may look into the integration of expert judgment, practical field data, and technological advancements to improve and perfect the decision-making procedure. Moreover, applying the model to other underground coal mines can help validate its applicability and enhance its flexibility for different mining conditions. Such improvements can support safer, more efficient, and more sustainable mining activities.

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