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Selecting an Appropriate Mining Method for Aragonite Blocks in the Sabz Rang Area, Helmand Province

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Abstract	Article History
Selecting an appropriate extraction method is an important decision in dimension-stone quarrying because method suitability depends on several technical, geological, operational, environmental, and safety considerations. This study evaluates three extraction alternatives—chainsaw cutting, diamond wire cutting, and controlled blasting—for aragonite dimension-stone blocks in the Sabz Rang area of Helmand Province, Afghanistan. The study used field investigation to characterize existing extraction practices and identify feasible alternatives, and it analyzed structured expert judgments within an Analytic Hierarchy Process (AHP) framework. Thirteen mining specialists evaluated the alternatives against five criteria: cutting quality, ease of use, environmental aspect, geological aspect, and safety. Pairwise judgments were aggregated and analyzed using AHP in SuperDecisions software, including consistency assessment and sensitivity analysis. The final priorities, ranked in order, were chainsaw cutting (0.48668), diamond wire cutting (0.42034), and controlled blasting (0.09298). The results identify chainsaw cutting as the preferred alternative within the decision criteria and site-specific conditions considered in this study. Keywords: Analytic Hierarchy Process (AHP); Aragonite; Dimension stone; Multi-criteria decision-making (MCDM); Sensitivity analysis	Published: September 30, 2026 Accepted: August 28, 2026 Revised: August 08, 2026 Received: May 31, 2026
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Introduction

Selecting an appropriate mining or quarrying method is a critical decision in mine planning because the selected method can directly influence operational feasibility, resource recovery, safety, environmental aspects, and the quality of the extracted product. Mining-method selection is inherently a multi-criteria decision problem because it often requires considering geological, technical, operational, environmental, and safety factors simultaneously. Although conventional approaches have often relied on empirical knowledge and engineering experience, they may be insufficient when several competing criteria and alternatives must be evaluated systematically. Consequently, multi-criteria decision-making (MCDM) methods have increasingly been applied to complex decision problems in mining and mineral processing (Mardani et al., 2015; Mutlu & Sari, 2017; Sitorus et al., 2019). A comprehensive review by

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Namin et al. (2022) further demonstrated the growing use of MCDM methods for mining-method selection and identified the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) as the most frequently applied approaches.

Among MCDM techniques, the Analytic Hierarchy Process (AHP) is particularly suitable for complex engineering decisions because it decomposes a decision problem into a hierarchy of objectives, criteria, and alternatives and evaluates their relative importance through pairwise comparisons. The method converts expert judgments into numerical priority weights and provides a mechanism for assessing the consistency of those judgments (Saaty, 2008; Ishizaka & Labib, 2011). Its methodological structure has made AHP applicable to a wide range of mining-related decisions, including mining-method selection, equipment selection, and quarry-design problems (Farkaš & Hrastov, 2021; Patyk & Bodziony, 2022). Consistency assessment is also an important component of AHP because it evaluates the logical coherence of pairwise judgments and identifies potentially problematic comparisons (Pant et al., 2022; Salomon & Gomes, 2024).

Previous studies have demonstrated the usefulness of AHP and related MCDM approaches for mining-method selection under different geological and operational conditions. Ataei et al. (2013) combined Monte Carlo simulation with AHP to account for variability in expert judgments during mining-method selection. Karimnia and Bagloo (2015) applied fuzzy AHP to evaluate alternative mining methods for the Qapiliq salt mine in Iran using multiple geological and technical factors. Yavuz (2015) applied AHP together with Yager's method to an underground mining-method selection problem and incorporated sensitivity analysis into the decision process. Similarly, Kabwe (2017) used AHP and Yager's method to evaluate alternative mining methods for the Nchanga Upper Orebody in Zambia. These studies illustrate how structured MCDM frameworks can support mining-method selection when several technical and geological factors must be evaluated simultaneously.

MCDM has since expanded to broader mining and quarrying decision problems. Bajić et al. (2020) developed a fuzzy AHP approach for underground mining-method selection, demonstrating the usefulness of expert-based, uncertainty-aware multi-criteria evaluation. Baloyi and Meyer (2020) examined a range of MCDM approaches and developed a mining-method selection model to provide a more systematic basis for selecting appropriate decision methods and criteria. Farkaš and Hrastov (2021) applied AHP and PROMETHEE II to a quarry-design problem, demonstrating the applicability of MCDM techniques to quarry operations. Patyk and Bodziony (2022) applied AHP to mining-equipment selection, further illustrating the usefulness of hierarchical decision models for evaluating competing technical alternatives. Ccatamayo-Barrios et al. (2023) later compared AHP and TOPSIS for mining-method selection and showed that the resulting ranking depends on the decision criteria and their relative priorities.

Dimension-stone extraction represents a distinct application of this decision-making problem. Unlike bulk-mineral extraction, the practical and economic value of dimension stone depends strongly on recovering commercially usable blocks with suitable dimensions, limited damage, and acceptable quality. Consequently, extraction-method selection should consider not only production-related factors but also cutting quality, geological suitability, operational feasibility,

environmental aspects, and safety. A comprehensive review by Samarakoon et al. (2023) showed that dimension-stone extraction involves a range of traditional and mechanized techniques, including diamond wire cutting, sawing technologies, and controlled blasting, and that the suitability of these methods depends on the stone's characteristics and the quarrying operation's requirements.

Recent studies have further emphasized the importance of considering multiple dimensions in quarrying decisions. Agharroud et al. (2023) demonstrated the importance of integrating environmental and sustainability considerations into quarrying assessment. In the context of dimension-stone operations, Yari et al. (2024) highlighted the importance of systematic risk assessment because quarrying activities involve multiple interacting technical, operational, and safety risks. Chen et al. (2024) also demonstrated the value of multi-stakeholder decision-making for sustainable mining-method selection by incorporating both resource-exploitation and environmental aspects. More recently, Pham et al. (2025) applied a combined AHP and PROMETHEE II framework to the selection of quarrying technology for a dimension-stone quarry. Their analysis considered factors including quarrying cost, time, safety, environmental impact, and stone loss, further demonstrating that quarrying technology selection depends on multiple interacting criteria.

Despite these developments, a key research gap remains in applying systematic decision-support approaches to site-specific dimension-stone block extraction. Existing studies have largely focused on underground mining-method selection, equipment selection, quarry design, aggregate quarrying, or general mining-method evaluation. Comparatively few studies have specifically addressed selecting extraction methods for dimension-stone blocks in deposits where local extraction practices rely primarily on practical experience and where no structured decision-support framework has been established. Dimension-stone extraction presents a particular decision context because block quality and integrity directly affect the usefulness of the extracted product, while geological suitability, ease of operation, environmental impact, and safety must also be considered simultaneously. Therefore, decision criteria developed for conventional mining-method selection cannot necessarily be transferred directly to dimension-stone extraction without considering the specific characteristics of the deposit and quarrying operation.

This research gap is particularly relevant to the Sabz Rang area of Helmand Province, Afghanistan, where local quarrying practices extract aragonite-bearing stone and where no systematic framework for comparing alternative extraction methods has been established. Field observations conducted during this study indicated that diamond wire cutting was the prevailing extraction technique at the site, while chainsaw cutting and controlled blasting were identified as feasible alternatives for comparative evaluation. Continuing an existing extraction practice does not, by itself, show it is the most appropriate alternative. A structured decision framework can instead make the basis of method selection explicit by identifying relevant criteria, incorporating the judgments of experienced mining specialists, quantifying the relative importance of the criteria, and producing a reproducible ranking of competing alternatives.

Accordingly, this study applies AHP as an MCDM framework to evaluate three extraction alternatives—chainsaw cutting, diamond wire cutting, and controlled blasting—for aragonite

dimension-stone blocks in the Sabz Rang area of Helmand Province. The alternatives are evaluated against five criteria: cutting quality, ease of use, environmental impact, geological considerations, and safety. Judgments from 13 mining specialists are incorporated into the pairwise-comparison process to determine the relative importance of the criteria and the alternatives' priorities. The study calculates consistency ratios to assess the consistency of the pairwise judgments, and uses sensitivity analysis to examine the stability of the resulting ranking. The study provides a site-specific decision-support framework for comparing alternative extraction methods under the geological, operational, environmental, and safety conditions considered at the Sabz Rang site. Specifically, the study aims to answer the following research questions:

1. Which of the three evaluated extraction methods—chainsaw cutting, diamond wire cutting, or controlled blasting—receives the highest overall priority under the five selected criteria in the Sabz Rang area?
2. How are the five evaluation criteria and three extraction alternatives prioritized through the AHP pairwise-comparison process based on the judgments of the 13 mining specialists?
3. How stable is the final ranking of the three extraction alternatives when the weights of the evaluation criteria are varied within the sensitivity-analysis framework?

Methods and Materials

Research Design

This study used an applied, analytical, multi-criteria approach to identify the preferred extraction method for aragonite stone blocks in the Sabz Rang area of Helmand Province. The methodology combined field investigation with structured expert judgment within an Analytic Hierarchy Process (AHP) framework. The study evaluated three extraction alternatives—chainsaw cutting, diamond wire cutting, and controlled blasting—based on five criteria: cutting quality, ease of use, environmental impact, geological considerations, and safety.

The study was designed to determine the relative suitability of the alternatives under the specific decision conditions of the study area rather than to establish a universally superior extraction technology.

The research followed a sequential decision-making design. First, the study conducted a field investigation to identify existing extraction practices and site conditions. Second, the study identified feasible extraction alternatives and defined evaluation criteria relevant to extraction-method selection. We then developed and distributed a structured AHP pairwise-comparison questionnaire to 13 mining specialists. The individual judgments were aggregated using the geometric-mean approach, after which the group pairwise-comparison matrices were constructed and analyzed. We derived criterion weights and local priorities for the alternatives, and assessed the consistency of the comparison matrices using the Consistency Index (CI) and Consistency Ratio (CR). Finally, the local priorities were synthesized to obtain the overall ranking of the alternatives, followed by sensitivity analysis to examine the stability of the ranking under variations in criterion weights.

Instrumentation

The principal research tools included structured AHP pairwise-comparison questionnaires, Microsoft Excel for organizing and aggregating expert responses, and Super Decisions software for AHP calculations, consistency assessment, priority synthesis, and sensitivity analysis.

The use of pairwise comparisons, consistency assessment, and hierarchical synthesis follows the standard AHP framework (Brunelli, 2015; Ishizaka & Labib, 2011).

Data Collection Methods

The primary data consisted of field observations and expert judgments. Field observations helped us understand existing extraction practices and the conditions relevant to selecting feasible alternatives. The expert-judgment data were obtained using structured pairwise-comparison questionnaires distributed to 13 specialists with relevant academic and professional experience in mining engineering.

Each expert evaluated the relative importance of the five criteria and the relative suitability of the three extraction alternatives under each criterion. The individual judgments were subsequently organized and aggregated for use in the group AHP model.

Data Analysis

The analysis was conducted in two principal stages. First, field information was reviewed to identify the extraction alternatives and the criteria relevant to the decision problem. Second, the AHP procedure was applied to the judgments obtained from the 13 experts.

The geometric mean was used to aggregate the individual pairwise judgments. The resulting group comparison matrices were then used to derive criterion and alternative priorities. We assessed the consistency of each matrix using the Consistency Index and Consistency Ratio. Finally, the local priorities were synthesized according to the criterion weights to obtain the global priority of each alternative.

Sensitivity analysis was subsequently conducted by varying each criterion weight and observing the corresponding changes in the priorities of the three alternatives. Sensitivity analysis was treated as an assessment of ranking stability and robustness within the specified AHP model rather than as independent experimental validation.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), originally developed by Thomas L. Saaty, is a multi-criteria decision-making method that decomposes a complex decision problem into a hierarchical structure and derives relative priorities through pairwise comparisons (Saaty, 2008). The method has been extensively reviewed and applied in mining and other engineering decision problems (Ishizaka & Labib, 2011; Sitorus et al., 2019).

Hierarchical Structuring of the Decision-Making.

The decision model consisted of three levels. The first level represented the overall objective: selecting the most suitable extraction method for aragonite dimension-stone blocks in the Sabz Rang area. The second level contained the five evaluation criteria, and the third level contained the three extraction alternatives.

The five criteria represent the principal technical, operational, geological, environmental, and safety considerations relevant to the decision problem.

Table 1: Evaluation criteria used for extraction-method selection

Code	Criteria
C1	Cutting quality
C2	Ease of use
C3	Environmental aspect
C4	Geological aspect
C5	safety

The model evaluated three alternatives: (chainsaw cutting), (diamond wire cutting), and (controlled blasting).

Pairwise Comparison Procedure

In the standard AHP formulation, a pairwise-comparison matrix is an ($n \times n$) matrix constructed in which each element a_{ij} represents the relative preference of element i over element j , while the reciprocal relationship is given by $a_{ji} = 1/a_{ij}$ (Canco et al., 2021). The diagonal elements are equal to 1 (Saaty, 2008; Ishizaka & Labib, 2011). The number of unique pairwise comparisons required for (n) elements is:

$$N = \frac{n(n-1)}{2} \quad (1)$$

Accordingly, five criteria require

$$N = \frac{5(5-1)}{2} = 10$$

For three alternatives under each criterion:

$$N = \frac{3(3-1)}{2} = 3$$

Comparisons are required for each criterion. Since five criteria were considered, the alternative level required $3 \times 5 = 15$. Therefore, the complete model required 25 unique pairwise comparisons: 10 among the five criteria and 15 among the alternatives. The pairwise comparison matrix, which represents the relative importance of each alternative and criterion, is represented as follows (Saaty, 1980; Ishizaka & Labib, 2011).

$$\begin{bmatrix} a_{11} & a_{12} & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

Saaty Pairwise-Comparison Scale

The pairwise judgments were expressed using Saaty's fundamental scale from 1 to 9. The values 2, 4, 6, and 8 represent intermediate judgments (Saaty, 2008).

Table 2: Fundamental scale for pairwise comparison

Numerical value	Interpretation
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2,4,6,8

Expert questionnaire

The AHP questionnaire was distributed to 13 experts with academic and professional experience in mining engineering. Participant selection emphasized practical familiarity with mining operations, extraction methods, and technical assessment. The expert panel aimed not to infer statistical population parameters but to systematically elicit informed judgments about the relative importance of the criteria and the suitability of the extraction alternatives. In group AHP applications, the quality, relevance, and consistency of expert judgments are central considerations in the decision process (Ishizaka & Labib, 2011; Brunelli, 2015). The individual questionnaires should be retained as the primary audit trail for the aggregated AHP matrices. The judgments obtained from the 13 experts were aggregated using the geometric mean.

Priority Derivation and Consistency Assessment

The consistency of all pairwise comparison matrices was assessed using the maximum eigenvalue ($\lambda_{\max}$), Consistency Index (CI), and Consistency Ratio (CR). For a perfectly consistent pairwise-comparison matrix, $\lambda_{\max}$ equals n ; deviations above n reflect inconsistency in the judgments. Therefore, for the five-criterion matrix, the theoretical value of $\lambda_{\max}$ is 5, whereas for each three-alternative matrix, the theoretical value is 3. Small deviations from these theoretical values are acceptable because they reflect minor inconsistencies in expert judgments.

Table 3: Consistency assessment of the pairwise comparison matrices for criteria and alternatives

Comparison Matrix	Matrix Size (n)	Maximum Eigenvalue ($\lambda_{\max}$)	Consistency Index (CI)	Random Index (RI)	Consistency Ratio (CR)	Consistency Status
Criteria	5 × 5	5.0001792	0.0000448	1.12	0.00004	Acceptable
Ease of Use	3 × 3	3.0891112	0.0445556	0.58	0.07682	Acceptable
Cutting Quality	3 × 3	3	0	0.58	0	Acceptable
Environmental aspect	3 × 3	3.0050576	0.0025288	0.58	0.00436	Acceptable
Geological aspect	3 × 3	3.0669784	0.0334892	0.58	0.05774	Acceptable
Safety	3 × 3	3.0000696	0.0000348	0.58	0.00006	Acceptable

The Consistency Index was calculated using:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

Where λ_{max} is the maximum eigenvalue of the pairwise-comparison matrix and n is the order of the matrix. To further evaluate the acceptability of inconsistency, we calculated the Consistency Ratio (CR) using Equation (3) (Pant et al., 2022). The Consistency Ratio (CR) was then calculated as:

$$CR = \frac{CI}{RI} \quad (3)$$

where (RI) is the Random Index associated with the order of the matrix (Pant et al., 2022; Salomon & Gomes, 2024). The random index (RI) is illustrated in Table (4).

Table 4: Random Index (RI) values used in the AHP consistency assessment

Matrix order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

A CR value below 0.10 is commonly used to indicate acceptable consistency in AHP applications. This criterion assesses the internal consistency of the judgments rather than the statistical validity of the expert sample. The RI values provide the reference values required to calculate the CR for matrices of different orders (Pant et al., 2022).

Findings

Within the multi-criteria decision-making framework, the AHP hierarchy was first developed as presented in Figure 1.

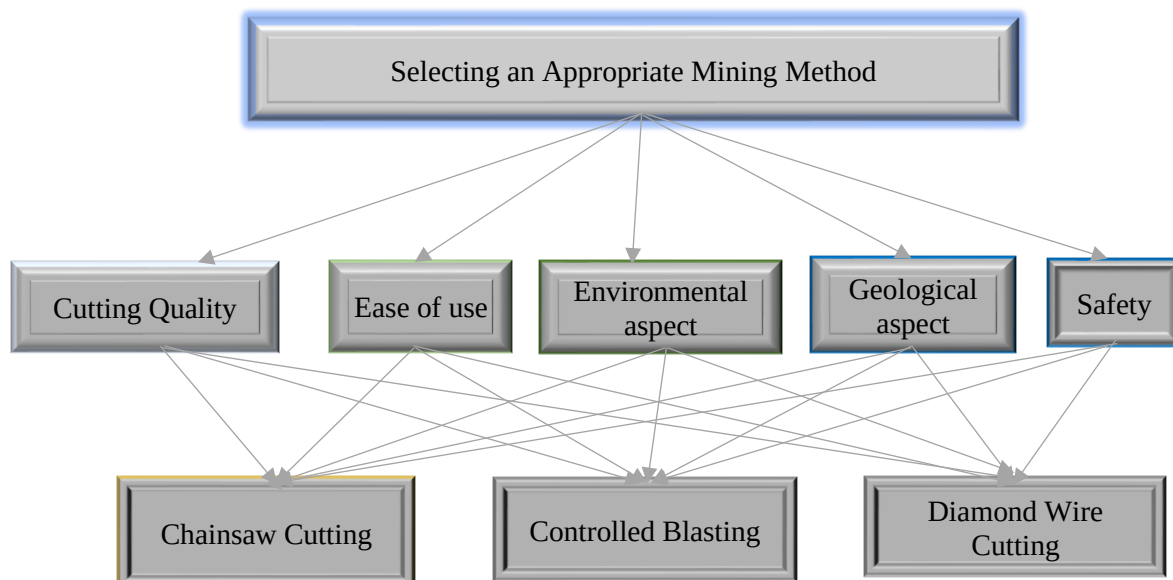


Figure -1 Hierarchical decision tree for selecting the optimal mining method.

The objective was positioned at the top level, the criteria at the second level, and the alternatives at the third level. This structure provided the basis for pairwise comparisons and calculating relative priorities using the AHP approach.

To determine the relative importance of the evaluation criteria with respect to the goal, pairwise comparison was conducted among the five criteria. Accordingly, a 5×5 pairwise comparison matrix was constructed, and after completing the matrix, the local weights of the criteria were derived using the Analytic Hierarchy Process (AHP), thereby establishing the relative priority of each criterion relative to the others. To assess the logical consistency and reliability of the elicited judgments, the consistency of the comparison matrix was evaluated by calculating the consistency ratio (CR) value, which fell within the acceptable range, indicating an adequate level of consistency among the pairwise judgments and supporting the reliability of the derived priority weights for subsequent analysis. The pairwise comparison matrix of the criteria, the resulting local weights, and the corresponding consistency ratio are presented (Table 5).

Table 5: Pairwise comparison matrix of the criteria with respect to the goal and local weights

Criteria	Pairwise Comparison Matrix					Local Weight	
	Cutting Quality	Ease of Use	Environmental aspect	Geological aspect	Safety	Weight	Consistency
Cutting Quality	1	4.384004	1.446	4.203995	1.316	0.34261	Acceptable CR=0.00004
Ease of Use	0.22810198	1	0.322477	0.94162	0.30618	0.07782	
Environmental aspect	0.69156293	3.1009963	1	2.98	0.93283	0.24037	
Geological aspect	0.23786897	1.0619995	0.33557047	1	0.31496	0.08149	
Safety	0.75987841	3.2659993	1.071999794	3.1749962	1	0.25772	

The results indicate that cutting quality received the highest criterion weight, followed by safety and environmental aspects. The geological aspect and ease of use received lower relative weights in the aggregated expert judgments.

Alternative Priorities Under Each Criterion

For the three alternatives considered in this study, we constructed five pairwise comparison matrices based on the evaluation criteria. In each matrix, the alternatives were compared pairwise with respect to the corresponding criterion, and the local priority weight of each alternative was subsequently determined. Additionally, the inconsistency ratio was calculated for each pairwise comparison matrix to evaluate the consistency of the experts' judgments. The results indicated that the inconsistency ratio was below 0.10 for all matrices, demonstrating an acceptable level of consistency in the pairwise comparisons. The pairwise comparison matrix of the criteria, the local priority weights of the alternatives under each criterion, and the corresponding inconsistency ratios are presented in Tables 6-10.

Table 6: Pairwise comparison matrix of alternatives with respect to the ease of use criteria

Alternatives	Pairwise Comparison Matrix			Local Weight	
	Chainsaw Cutting	Controlled Blasting	Diamond Wire Cutting	Weight	Consistency
Chainsaw Cutting	1	5.83	3.408003	0.65862	acceptable

Controlled Blasting	0.171526587	1	0.251067	0.08524	CR= 0.07682
Diamond Wire Cutting	0.293426972	3.983000554	1	0.25614	

Table 7: Pairwise comparison matrix of alternatives with respect to the cutting quality criteria

Pairwise Comparison Matrix				Local Weight	
Alternatives	Chainsaw Cutting	Controlled Blasting	Diamond Wire Cutting	weight	Consistency
Chainsaw Cutting	1	2.533	0.397141	0.25557	acceptable
Controlled Blasting	0.394788788	1	0.156789	0.10090	CR= 0
Diamond Wire Cutting	2.517997386	6.3779985	1	0.64353	

Table 8: Pairwise comparison matrix of alternatives with respect to the environmental aspect criteria

Pairwise Comparison Matrix				Local Weight	
Alternatives	Chainsaw Cutting	Controlled Blasting	Diamond Wire Cutting	Weight	Consistency
Chainsaw Cutting	1	6.71	3.000003	0.66851	acceptable
Controlled Blasting	0.149031297	1	0.365364	0.09315	CR= 0.00436
Diamond Wire Cutting	0.333333	2.736996529	1	0.23835	

Table 9: Pairwise comparison matrix of alternatives with respect to geological aspect criteria

Pairwise Comparison Matrix				Local Weight	
Alternatives	Chainsaw Cutting	Controlled Blasting	Diamond Wire Cutting	Weight	Consistency
Chainsaw Cutting	1	3.845	0.320513	0.26487	acceptable
Controlled Blasting	0.260078023	1	0.173551	0.08796	CR=0.05774
Diamond Wire Cutting	3.119998253	5.761995033	1	0.64717	

Table 10: Pairwise comparison matrix of alternatives with respect to safety criteria

Pairwise Comparison Matrix				Local Weight	
Alternatives	Chainsaw Cutting	Controlled Blasting	Diamond Wire Cutting	Weight	Consistency
Chainsaw Cutting	1	7.513	2.35	0.64256	acceptable
Controlled Blasting	0.133102622	1	0.320513	0.08622	CR=0.00006
Diamond Wire Cutting	0.425531915	3.119998253	1	0.27122	

Overall Ranking of the Alternatives

The overall priority of each alternative was obtained by hierarchically synthesizing the criterion weights and the corresponding local priorities.

Chainsaw Cutting	0.48668	
Controlled Blasting	0.09298	
Diamond Wire Cutting	0.42034	

Figure -2 Global priority ranking of the three extraction alternatives.

Chainsaw cutting received the highest global priority (0.48668), followed by diamond wire cutting (0.42034), while controlled blasting received the lowest priority (0.09298). Thus, chainsaw cutting ranked highest under the criteria and expert judgments incorporated into the AHP model. All reported values are below 0.10. These values indicate acceptable internal consistency according to the conventional AHP criterion.

Sensitivity Analysis

Sensitivity analysis was performed separately for each of the five evaluation criteria—cutting quality, ease of use, environmental aspect, geological aspect, and safety—to examine the stability of the final AHP ranking. For each analysis, the weight of the selected criterion was varied across the evaluated range while the resulting priorities of the three extraction alternatives were observed. The analyses were conducted independently for each of the five criteria to examine how changes in each criterion weight affect the relative priorities of chainsaw cutting, diamond wire cutting, and controlled blasting.

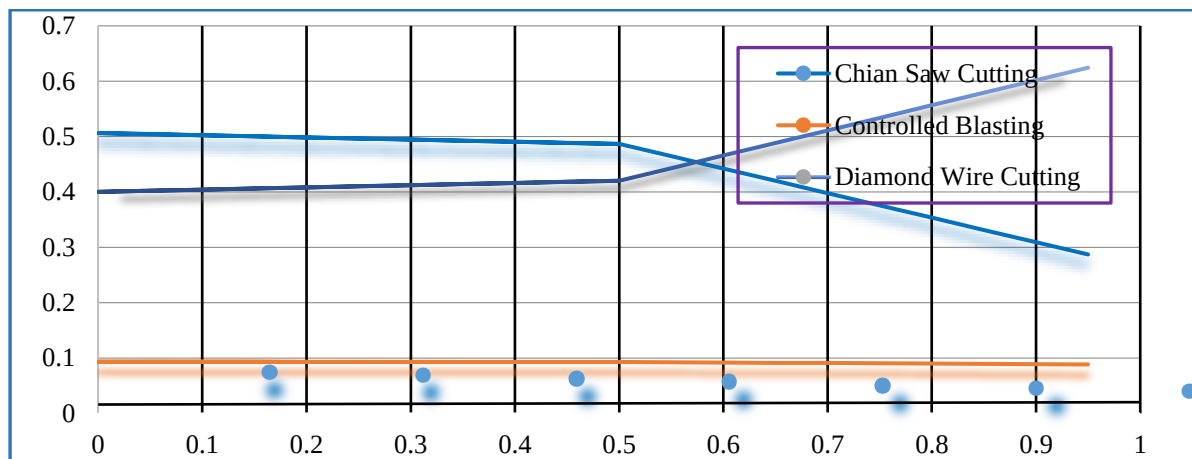


Figure 3. Sensitivity analysis of the geological aspect criterion for extraction-method selection.

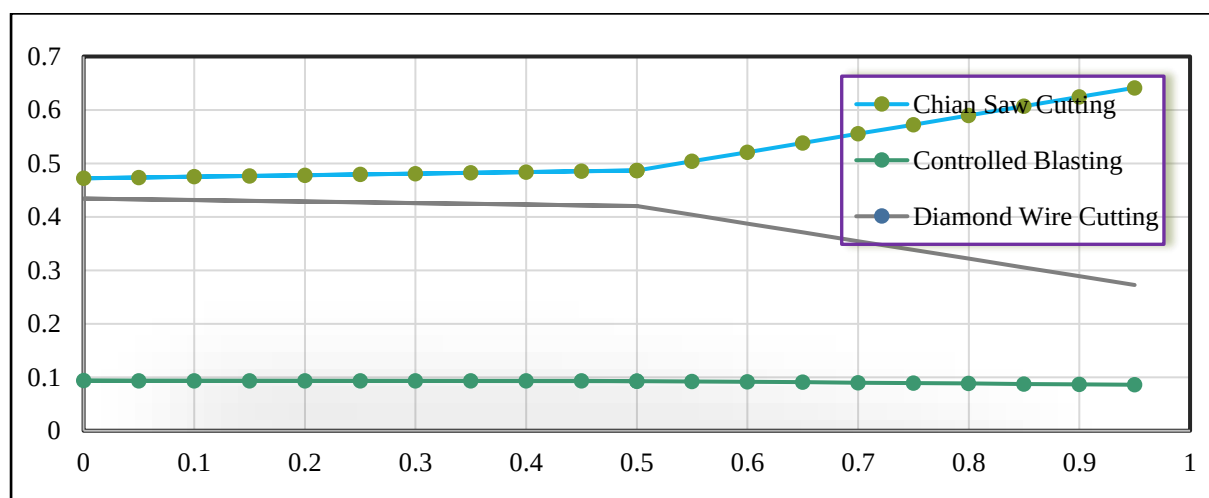


Figure 4. Sensitivity analysis of the ease-of-use criterion for extraction-method selection.

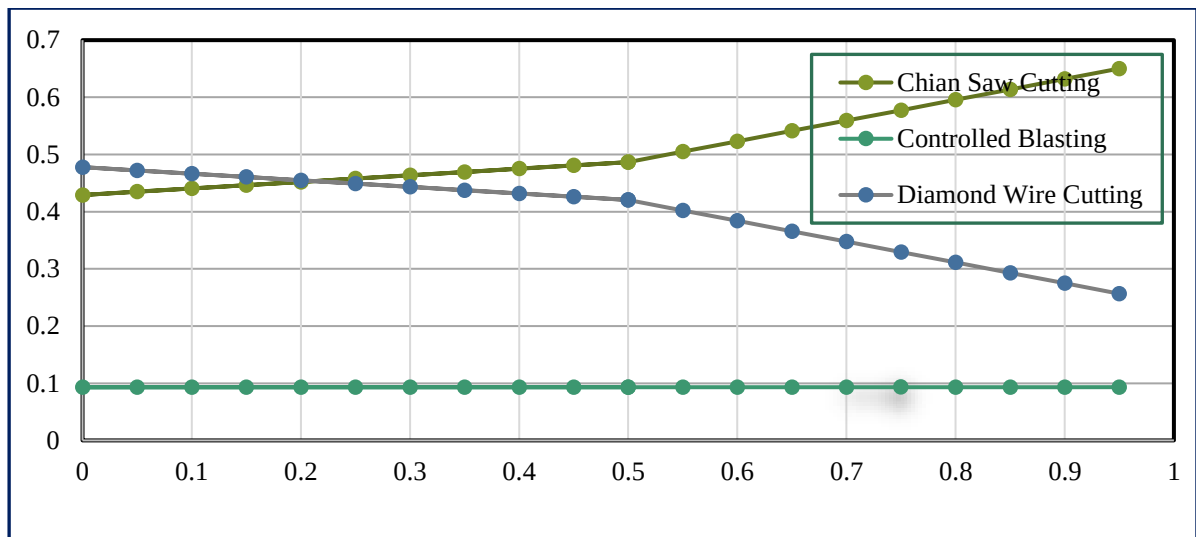


Figure 5. Sensitivity analysis of the environmental aspect criterion for extraction-method selection.

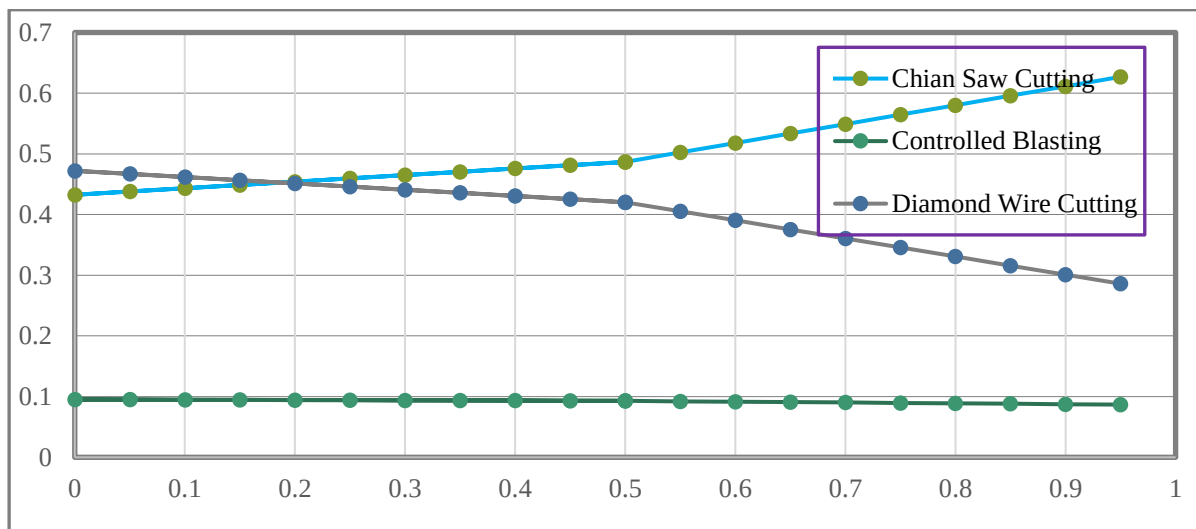


Figure 6. Sensitivity analysis of the safety criterion for extraction-method selection.

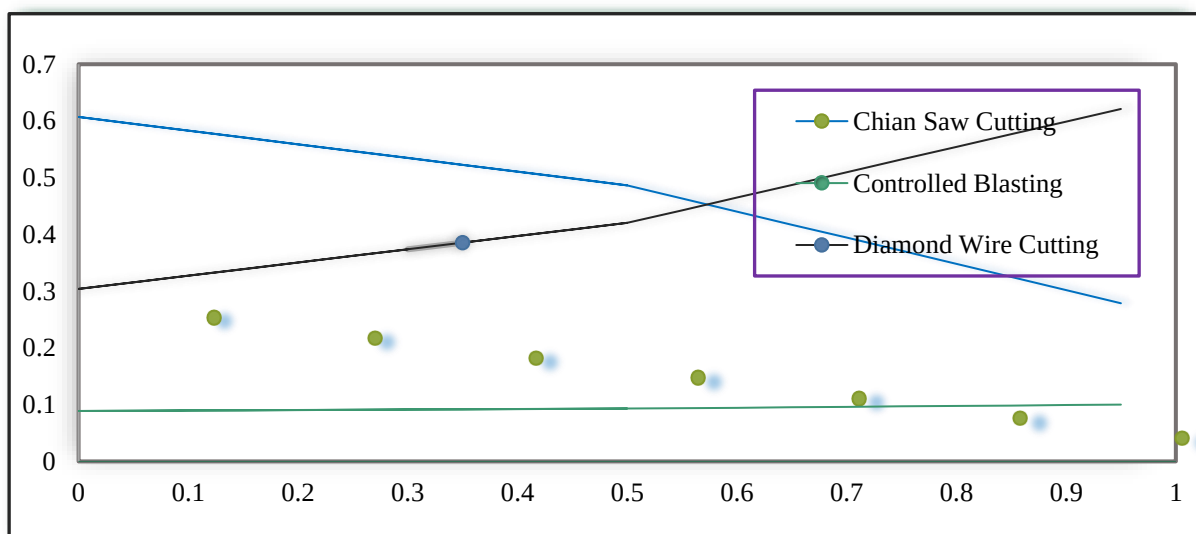


Figure 7. Sensitivity analysis of the cutting-quality criterion for extraction-method selection.

The five sensitivity analyses showed that the relative ordering of the alternatives remained unchanged within the evaluated ranges. Chainsaw cutting consistently retained the highest priority, followed by diamond wire cutting and controlled blasting. Although changes in criterion weights altered the magnitude of the alternative priorities, they did not change the final order of the alternatives within the tested ranges. This indicates that the final AHP ranking is reasonably stable with respect to variations in individual criterion weights.

The stability observed across the five separate analyses strengthens the interpretation of chainsaw cutting as the preferred alternative within the defined decision framework. However, the sensitivity results represent the robustness of the AHP ranking to changes in the specified criterion weights and should not be interpreted as independent field validation of the actual operational performance of the extraction methods.

Discussion

The AHP results provide a clear ranking of the three extraction alternatives considered for the Sabz Rang area. Chainsaw cutting obtained the highest overall priority (0.48668), followed by diamond wire cutting (0.42034) and controlled blasting (0.09298). The ranking indicates that, within the five-criterion decision framework, chainsaw cutting was the most preferred alternative according to the aggregated judgments of the 13 experts.

The criterion weights also explain the basis for this ranking. Cutting quality received the highest priority (0.34261), followed by safety (0.25772), environmental aspect (0.24037), geological aspect (0.08149), and ease of use (0.07782). These weights indicate that the expert panel placed greater relative importance on the quality of the extracted block and operational safety than on ease of use alone. Because these values come from expert judgments, interpret them as decision priorities rather than direct measurements of the physical performance of the extraction methods.

The ranking is consistent with the nature of dimension-stone extraction, where controlled separation and preservation of block geometry are important considerations. Previous research has emphasized the role of mechanized extraction techniques, including diamond wire and saw-based cutting, in achieving controlled separation and reducing unwanted damage during dimension-stone extraction (Samarakoon et al., 2023). However, the present study does not directly measure block recovery, waste generation, productivity, or environmental aspects. Therefore, the higher AHP priority of chainsaw cutting should not be interpreted as experimental evidence that it necessarily produces greater productivity or lower waste than the other alternatives.

The findings also demonstrate the importance of the decision context in mining-method selection. Previous studies have incorporated different combinations of geological, geotechnical, economic, operational, and environmental criteria. Ataei et al. (2013), for example, considered several geological, geotechnical, geographical, safety, and economic factors in mining-method selection. Patyk and Bodziony (2022) focused on mining-equipment selection using technological and economic considerations, whereas Farkaš and Hrastov (2021) evaluated quarry-design alternatives using a multi-criteria framework. More recent work by

Ccatamayo-Barrios et al. (2023) further demonstrates that different MCDM approaches can produce different priorities depending on the decision criteria and weighting structure.

These differences help explain why a particular extraction method may rank first in one case study but not in another. The present study emphasizes cutting quality, ease of use, environmental aspect, geological aspect, and safety. Consequently, its ranking reflects the priorities assigned to these criteria in the Sabz Rang case rather than a universal hierarchy of extraction technologies.

The reported consistency ratios were all below 0.10, indicating acceptable internal consistency in the pairwise judgments according to the conventional AHP criterion. In addition, the sensitivity analysis indicated that the ordering of the alternatives remained stable within the evaluated changes in criterion weights. This provides evidence that the final ranking is not highly sensitive to the tested changes in the weighting structure. Nevertheless, sensitivity stability within an AHP model should not be confused with independent field validation.

Overall, the findings support chainsaw cutting as the preferred alternative among the three methods considered under the defined decision framework. The result is particularly relevant to the Sabz Rang case because it provides a transparent basis for comparing the existing diamond wire cutting approach with two alternatives. At the same time, the result should remain site-specific and should not be generalized to other dimension-stone deposits without further geological, technical, economic, environmental, and safety assessment.

Conclusion

This study applied the Analytic Hierarchy Process to evaluate three extraction alternatives for aragonite dimension-stone blocks in the Sabz Rang area of Helmand Province, Afghanistan. The decision framework included five criteria—cutting quality, ease of use, environmental aspect, geological aspect, and safety—and incorporated the judgments of 13 mining specialists through pairwise comparisons. The final AHP priorities ranked chainsaw cutting first (0.48668), diamond wire cutting second (0.42034), and controlled blasting third (0.09298). The reported consistency ratios for the criteria matrix and the five alternative-comparison matrices were below 0.10. Sensitivity analysis further indicated that the ranking remained stable under the evaluated changes in criterion weights.

Accordingly, chainsaw cutting is identified as the preferred alternative within the specific decision framework and site conditions considered in this study. The finding does not imply that chainsaw cutting is universally superior to diamond wire cutting or controlled blasting. Rather, it reflects the expert panel's relative priorities for the five criteria selected for the Sabz Rang case. The main practical contribution of the study is the development of a transparent, site-specific decision framework for comparing alternative extraction methods for dimension-stone blocks. The framework can assist technical decision-making by making the criteria, expert preferences, consistency assessment, and final ranking explicit. Future research should complement the present expert-based assessment with field measurements of cutting productivity, block recovery, waste generation, operating cost, equipment performance, and environmental aspects. Such data would permit direct comparison between the predicted AHP preference and measured performance during actual quarry operations.

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Author Contributions

- Mohammad Wafa: Conceptualization, field investigation, development and distribution of the AHP questionnaire, expert-judgment data collection, AHP analysis using Super Decisions software, interpretation of results, and preparation of the original manuscript.
- Ghulam Sidiq Zahib: Supervision, methodological guidance, conceptual development, and critical review of the manuscript.
- Mohammad Fahim Weyaar: Methodological support, interpretation and validation of the findings, and review and editing of the manuscript.
- All authors reviewed and approved the final version of the manuscript.

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