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Ranking the efficiency of selected platinum mining methods using the analytic hierarchy process (AHP)

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The South African platinum mining industry is using a number of different mining methods, including variations of the same method, to extract the narrow reef tabular platinum deposits of the Bushveld Complex. These mining methods fall into three broad categories, namely conventional, mechanised and hybrid mining. A question sometimes asked in the industry is whether mechanized mining methods are more efficient than conventional mining methods. An objective answer requires the methods to be evaluated against multiple criteria simultaneously, whereby each criterion has a relative degree of importance in the overall decision. The most efficient method is the one that scores highest on each criterion. However, some of the criteria can be conflicting, such as by increasing dilution the shaft head grade decreases. The analytic hierarchy process (AHP) methodology was selected for the study because it is used to solve problems of this nature.

A survey was carried out to determine the relative importance of each efficiency criterion by drawing on the knowledge and experience of mine technical services and project management practitioners in the industry. Efficiency data for four different mining methods drawn from the Egerton (2004) study were used as a case study. The conventional mining method ranked as the most efficient mining method from the four methods considered. The exercise indicates potential for the AHP to be used in the South African platinum mining industry as a tool for selecting optimal layout designs, conduct regular evaluation of the performance of production shafts, or objectively evaluate line managers for promotion. The work described in this paper is part of the methodology used in a current PhD research study at the University of the Witwatersrand.

Keywords: Analytic hierarchy process (AHP); multiple criteria decision analysis (MCDA); decision-making; conventional mining, hybrid mining, mechanized mining.

Introduction

The South African platinum mining industry is using a number of different mining methods, including variations of the same method, to extract the narrow reef tabular platinum deposits of the Bushveld Complex. Some of the mining methods are still under trial for assessment as alternatives to those in current use. These mining methods fall into three broad categories, namely conventional, mechanized and hybrid mining (Figure 1).

Conventional mining includes up-dip, down-dip and breast mining. Mechanized mining includes room and pillar, room and pillar with T-cut, extra low profile (XLP) and continuous rock cutting technology. Hybrid mining includes two-drive and three-drive on-reef scattered breast mining. Hybrid methods were developed to maintain the advantages of conventional mining on reef such as low dilution and a high shaft head grade, while adding the many advantages of mechanized development such as faster development rates and safer operating procedures (Egerton, 2004).

A question sometimes asked in the industry is whether mechanized mining methods are more efficient than conventional mining methods. An objective answer to this question requires that the methods be evaluated against multiple criteria simultaneously, whereby each criterion has a relative degree of importance in the overall decision. The most efficient method then is the one giving the highest score on all the criteria. This paper provides a methodology for answering the question by drawing case study data from Egerton (2004). Egerton (2004) used eight criteria to report the efficiencies of eight mining methods for mining the UG2 reef of the Bushveld Complex based on a design capacity of 100 000 tpm. For purposes of illustration and proprietary reasons, only four of the eight methods are presented in Table I, but selected to include all the three broad categories of mining methods. For the same reasons, data for some criteria are reported as relative data. The on-reef replacement ratio for conventional mining of 165.7 m²/m might seem high but reduces to ±40 m²/m when off-reef development metres are factored in. It is not immediately clear from Table I which of the mining methods is the most efficient. The best mining method is the one giving the best trade-off between maximizing shaft head grade, extraction ratio, production rate, replacement factor and productivity, while simultaneously minimizing dilution, capital costs and operating costs.

The criteria shown in Table I cannot be directly aggregated since they are measured in different units. The analytic hierarchy process (AHP) methodology can be used to resolve this problem because it allows for the data to be normalized and subsequently aggregated. AHP belongs to a group of techniques called multiple criteria decision analysis (MCDA) techniques. The work described in this paper is part of the methodology used in a current PhD study at the University of the Witwatersrand.

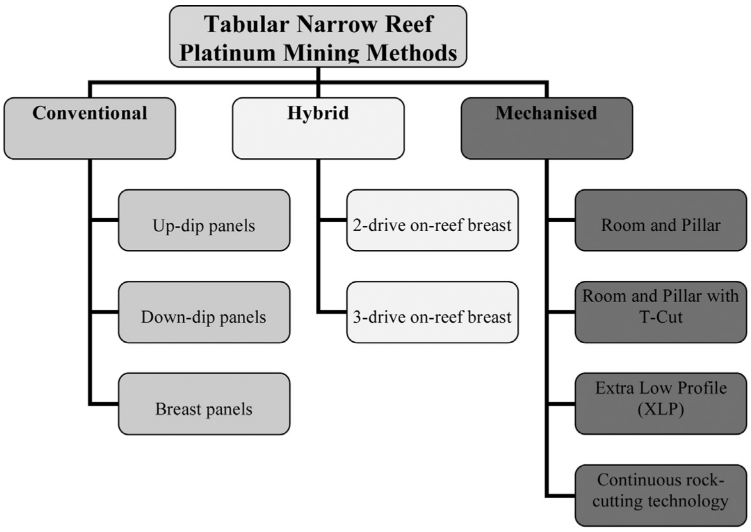


Figure 1. Classification and examples of underground platinum mining methods in South Africa

Table I
Efficiencies of four mining methods to mine the UG2 (Source: Egerton, 2004)

Criterion method	Shaft head grade (g/t)	Extraction ratio (%)	Dilution (%)	Production rate (tpm)	On-reef replacement ratio* m²/m	Capital costs** (R/t)	Operating costs** (R/t)	Productivity (t/half level)
Room and pillar (R&P)	2.36	72	42	100 000	-	124	120	27 240
R&P with 2 m T-cut	2.87	69	30	100 000	2.9	122	130	13 535
Two-drive breast hybrid	3.62	89	11	100 000	36.2	104	220	19 166
Conventional breast	3.77	94	7	100 000	165.7	100	250	17 644

Key: *excludes off-reef development metres
**relative costs, not absolute values

MCDA techniques

MCDA-type problems require decision-makers to select the best alternative or group of alternatives from a finite set of alternatives using two or more criteria that can be conflicting (Chen, 2006). For example, in Table I, as dilution increases the shaft head grade decreases, and as capital costs decrease the associated operating costs increase. The best method must therefore give the best trade-off among the competing criteria.

Structure of the MCDA decision problem

The basic structure of a generic MCDA problem (Table II) is premised on requiring a decision-maker to select an alternative, A_i, from a set of alternatives $A = (A_1, A_2, \ldots, A_m)$, such that A_i gives the best trade-off on decision criteria defined by a set $C = (C_1, C_2, \ldots, C_n)$. Each criterion has a greater or lesser degree of importance relative to other criteria in the overall decision. The decision-maker uses the efficiency of each alternative on each criterion to compare the different alternatives. In total there are m alternatives and n criteria. The efficiency of alterative 1 against criterion 1 is expressed as E_{11}, that of alternative i against criterion j is expressed as E_{ij} and so on, as shown in Table II by the matrix, $E = \{E_{11}, \ldots, E_{ij}, \ldots, E_{mn}\}$.

Categories of MCDA techniques

During the last thirty years, the original algorithms of most MCDA techniques have undergone various enhancements or have had their aggregation mechanisms changed, resulting in new methods or improvements on existing ones (Chen, 2006; Geldermann and Rentz, 2005). However, only four broad categories of MCDA methods can be identified. These are the French version *elimination et choix traduisant la réalité* (ELECTRE, which was translated into the English version elimination and choice translating the reality), preference ranking organisation method for enrichment evaluation (PROMETHEE), multiple-attribute utility (MAUT) and analytic hierarchy process (AHP) and its generalization the analytic network process (ANP) (de Almeida, Alencar and Miranda, 2005; Varlan and Le Paillier, 1999).

The methods are classified according to the type of information given by the decision-maker and the salient feature of the information depending on whether it is

Table II
The matrix structure of a generic MCDA problem

Alternatives	Criteria					
	C_1	C_2	…	C_j	…	C_n
A_1	E_{11}					
A_2		…				
…			…			
A_i				E_{ij}		
…					…	
A_m						E_{mn}

ordinal or cardinal scale information (Geldermann and Rentz, 2005). MAUT and AHP methods are most often applied when the information is cardinal while ELECTRE and PROMETHEE methods are applied to mostly ordinal scale information (Geldermann and Rentz, 2005). Data is ordinal when linguistic scales (i.e. non-numerical scales) have to be assigned to it. An example of a linguistic scale is the rating from ‘low’ to ‘medium’ and ‘high’. A linguistic scale can be assigned numerical values on a scale. For example on a scale of 1–10, ‘low’ could take any values in the range 1–3, ‘medium’ 4–6, and ‘high’ 7–10. Data are cardinal if they are expressed as a real number.

Choice of AHP methodology

The AHP was selected over other MCDA methods in this study for three main reasons. Firstly, the method has significant advantages, which are:

- When compared with other MCDA techniques, the AHP can detect inconsistent judgements and provide an estimate of the degree of inconsistency in the judgements (Coyle, 2004).
- The AHP is supported by an easy-to-use commercially available software package called Expert Choice® (Geldermann and Rentz, 2005)
- The AHP can rank alternatives in the order of their effectiveness when conflicting objectives or criteria have to be met (Coyle, 2004).

Secondly, the AHP has been successfully used to solve MCDA decision problems in the minerals industry and is gaining gradual recognition because most optimization and decision-making problems encountered in the minerals industry are of a multi-criteria nature. The examples in Table III, illustrate the wide range of multi-criteria decision problems that have been reported in recent editions of the *Journal of the Southern African Institute of Mining and Metallurgy*. Lastly, the AHP was a preferred choice because the efficiency data in Table I are cardinal data.

Overview of AHP theory

Saaty (1980) developed the AHP methodology. Matrix and vector algebra form the mathematical framework of the AHP methodology and this is the reason why AHP calculations can easily be performed in Excel. The book, *The Analytic Hierarchy Process*, by Saaty (1980) provides a comprehensive treatment of the AHP mathematical theory. A summary of the theory is presented below.

The mathematical framework starts with a pairwise comparison of the relative weight or importance of each criterion over another. The relative weight of C_i over C_j is denoted by w_{ij} such that $w_{ij} = \frac{1}{w_{ji}}$ for $i \neq j$ and $w_{ii} = 1$, for all i since a criterion is as important as itself. These weights form a square matrix $\mathbf{W} = (w_{ij})$, of order n, corresponding to the number of criteria. The matrix, $\mathbf{W}$, is referred to as a

Table III
Examples of minerals industry problems solved using MCDA techniques

Source	MCDA decision problem
Vieira (2003; 2004; 2005)	Used MAUT to select the best mining method from four possible methods to mine ultra-deep tabular gold deposits of the Witwatersrand Basin. Four mining methods were compared on the basis of 49 attributes clustered into five decision criteria.
De Almeida, Alencar and de Miranda (2005)	PROMETHEE II used to select the mining method for ornamental rocks that best satisfies a set of evaluation criteria. Six mining methods were compared on the basis of five criteria.
Liquin, *et al*. (1995)	Used AHP to select an optimal mining plan from a set of possible mining plans for a generic multi-criteria decision-making model.
Elevli and Demirci (2004)	PROMETHEE I and PROMETHEE II used to select the most suitable underground ore transport system for a chromite mine in Turkey. Five alternative transportation systems were compared on the basis of six criteria.
Dessureault and Scoble (2000)	AHP used by a mine to decide whether to purchase new drill-monitoring technology, maintain status quo, or retrain drillers and surveyors to work more productively and safely. The three alternatives were compared on the basis of six criteria.
Karadogan, Kahriman and Ozer (2008)	Used AHP based fuzzy multiple attribute decision-making methodology to select the most suitable underground mining method for the Ciftalan Lignite Mine in Turkey. Five possible mining methods were compared on the basis of 18 criteria.
Bitarafan and Ataei (2004)	Used two methods, an AHP based fuzzy multiple attribute decision-making method and fuzzy dominance method, to select the optimal mining method for extracting the No. 3 Anomaly at the Gol-Gohar iron mine in Iran. Seven mining methods were compared on the basis of 15 criteria.
Ataei (2005)	Used AHP to select the best location of an alumina-cement plant in Iran. Five possible locations were compared on the basis of five criteria.
Kazakidis, Mayer and Scoble (2004)	Used AHP based Expert Choice® software to model mining scenarios for selecting the (i) best rockbolt support system from 14 possible rockbolt support systems on the basis of 10 criteria; (ii) best option from five operational options to improve tunnelling advance rates based on seven criteria; and (iii) mine with the highest risk to mine production performance arising from ground problems, from a set of eight mines in a mining company, based on four criteria.
Uysal and Demirci (2006)	Used a hierarchical multi-dimensional objective system similar to AHP to select the more suitable mining method for the ELI and GLI coalfields in Turkey. Two mining methods compared on the basis of 19 criteria.
Wu, *et al*. (2007)	Used AHP to advise the board of directors of Wugang Mining Cooperation on the order in which the company was weakest in terms of core competence for each of the four products (iron concentrates; pellets; copper and sulphur concentrates; and non-metallic concentrates). The products were compared on the basis of eight criteria clustered into three criteria.

reciprocal matrix because the inverse of the weight of one criterion over another is equal to the weight of the second criterion over the first one. For example, if capital costs are twice as important as operating costs in choosing a mining method, then logically operating costs will be half as important as capital costs.

The matrix, **W**, of weights is then evaluated for transitivity. A relationship is transitive if the relative importance is multiplicative. For example, if criterion $\boldsymbol{C}_2$ is twice as important as criterion $\boldsymbol{C}_1$ and criterion $\boldsymbol{C}_3$ is three times as important as $\boldsymbol{C}_2$, then it follows that criterion $\boldsymbol{C}_3$ should be six times as important as $\boldsymbol{C}_1$. A matrix satisfying the transitive axiom represents consistent judgements. Typical human judgements are characteristically inconsistent to a greater or lesser degree and cannot satisfy the transitive axiom. The AHP methodology provides a way of measuring the degree of inconsistency in judgements.

The transitive relationship between weights can be expressed mathematically as $w_{ik} = w_{ij}w_{jk}$ for all i, j, and k. A vector, $\boldsymbol{w}$, of order $\boldsymbol{n}$ can be established such that $\mathbf{W}\boldsymbol{w} = \boldsymbol{\lambda_w}$. The vector, $\boldsymbol{w}$, is called an eigenvector of the matrix **W** and the constant λ is its corresponding eigenvalue. If the matrix, **W**, is consistent then $\lambda = \boldsymbol{n}$. For inconsistent human judgements, the eigenvector, $\boldsymbol{w}$, cannot satisfy the earlier condition but will satisfy the condition $\mathbf{W}\boldsymbol{w} = \boldsymbol{\lambda_{max}w}$ such that $\lambda_{max} \geq \boldsymbol{n}$. The difference between λ_{max} and n indicates that there is some inconsistency in the judgements but, if $\lambda_{max} = \boldsymbol{n}$ then logically, the judgements were consistent.

Several methods are available for estimating the eigenvector. Of these, a close approximation of the eigenvector is obtained when geometric means are used to estimate the eigenvector elements. The rationale for geometric means is simple. If a typical scale of 1 to 10 is used to denote the relative weights, then from the reciprocity axiom, the reciprocal weights 0.1 and 10 will differ by an order of magnitude of 100. Costa (2007) indicated that geometric means are meaningful when evaluating data that differs by several orders of magnitude, the minimum order being three (i.e. the largest number is three times as big as the smallest number in the data-set). The geometric mean is useful for such data because unlike the arithmetic mean, it tends to dampen the effect of very high or low values, which could bias the mean if an arithmetic mean were calculated (Costa, 2007).

A Consistency Index, *CI*, is then calculated from λ^{max} and $\boldsymbol{n}$ using the relationship defined by Equation [1].

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \qquad [1]$$

In order to determine if judgements are reasonably consistent a *C*onsistency *R*atio, *CR*, is calculated by assessing the calculated *CI* against judgements that are made completely at random. Saaty (1980) simulated large samples of random matrices of increasing order and calculated their corresponding *CIs* which are random indices, *RIs*. For matrices of order between 1 and 15, Saaty (1980) established the corresponding *RIs* as shown in Table IV.

The *CR* is obtained by dividing the *CI* by its corresponding *RI*. Saaty (1980) suggests that if the *CR* exceeds 0.1 then the judgements are likely to be too inconsistent to be reliable and the assignment of weights to criteria should be redone. The threshold ratio of 0.1 can be interpreted to mean that the judgments are approximately 10% random and a ratio of 1.0 would therefore mean that the judgements are completely too random to be trusted. A *CR* ratio of 0 therefore implies that judgements are perfectly consistent (i.e. not random at all). In practice *CR*s of more than 0.1 are sometimes accepted provided there is adequate justification for their acceptance (Coyle, 2004).

If the degree of inconsistency in judgements is acceptable, the efficiencies of all alternatives on a criterion, $\boldsymbol{E_{ij}}$, are then normalized to eliminate the effect of different units of measure for each criterion. For $\boldsymbol{m}$ alternatives on a criterion, the normalized $\boldsymbol{E_{ij}}$ values denoted by, $\boldsymbol{E^{N}{}_{ij}}$, are derived as shown in Equation [2].

$$E^{N}{}_{ij} = \frac{E_{ij}}{\sum_{i=1}^{m} E_{ij}} \qquad [2]$$

The matrix of normalized performance outcomes is finally multiplied by the eigenvector to obtain the aggregated AHP performance score. The decision is then made based on the logic that the higher the AHP performance score, then the more preferable the alternative.

AHP limitations

There are three main limitations of the AHP methodology. Firstly, the AHP works only if the matrix for the criteria weights is a positive reciprocal matrix (Coyle, 2004). Positive reciprocity is satisfied if criterion $\boldsymbol{C}_i$ is x times more important than criterion $\boldsymbol{C}_j$ and correspondingly $\boldsymbol{C}_j$ is $\frac{1}{x}$ times as important relative to criterion $\boldsymbol{C}_i$. Secondly, when the scale for measuring the relative importance of criteria with respect to each other is changed, say from a scale of 1 to 10 to a scale of 1 to 20, the weight vector will also change, in some cases affecting the final decision (Coyle, 2004). Lastly, as the number of criteria to be compared increases, the number of pairwise comparisons increases rapidly following a power function, as shown in Table V, thus clouding judgement and rendering the calculations more complex . For example, for the recommended maximum number of criteria of 9, a total of 36 comparisons have to be made.

Table IV
Random index (RI) for *n*-ordered matrix (Source: Saaty, 1980)

Matrix order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table V
Relationship between number of criteria and comparisons (Source: Kardi, 2006)

Number of criteria	1	2	3	4	5	6	7	n
Number of comparisons	0	1	3	6	10	15	21	$\frac{n\,(n-1)}{2}$

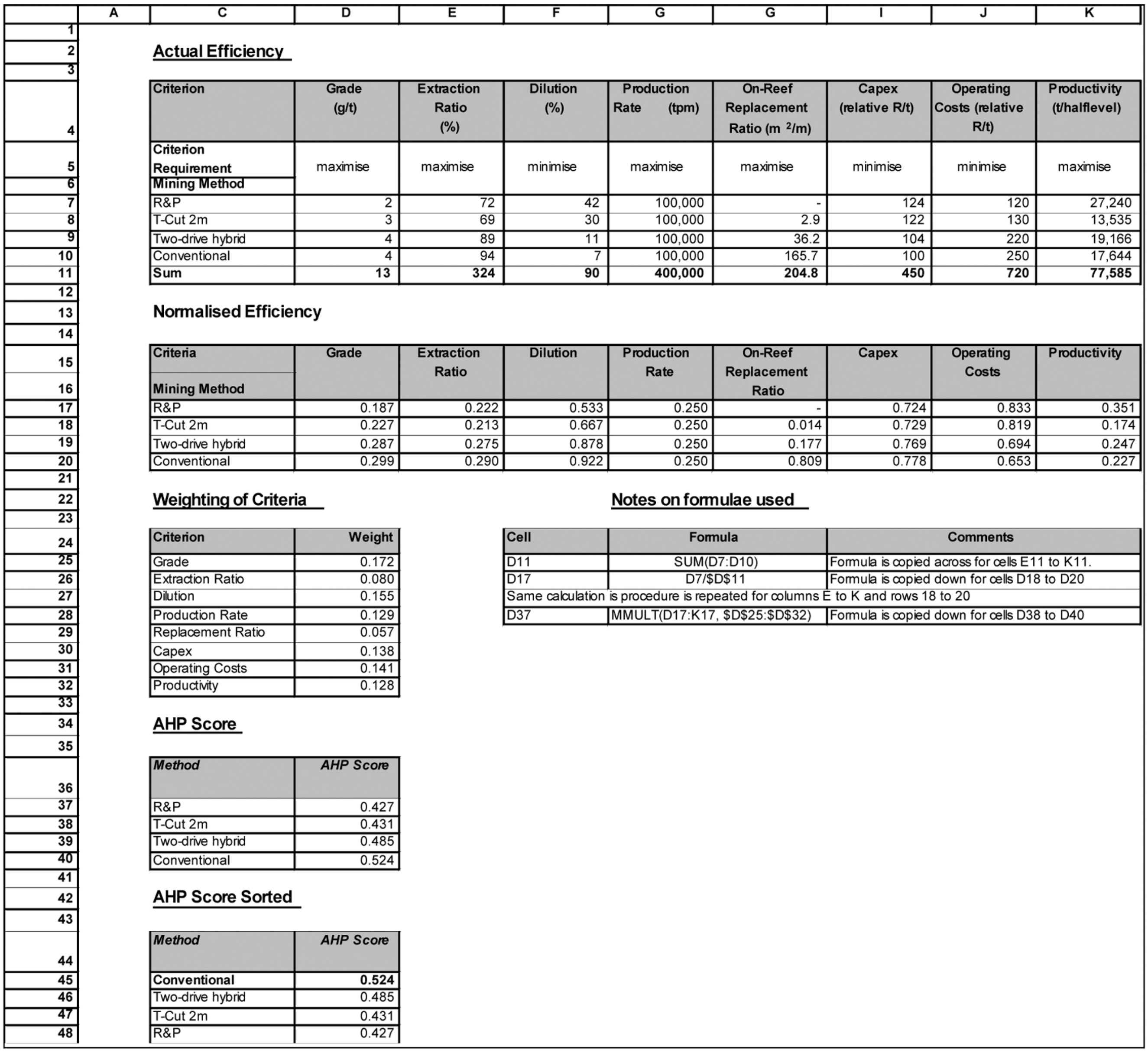
Application of AHP to Egerton (2004) case study

Prior to ranking the methods investigated by Egerton (2004), a structured questionnaire survey was undertaken to establish the relative weights of the criteria. The questionnaires were completed by three independent divisions, namely Anglo Platinum Mine Technical Services, Anglo Platinum Strategic Long Term Planning and Impala Mining Projects.

The survey results were subsequently analysed in Excel. Firstly, the individual responses were aggregated into a single composite industry matrix, by taking the geometric means of responses for each criterion. The weights were then normalized using Equation [2], such that the sum of the weights equals 1.00. The degree of inconsistency in the normalized weights was estimated to be about 1.2% which is less than 10%, suggesting that the judgements could be trusted. The relative weights of the criteria are shown in Table VI. The matrix of efficiencies was normalized using Equation [2] to obtain the normalized matrix of efficiencies. The weights were then applied to the normalized efficiencies of each method to obtain the aggregate AHP score for each method. The AHP score matrix is a matrix multiplication of the normalized efficiency matrix and the matrix of criteria weights. Lastly, the aggregate AHP scores were then used to rank the methods. Table VI illustrates the results obtained from the Excel exercise.

As argued by Saaty and Ozdemir (2003), Yavuz and Pillay (2007a), Yavuz and Pillay (2007b) and Yavuz (2007), the AHP produces more reliable results when the number of criteria does not exceed nine because of the general limitations on human performance on abstract thinking. Therefore the results presented in this paper can be accepted because they were derived from eight criteria. From Table VI, it is safe to conclude that the conventional mining ranked first, followed by the two-drive breast hybrid, then the T-cut and lastly, room and pillar. This finding suggests that mechanized mining methods in their current form are not more efficient than conventional

Table VI
Results of the AHP calculations



Actual Efficiency

Criterion	Grade (g/t)	Extraction Ratio (%)	Dilution (%)	Production Rate (tpm)	On-Reef Replacement Ratio (m^2/m)	Capex (relative R/t)	Operating Costs (relative R/t)	Productivity (t/halflevel)
Criterion Requirement	maximise	maximise	minimise	maximise	maximise	minimise	minimise	maximise
Mining Method								
R&P	2	72	42	100,000	-	124	120	27,240
T-Cut 2m	3	69	30	100,000	2.9	122	130	13,535
Two-drive hybrid	4	89	11	100,000	36.2	104	220	19,166
Conventional	4	94	7	100,000	165.7	100	250	17,644
Sum	**13**	**324**	**90**	**400,000**	**204.8**	**450**	**720**	**77,585**

Normalised Efficiency

Criteria Mining Method	Grade	Extraction Ratio	Dilution	Production Rate	On-Reef Replacement Ratio	Capex	Operating Costs	Productivity
R&P	0.187	0.222	0.533	0.250	-	0.724	0.833	0.351
T-Cut 2m	0.227	0.213	0.667	0.250	0.014	0.729	0.819	0.174
Two-drive hybrid	0.287	0.275	0.878	0.250	0.177	0.769	0.694	0.247
Conventional	0.299	0.290	0.922	0.250	0.809	0.778	0.653	0.227

Weighting of Criteria

Criterion	Weight
Grade	0.172
Extraction Ratio	0.080
Dilution	0.155
Production Rate	0.129
Replacement Ratio	0.057
Capex	0.138
Operating Costs	0.141
Productivity	0.128

Notes on formulae used

Cell	Formula	Comments
D11	SUM(D7:D10)	Formula is copied across for cells E11 to K11.
D17	D7/$D$11	Formula is copied down for cells D18 to D20
Same calculation is procedure is repeated for columns E to K and rows 18 to 20		
D37	MMULT(D17:K17, $D$25:$D$32)	Formula is copied down for cells D38 to D40

AHP Score

Method	*AHP Score*
R&P	0.427
T-Cut 2m	0.431
Two-drive hybrid	0.485
Conventional	0.524

AHP Score Sorted

Method	*AHP Score*
Conventional	**0.524**
Two-drive hybrid	0.485
T-Cut 2m	0.431
R&P	0.427

mining and that the performance of hybrid mining methods falls somewhere in between that of conventional and mechanized mining methods. The finding that conventional mining ranks first could partly be the reason why conventional mining still finds widespread use in the South African platinum mining industry. For example, some recent new projects such as the Impala 16 shaft and 20 shaft projects were planned on conventional breast mining (Jagger, 2006).

The stability of the ranking obtained above can be subjected to sensitivity analysis of the weights since these carry inherent subjectivity based on the experiences and opinions of individuals or individual companies surveyed. Sensitivity analysis is done particularly in cases where the degree of inconsistency is high. In this study the degree of inconsistency was low so a sensitivity analysis was not imperative.

Other AHP applications to platinum mining

There are several possible applications of the AHP to decision-making in the South African platinum mining industry. To name but a few, examples include performance evaluation of line managers for promotion, performance evaluation of operating shafts, ranking of projects competing for funding, measuring company performance on mining score card in meeting the requirements of the Mining Charter, comparison of different ore haulage systems, and the evaluation of different support systems for production stopes.

Taking the first example, consider a mining company in which the general manager position has fallen vacant and there are five production managers on operating shafts, eligible to occupy the general manager position and all have been interviewed for the post. The performance of the production managers' respective shafts over the past year are summarized in Table VII together with the personal attributes of each manager. Which of the five production managers should be hired for the general manager's position?

If the ideal candidate is one who has excellent interpersonal relations, has the most experience as a production manager, achieves the lowest production cost per tonne, writes excellent month-end reports, always meets production targets, has the lowest accident severity rate, achieves highest productivity, is running the largest shaft, and performed extremely well at the interview, then it is not clear from Table VII who should be appointed. An objective assessment to identify the best candidate may best be done using the AHP and can be defended should unsuccessful candidates challenge the decision as an unfair appointment. The personal attributes can be converted to cardinal data using Saaty's (1980) rating scale and then the performance measures normalized. The weight attached to each criterion of what is expected of a general manager can be greed upon by the selection committee making the appointment and checked for inconsistency. The product of the normalized performance scores and the associated weights is then used to rank the candidates.

Conclusions

Many decisions that are made in the minerals industry tend to be multiple criteria decisions, such as the selection of the best mining method discussed in this paper. Multi-criteria decision analysis problems can be solved using MCDA techniques. The AHP used in this study is a widely used MCDA technique for providing insight into the decision-making process. Four mining methods to mine the UG2 reef were analysed and ranked for efficiency. The methods were selected to include a method from each of the three main categories of conventional, hybrid and mechanized methods. The conventional mining method ranked as the most efficient in relation to the other three methods and this could partly be the reason why despite being a labour-intensive method, it is still used widely in the South African platinum mining industry. There is potential for increased use of the AHP in the South African platinum mining industry given that many decisions that need to be made are multi-criteria in nature as illustrated by the examples highlighted in this paper.

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Table VII
Hypothetical performance of production managers eligible for general manager's post

Criteria	Interpersonal relations	Experience at production manager level	Production cost in R/t achieved on shaft	Quality of month end reports	Degree to which production target has been met	Accident severity rate on shaft	Productivity achieved on shaft	Shaft size	Interview rating
Manager 1 shaft	Good	5 years	300	Excellent	90%	0.3 per 1000 workers	40t/man/mth	120ktpm	Excellent
Manager 2 shaft	Excellent	3 years	350	Average	90%	0.2 per 1000 workers	42t/man/mth	100ktpm	Good
Manager 3 shaft	Average	8 years	300	Good	100%	1.5 per 1000 workers	32t/man/mth	150ktpm	Good
Manager 4 shaft	Average	7 years	300	Excellent	95%	0.4 per 1000 workers	32t/man/mth	180tkpm	Excellent
Manager 5 shaft	Good	4 years	250	Excellent	95%	1.2 per 1000 workers	42t/man/mth	120ktpm	Good

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