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OPTIMIZATION OF MECHANIZED MINING LAYOUT WITHIN ANGLO AMERICAN PLATINUM

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Abstract

Anglo American Platinum Limited is constantly striving to improve safety and productivity. There are many different initiatives taking place within the organization in order to ensure continued safe operation and profitable ounces for the future. One of the opportunities and potential growth areas that has been identified and is being explored is that of mechanization.

In order to do this, the approach that has been adopted by Anglo American Platinum is to fully understand and analyse the current mechanized mining methods. Once each configuration is fully understood, the method can then be optimized and new mining technologies and systems can be developed to overcome the current shortfalls. This paper will discuss a methodology that was developed by Anglo American Platinum (in conjunction with Cyest Corporation) and adopted to optimize the mechanized mining layout and fleet configuration, and will also present the final findings of the study.

Due to the impracticability of piloting every possible option in the workplace, extensive modelling and simulation exercises were conducted to determine realistic parameters for productivity and value.

The study resulted in a full understanding of mechanized mining systems and their associated layout. From the results of the study a mining / logistic layout was developed which highlighted the following opportunities:

1. Create safe operations through the reduction of personnel in the 'high-risk zone' of stopes
2. Separate machines and personnel by use of remotely operated machines
3. Create focused mining on primary development from the production stoping, thus having dedicated teams on development and stoping.
4. Develop primary development ahead of the stoping activity. This enables:
 - a) Understanding of the geology and subsequent implementation of the correct
 - b) technology ('fit-for-purpose') required to mine that area based upon this geological knowledge

- c) Ability to install tipping points ahead of stoping, creating 'immediate stoping reserves', thus increasing flexibility and reducing production risk
 - d) Improved productivity by having adequate faces available and reduction in re-development to establish faces.
5. Quicker return on Investment due to recovering revenue from 'on-reef development'
 6. The layout allows flexibility between stope sections enabling better 'resource sharing'
 7. Optimize the long-term ratio of machine makeup of the fleet in relation to the production outputs
 8. Creates an agile mining layout allowing rapid response to market pressures.

The findings and work presented in this paper is currently being implemented at different test sites within Anglo American Platinum and will demonstrate that improved safety and productivity can be achieved through the adoption of mechanization.

Introduction

Anglo American Platinum is the world's leading primary producer of platinum group metals (PGMs) and accounts for about 40 per cent of the world's newly-mined platinum. The company is listed on the JSE Limited and has its headquarters in Johannesburg, South Africa.

By understanding and developing the markets for PGMs, Anglo American Platinum is able to sustain and, markets allowing, grow the business by leveraging the company's extensive access to PGM resources. Current South African and Zimbabwean Mineral Resources, inclusive of Ore Reserves, are estimated at 649.7 million 4E ounces, and 180.8 million 4E ounces are classified as Reserves. In order to respond to supply-and-demand shifts in the market, the company is increasing its ability to adapt production to meet short-term market movements.

Strong and sound stakeholder relations are fundamental for Anglo American Platinum to be able to sustain and grow the business. This is achieved through active engagement with our stakeholders. We recognize the value of partnerships in building capacities, improving governance, and promoting sustainable development.

Anglo American Platinum's strategy of zero harm focuses on finding engineering solutions to remove or eliminate hazards; and on sound management systems, behavioural change, and wellness in the workplace. One key aspect of this system is to explore and develop new mining technologies into the future.

For Anglo American Platinum to remain an attractive investment and to ensure ongoing returns and the ability to grow the business, it is imperative that its operations fall within the lower half of the cost curve. To improve the overall cost position, the company is focusing on four areas: value engineering, people's productivity, cost management, and overhead management.

These projects include partnerships with key stakeholders to develop new technologies and methods of mining going forward. This paper will present a methodology used to evaluate and enhance existing methods/ technologies going forward and will include a high-level case study of the potential mechanized mining methods as well as a partial comparison of each mechanized method with a conventional system.

Current positioning of underground mechanization within Anglo Platinum

Anglo American Platinum currently has underground mechanized mining methods at a small percentage of its mines.

These methods are:

- Bord and pillar (1.8 m–2.2 m stope widths using low-profile (LP) mechanized equipment)
- Breast mining (1.3 m stope width using extra-low profile (XLP) mechanized equipment)

A graphical representation of the bord and pillar and mechanized breast mining methods is shown in

Figure 1 and Figure 2. It is important to note that the abovementioned methods of mechanization are currently being used only on the UG2 reef horizon.

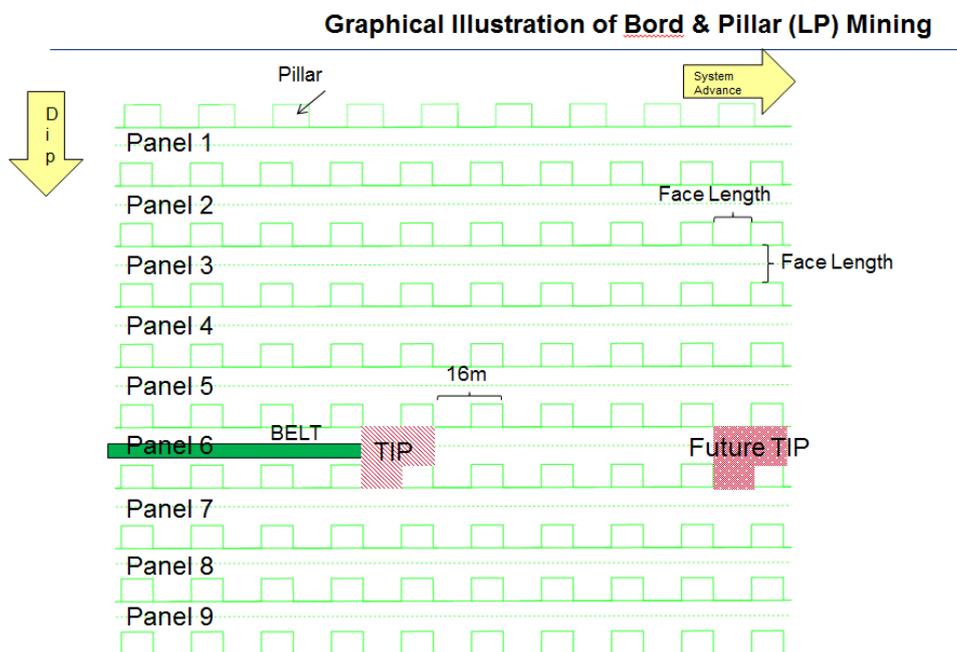


Figure 1-Graphical representation of the bord and pillar mining method with 9 bords and sequencing of belt installation

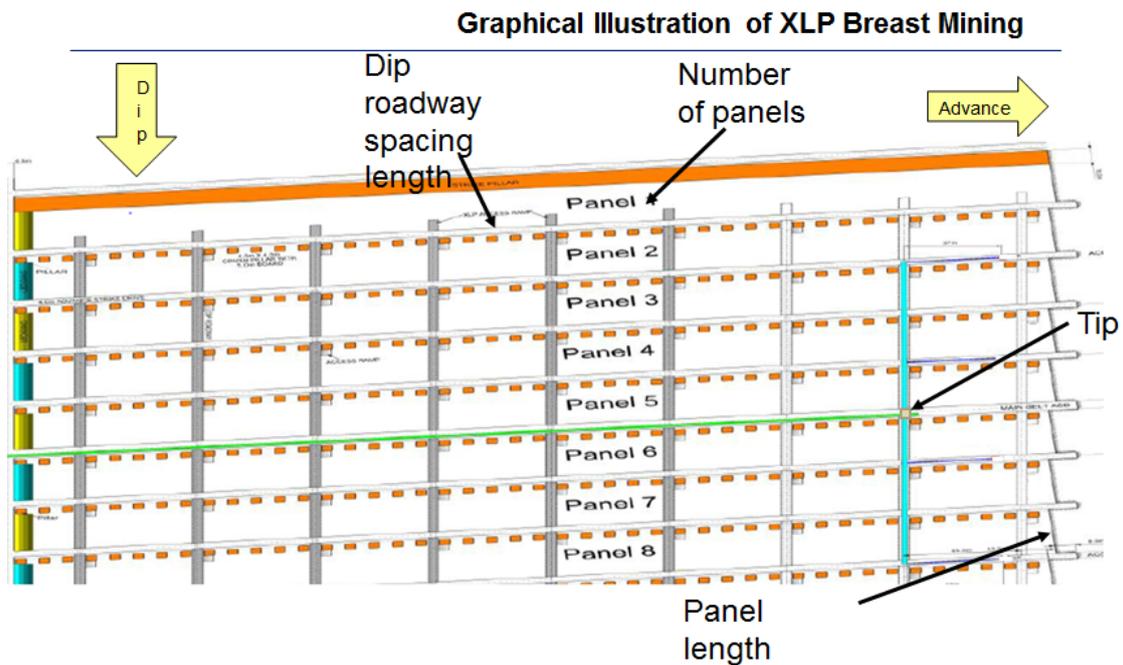


Figure 2-Graphical representation of mechanized breast mining method utilizing 8 production panels

Currently a large portion of the underground operations production is being mined conventionally, and ongoing challenges are faced with the optimization of mining operations. It is for this reason that mechanization is being explored as a means to ensure that Anglo American Platinum continues to conduct its operations safely, cost-effectively, and competitively.

Safety

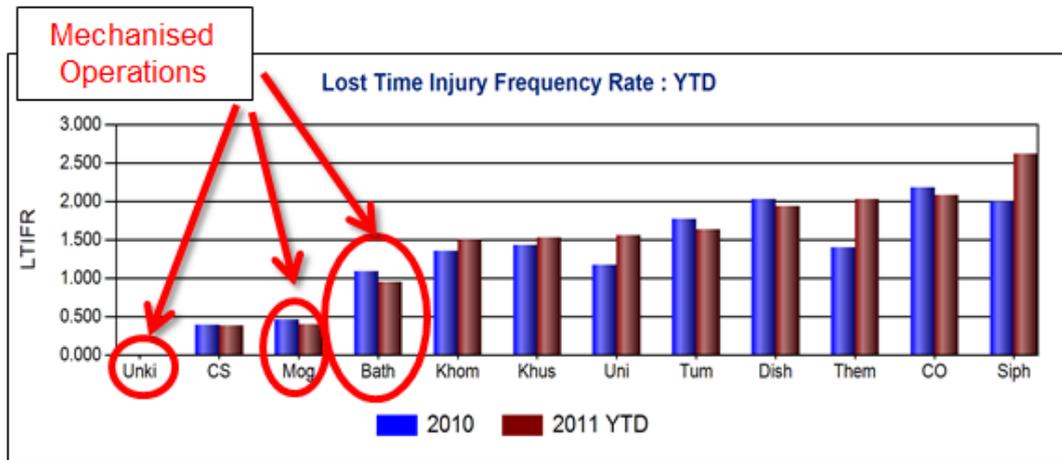
Safety is a key driver within Anglo American Platinum, and as a company it endeavours to continuously improve its safety record through its 'zero tolerance' programme.

Mechanization is therefore being explored further for the following reasons:

- Mechanization has inherent safety considerations, where the focus is to efficiently and effectively mine ore with increased productivity and reduced lost time
- There is strong correlation between improved safety performance (lower injury frequency rates) and improved productivity (square metres per operating employee).
- Additional time allocated to mechanized mining cycle time is mitigated by the decreased lost time due to fall of ground and transportation-related incidents.

When compared to other conventional mines, mechanized mining shows a favourable lost-time injury frequency rate.

This is illustrated in Figure 3.



Source: Anglo American Platinum SHE Department, 10 October 2011

Figure 3- Lost-time injury frequency rate

Productivity, cost-effectiveness, and competitiveness

In the current economic climate productivity within the mining industry has been severely constrained, with various factors affecting output and potential future productivity. Some of these factors include mandatory legislation compliance as well as the need to instil safety practices to achieve zero harm within the industry. To this end, the move towards automated mechanization has been identified as a potential solution to address Anglo American Platinum's future goals.

The platinum industry has also been severely affected by low platinum prices; the focus for the past few years has therefore been on improving internal efficiencies as well as optimizing mining methods. In terms of Mechanized mining, the following key performance drivers have been identified and focused on:

Mechanized Mining key drivers:

- m^2 per employee (labour efficiency)
- production m^2 per month (ounces, tons) ;
- extraction ratios (grade, g/t 4E);

Financial key indicators:

- Cost per ounce (rand per ounce cost 5¹, rand per square metre shaft head)
- NPV and IRR.

Evaluation methodology

In order to effect change within the industry and align with the vision for mechanized mining, a holistic evaluation of each mining method over the entire supply chain activity (from mining to treatment process) is required.

The approach that has been adopted by Anglo American Platinum is as follows:

- Understand the current mining methods through observation and modelling (production and financial)
- Optimization of mining methods
- Proposed layout recommendation.

Current mining methods

The current mining methods that were evaluated for the purposes of the study were conventional scattered breast mining, bord and pillar (LP) and mechanized breast (XLP) mining. In order to better understand these methods, significant time was spent underground observing each individual method.

Table I summarizes the current identified strengths and weaknesses of the abovementioned mining methods

¹ Cost 5 is comprised of the Direct On & Off Mine Cash Costs (inclusive of treatment), Indirect Costs, On & Off - Mine Stay in Business Capital (SIBC) as well as the On Mine Capital required.

Table I-Conventional and mechanized mining – strengths and weaknesses

Strengths		
Conventional	Bord and pillar (LP)	Breast mining (XLP)
<p>Footwall development provides flexibility of IMS reserves</p> <p>Predictable cost</p> <p>Reliable mining method</p> <p>Available resources</p>	<p>Layout simple</p> <p>High tonnage</p> <p>Low R/ton</p> <p>Safe mining method</p> <p>Better work environment</p> <p>On-reef mining with rapid establishment of mining faces</p> <p>Early return on capital investment</p>	<p>Lower stoping width</p> <p>Good extraction ratio</p> <p>High-level NPV and IRR</p> <p>On-reef mining with rapid establishment of mining faces</p> <p>Early return on capital investment</p>
Weaknesses		
Conventional	Bord and pillar (LP)	Breast mining (XLP)
<p>High labour requirement/cost</p> <p>Higher LTIF</p> <p>Labour cost high %, labour cost escalating at high rate.</p> <p>Saturated team efficiencies (averaging 350 to 450 m² per crew)</p> <p>Long lead time for production ramp-up</p> <p>Late return on capital</p>	<p>Reliant on scarce artisan labour</p> <p>Low extraction ratio</p> <p>Extraction ratio decreases with depth</p> <p>No IMS/ flexibility</p> <p>Movement and scheduling of tips not always achievable</p> <p>Strike belts restrict movement of equipment between sections</p> <p>Potential long tramming distances to tip</p> <p>Equipment constraints</p>	<p>Reliant on scarce artisan labour</p> <p>No IMS/ flexibility</p> <p>Movement and scheduling of tips not always achievable</p> <p>Strike belts restrict movement of equipment between sections</p> <p>Layout did not support suitable logistics and operational call</p> <p>Complexity of equipment</p>

Once the mining method was fully understood, it was then possible to model and optimize the method in question using the approach outlined in Figure 4.

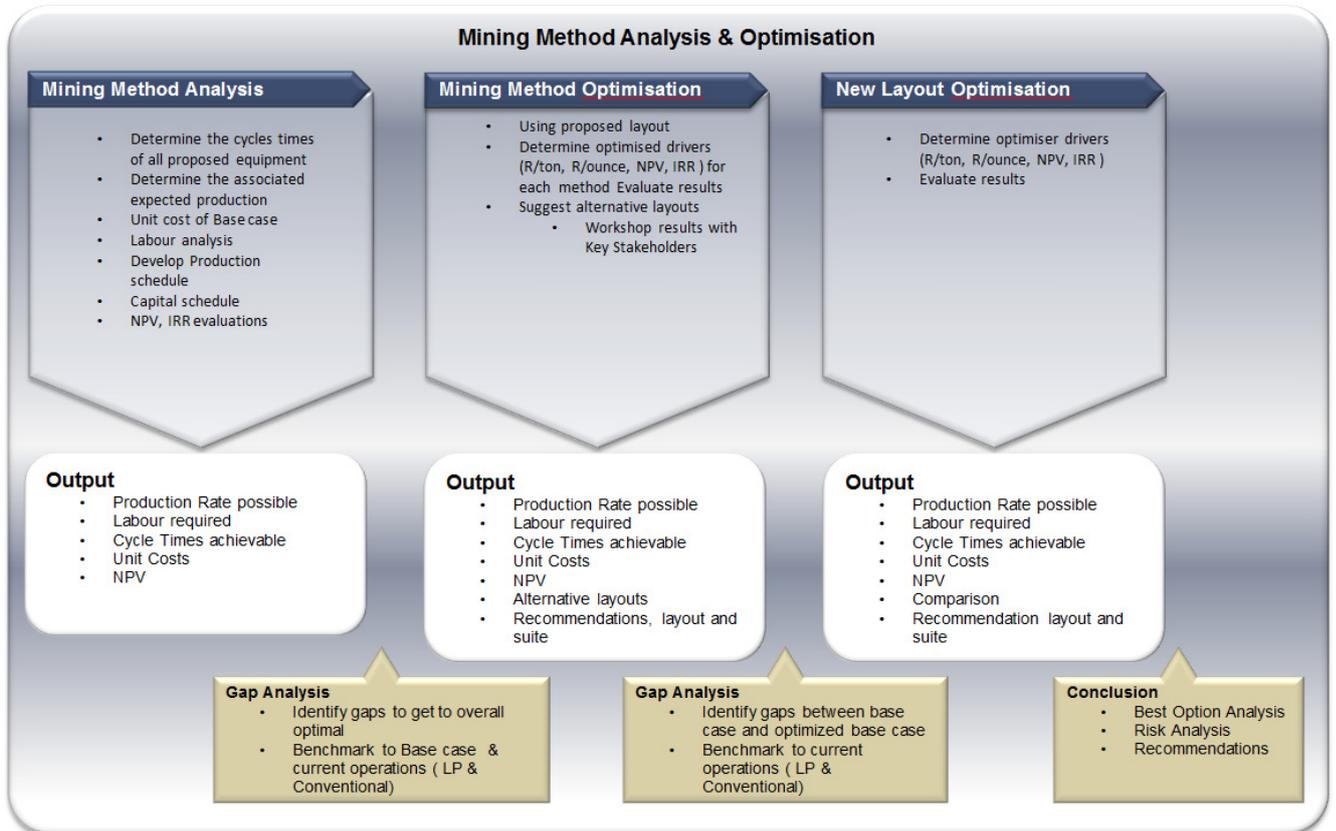


Figure 4-Mining method analysis and optimization

Mining method analysis – a modelling approach

In order to accurately model and compare each mining method a block of ground of a typical Anglo American Platinum shaft was used. The methodology is illustrated in Figure 5.

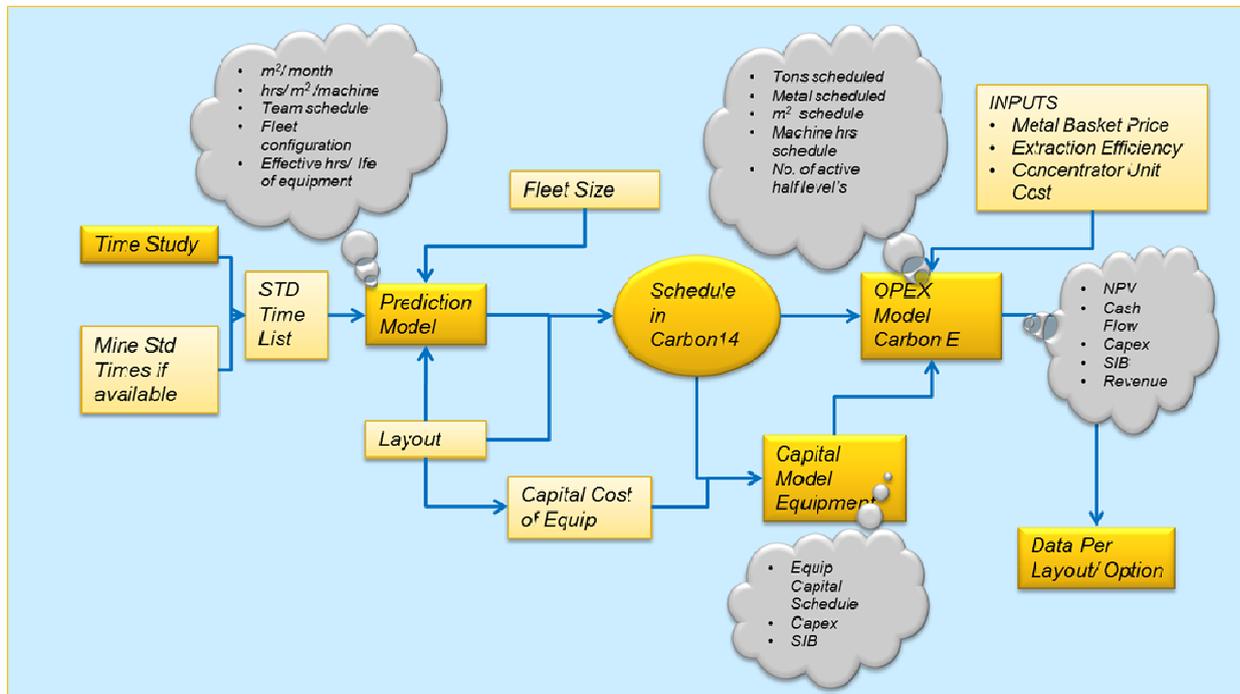


Figure 5-Mining method analysis

Time study

A detailed time study was conducted on the conventional, bord and pillar, and XLP mining methods. The time study needed to be sufficiently detailed to enable effective modelling of varying face length, stoping width etc.

Logistical study

In conjunction with the detailed time study, logistical studies were carried out using Arena™ simulation software in order to understand the logistical requirements for each option.

Prediction model

Using the time study information, standard times are calculated for each mining activity at each set of parameters. The prediction model then sequences the mining activities together to arrive at the mining cycle per shift.

Based on each activity's mining cycle, a monthly mining schedule can be modelled taking into account equipment availability, layout configuration, as well as any other constraints.

This results in a predicted monthly production rate that can be used in future mine planning. Before this can be done, a calibration exercise is necessary to ensure that what was modelled is a true reflection of reality.

Scheduling

Once the monthly production rate had been established, a schedule using a standard block of ground was developed. The use of Carbon¹⁴ Mine Scheduler from Cyst allowed for a rules-based design and production schedule to be produced in a very short space of time for all the conceived mining layouts/scenarios. Based upon the output of this schedule the capital and operating cost requirements can be determined for that specific scenario/ mining method. For each layout the correct extraction ratios and dilutions are taken into account.

Financial evaluation

In order to arrive at an optimal solution, a method was required to compare existing mining methods/ derivatives of each mining method to one another. In the case of the modelling that was done for this paper, an indicative NPV was used to evaluate each scenario. The Carbon Economics solution allowed for the rapid generation of a rules-based economic model that calculated all activity-based costs and financial output for each option and scenario considered. All aspects of capital as well as operating costs are included in the financial evaluation.

Optimization methodology

Within each method, the effect of changing the following mining parameters was measured:

1. Stope width - for bord and pillar (LP) and mechanized breast mining (XLP)
2. Face length (optimal face length based on previous conventional findings and level of complexity of equipment)
3. Mining equipment *versus* method
4. Development requirements
5. Resource availability
6. Resource size / configuration.

By changing and measuring the abovementioned parameters, one is then able to understand the interactions that exist. Once these interactions are clearly understood, the mining method

can be optimized to an optimal face length and fleet configuration with the aim of ensuring safe and profitable production.

The key performance indicators (KPIs) used for evaluating each scenario were:

1. Safety and risk
2. Labour efficiencies
3. NPV
4. IRR
5. Costs 5 per ounce (including treatment and off-mine costs but not tax)
6. Capital (sing both real and constant money terms)
7. OPEX (using both real and constant money terms)
8. Revenue (using both real and constant money terms)

Results

From the initial analysis, different scenarios and options were identified², and these were analysed using the methodologies discussed in the previous section.

The results of the analysis highlighted the importance of:

1. Understanding the process
2. Understanding the operating eenvironment
3. Importance of equipment availability
4. Logistics in the design
5. Financial considerations.

Once these items are fully understood, the mining method can then be optimized.

Understanding the process of the LP and XLP mining methods

² In total more than 600 different scenarios were analysed in order to optimize the mining method. Each permutation was based on different face length, availability, and equipment configurations

By conducting a time study, one is able to fully understand the constraints that limit throughput/production in a system; one can then extract a series of metrics to help optimize the mining method:

1. Identify the bottleneck within the activity / process
2. Quantify how non-bottleneck activities impact the constraints within the system
3. Understand the critical levers available to increase throughput of the value chain.

A detailed time study was conducted whereby the operators were observed and a full understanding of each individual process within the mining cycle was developed. The results of the time study were discussed with key mine personnel and then benchmarked against the historical times that were being achieved at the mine in order to ensure that the modelling was consistent with reality.

Once satisfied, bottlenecks and areas for improvement within the process/method were identified. An example of the analysis that was done in order to understand a process is illustrated in Figure 6 and Figure 7.

LP Roofbolting Results Panel 9 West

The graph below shows the Face Time for a 1.6m Roofbolt for LP Bord & Pillar in Class A Ground Conditions.

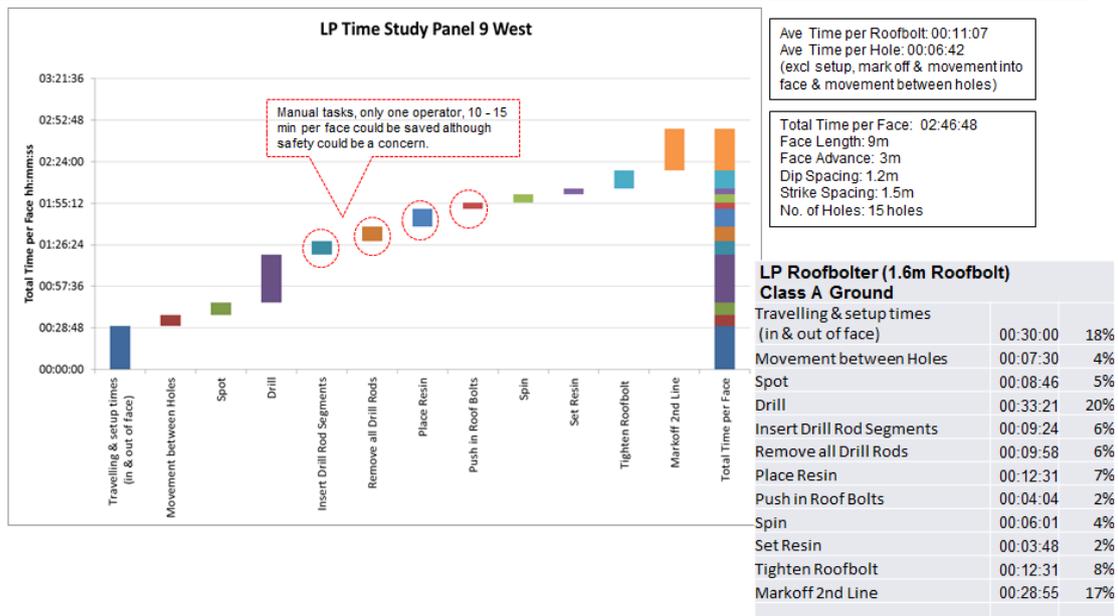


Figure 6-LP roofbolter time study results

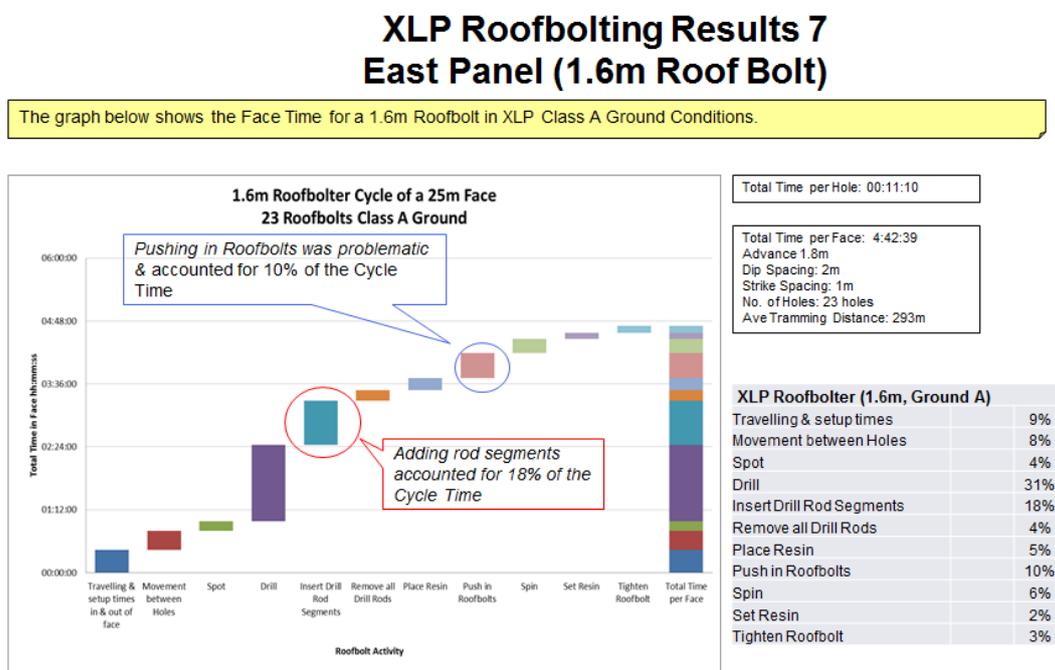


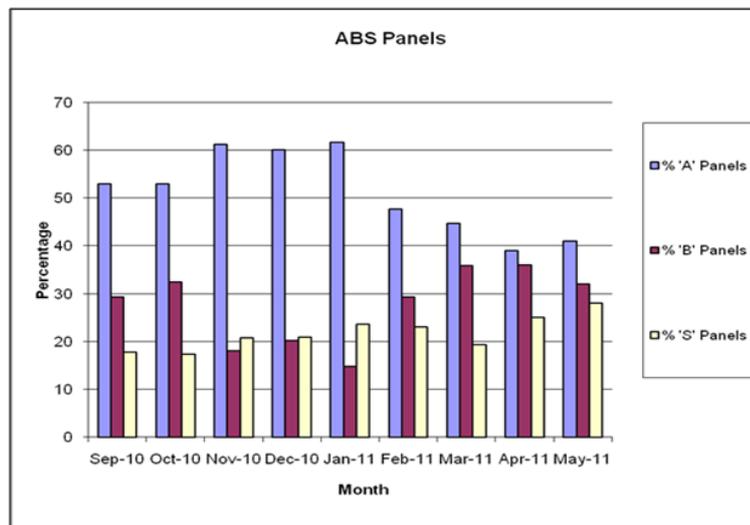
Figure 7-XLP roofbolter time study results

The operating environment

Once the process is understood, the effect that the operating environment has on the process can then be modelled and fully appreciated. In the case of roofbolting the effect that varying ground conditions and the subsequent support requirements would have on the cycle were modelled.

In order to do this the ratio of 'good to bad ground' was obtained from the mine and the production rates possible for the analysed mechanized mining were calculated. The modelling

incorporated the support standards that were specified by the mine when determining the production rate that was achievable (illustrated in Figure 8).



Source: Bathopele Mine

Support Standards (m)				
Ground Type	Strike Spacing	Dip Spacing	Panel Length	No of Roofbolts
Class A	1.2	1.5	9	15
Class B	1	1	9	27
Class S	1	1	6	18

Figure 8-Ratio of panels blasted under varying ground conditions and the required support standards for a bord and pillar section

The modelling found that if the current equipment availabilities and fleet configuration were taken into account the following monthly production rates could be achieved per a LP team for A, B, and S ground classification conditions³:

- Class A ground conditions: a production rate of 2 151 m²/month was achievable for a 9 m panel length
- Class B ground conditions: 1 431 m²/month was achievable for a 9 m panel length
- Class S ground conditions: 1 236 m²/month was achievable for a 6 m panel length.

The study also found that based on the geological mix of A, B, and S ground in the observed section, an average production of 1714 m²/month would be achieved in the bord and pillar section. This in turn explained the drop in production that had been experienced by that specific crew. The findings of this analysis could then be inferred to the XLP section.

Figure 9 illustrates that for Class A ground conditions, the LP drill rig (DR) is the limiting piece of equipment (constraint), as it is doing the most work.

³ Class A - normal ground conditions in which no undue rockfall risk is posed

Class B and S - Areas where there is an increased risk of rockfalls and which require additional support and mining strategies over and above the normal standards. These areas are to be stopped until visited by the relevant team. Thereafter, mining may continue under precautionary conditions with the panels classified as Pb or Ps.

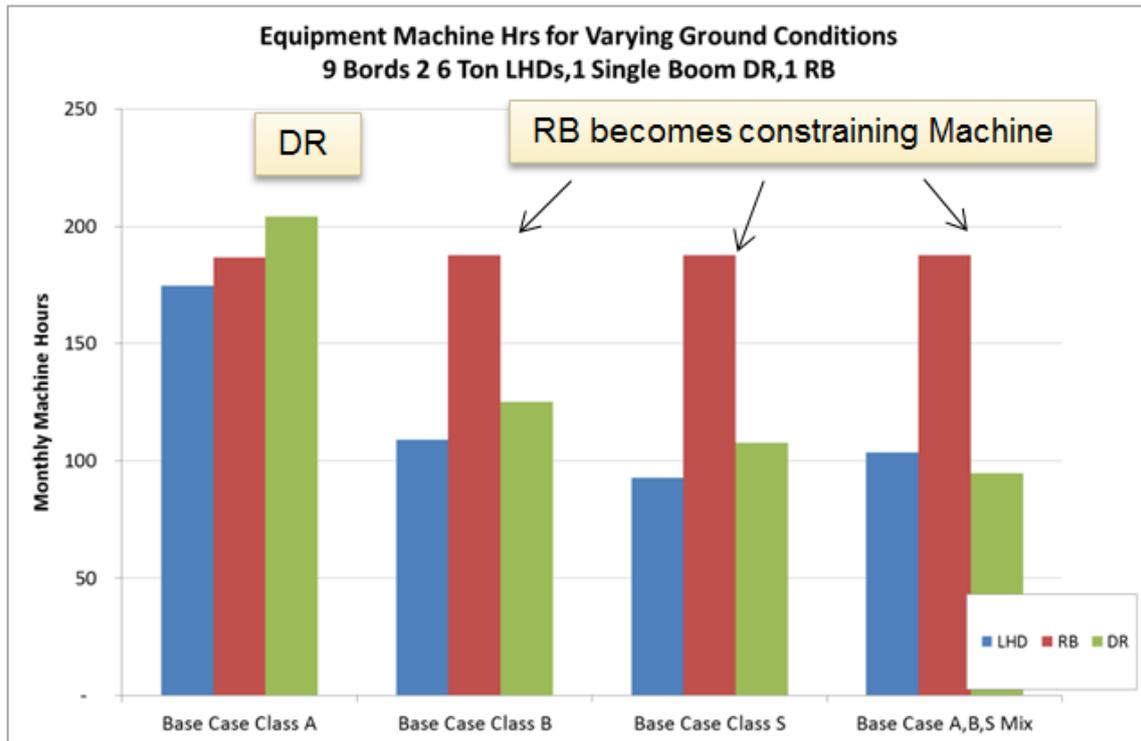


Figure 9-LP Equipment efficiency under varying ground conditions

It can be seen, however, that when the ground conditions change from the favourable Class A to the less favourable B and S ground conditions, that the LP roofbolter (RB) becomes the critical machine within the mining cycle.

Outcome: In the case of the bord and pillar Section in question, the bucket capacities of the LHDs were increased to greater than 5 t and an additional roofbolter was added to the fleet in order to ensure that the machines were utilized more effectively, thereby resulting in an increased productivity yield.

Mechanized mining method optimization

Each mining method has different constraints that ultimately influence the final delivery on production. In order to optimize each mining method, the following key levers were focused on in the modelling:

- Number of faces (the number of bords in the case of LP Mining)
- Face length
- Fleet mix.

The analysis was done on the drivers listed in Table II.

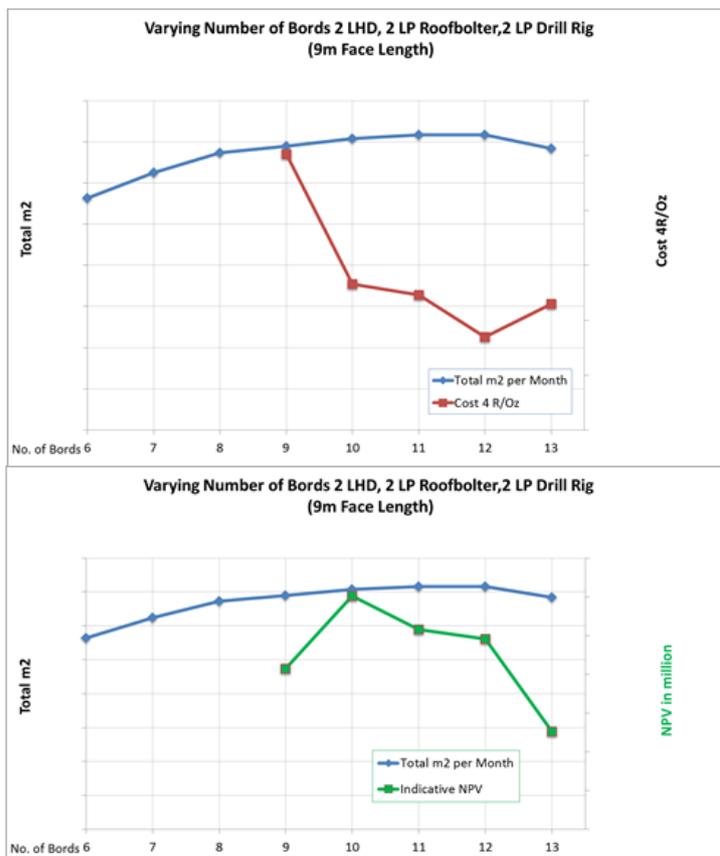
Table II-Analysed mining method parameters

Modelled criteria	LP bord and pillar	XLP breast mining
Number of faces/bords	7 to 11 bords	3 to 15 faces
Face length	9m	15, 20 & 25m
Fleet mix	LP : 2 LHDs, 1 roofbolter, 1 face rigs LP : 2 LHDs, 2 roofbolters, 1 face rigs LP : 2 LHDs, 1 roofbolter, 2 face rigs LP : 2 LHDs, 2 roofbolters, 2 face rigs LP : 2 LHDs ,3 roofbolters, 2 face rigs LP : 2 LHDs, 3 roofbolters, 3 face rigs	XLP : 1 dozer, 1 roofbolter, 1 face rigs XLP : 2 dozer, 2 roofbolrt, 2 face rigs XLP : 1 dozer, 3 roofbolter, 2 face rigs XLP : 1 dozer, 3 roofbolter, 3 face rigs XLP : 1 dozer, 3 roofbolter (1 swing), 3 face rigs (1 swing)

Figure 10 and

Figure 11 illustrate an example of the analysis that was done on each mining method. The matrix illustrates the relationship between NPV, cost per ounce, and square metres for the modelled fleet, face length, and panel configurations for both the LP and XLP mining methods. Based upon this analysis, an optimal solution can be determined.

Bord & Pillar: 10 Bords 9m FL 2 6t LHDs, 2 LP RB, 2 LP DR



Fleet at Current Configuration	Units	Avail.	Util
LHD	2	80%	74%
LP Drill Rig	2	80%	49%
LP Roofbolter (1.6m)	2	80%	49%

Figure 10-LP mining method optimization

The logistics and modelling analysis concluded that the optimal LP configuration was 10 bords comprising a fleet of two LHDs, two RBs, and two DRs, as this configuration resulted in the optimal NPV.

XLP Breast Mining: 25m FL 1 Dozer,3 XLP RBs,2 XLP DR



Figure 11- XLP mining method optimization

The logistics and modelling analysis concluded that the optimal XLP configuration was for six active panels with a 25 m face length comprising a fleet of one dozer, three roofbolters, and two drill rigs.

Financial considerations

In the process of optimization, many options within each mining method were explored based on the identified levers (face length, fleet mix, and number of panels/bords). From this a hills of value graph was generated to assist with a ranking exercise of the optimal configuration for the specified mining method. Figure 12 illustrates this.

NPV's for different Levers

- Face length
- Fleet mix
- Number of panels

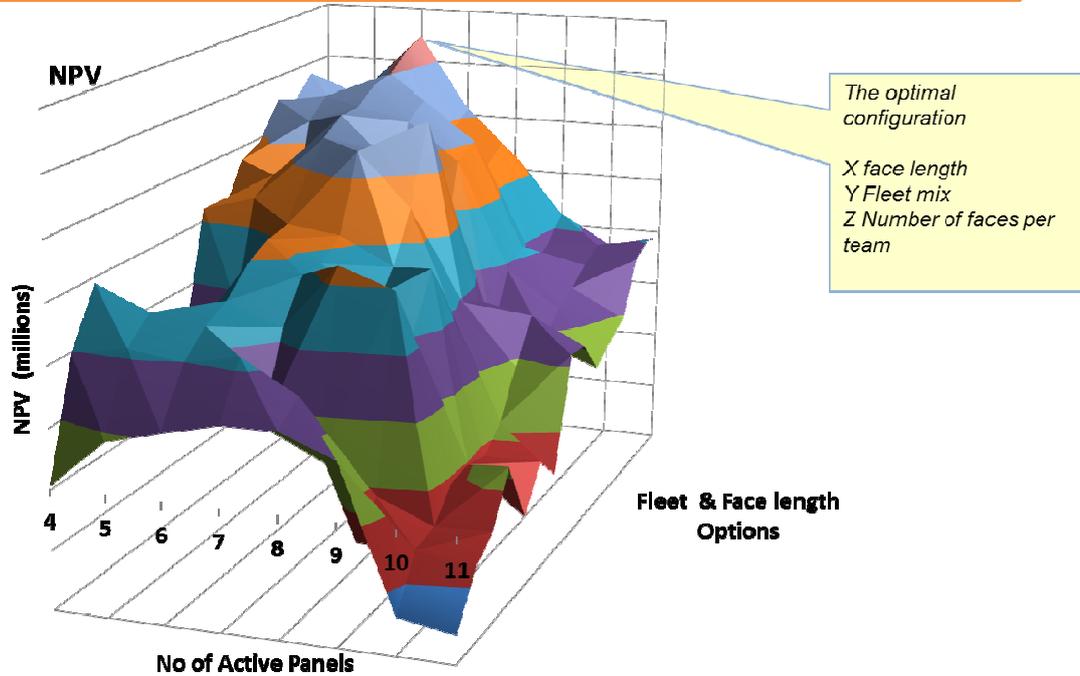


Figure 12-Hills of value NPV

The cost per ounce (rand per ounce) and NPV KPI metrics for conventional scattered breast mining, bord and pillar (LP), and XLP mining methods are shown in Figure 13.

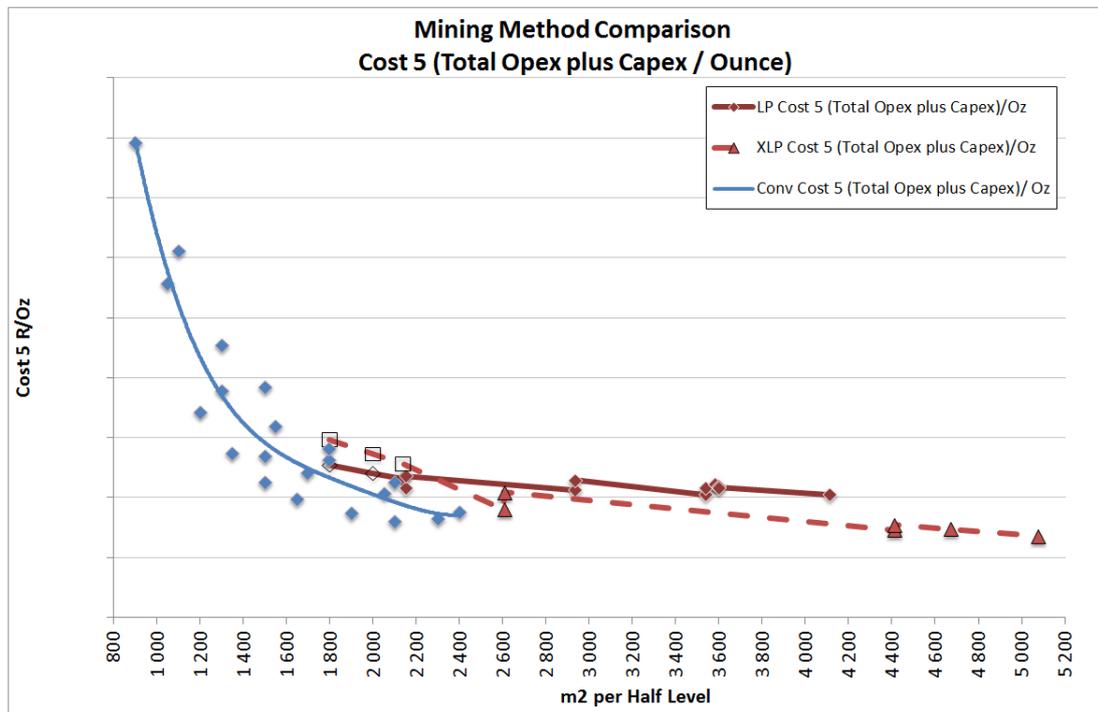


Figure 13-Mining method comparison cost 5 rands per ounce ('000s)

The cost 5 rand per ounce (all costs up to treatment excluding tax) analysis shows a similar cost per ounce between the three mining methods, but clearly illustrates the escalation in costs at the low end performance (800 -1 400 m² per half level) of conventional mining. This highlights the need for consistent performance in conventional mining in order to compete against the other mining methods on a cost 5 rand per ounce basis.

Furthermore, the NPV results (Figure 14) show that the on-reef mechanized methods have favourable NPVs, as a majority of capital development costs are offset by revenue generated by on-reef development and the resultant earlier ounces from the stoping activities. What is also of interest is the low-performing options of conventional mining (less than 2000 m² per half level), resulting in a negative NPV.

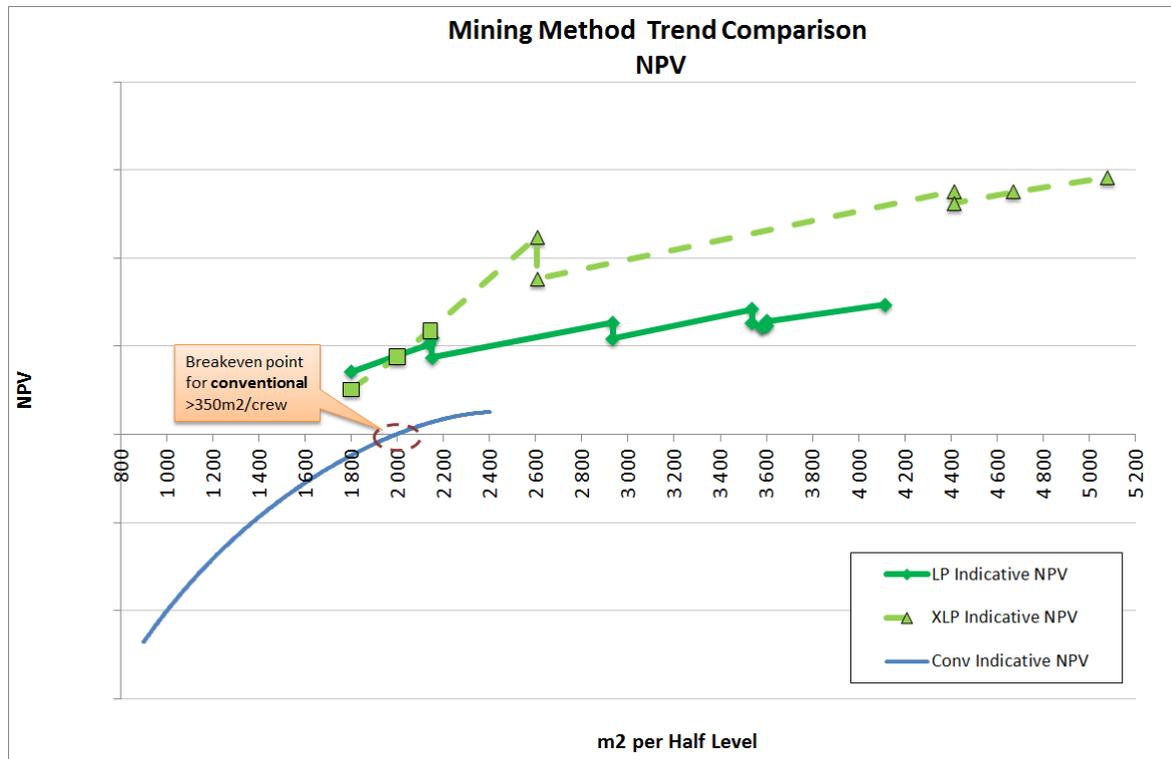


Figure 14-NPV trends using various mining methods⁴

From the results and analysis work the following elements were identified as important criteria to be incorporated into the new layout design:

Safety

- Two dedicated drives (Transport drive and strike belt drive) to separate machinery from personnel and material
- Creation of a controlled working environment through the separation of primary, secondary, and stoping activities.

⁴ Note: the drop in NPV displayed in both the LP and XLP mining methods shown in Figure 14 is due to the introduction of additional equipment. A trendline was fitted to obtain the conventional NPV curve

Productivity and cost-effectiveness

- Better planning due to better knowledge of geological features such as potholes, faults, and dykes
- Flexibility created through developing immediate stopeable reserves
- Create a logistical layout to assist with ore extraction, material and people transportation.

Logistics

- Pre-developed layout where infrastructure and development is ahead
- Layout designed to incorporate optimal tram distances for machinery and designed around logistics
- Opportunities created for concentrated and focused mining.

Equipment availability

Through the analysis and clear understanding of each mining method's mining cycle and the associated constraints, it became evident that another key element that had a significant effect on production was the availability of the equipment. Figure 15 illustrates the results from an analysis that was conducted on one of Anglo American Platinum's XLP sections.

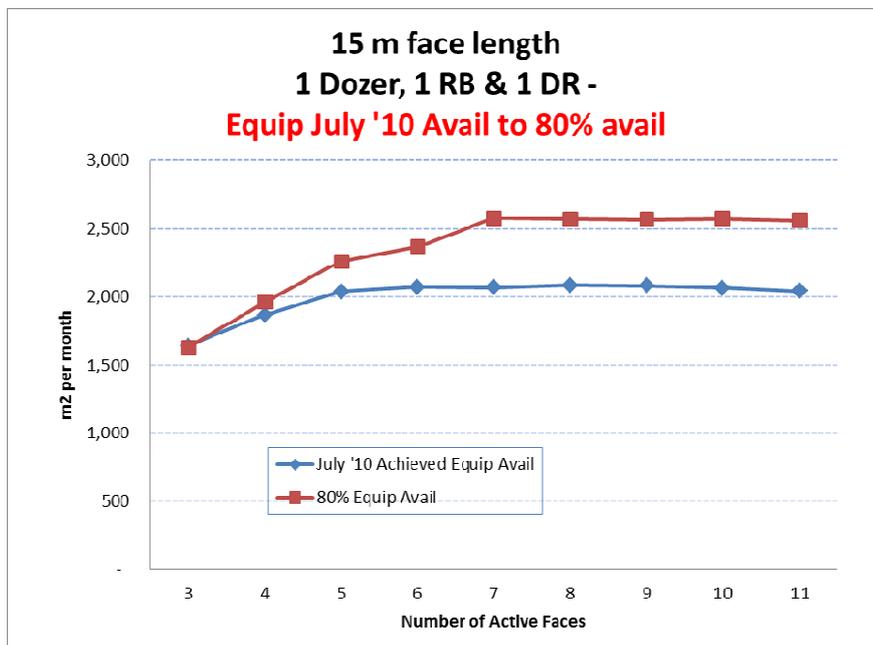


Figure 15-Effect of equipment availability on production

The analysis looked at the production that had been accomplished by the XLP section and used the equipment availabilities that were being achieved at the time of the study (July 2010) and compared the production that would have been achieved using the same equipment with a higher availability (80 per cent) using the same ground conditions.

The study concluded that there is a direct correlation between equipment availability and production. In the case of the analysed XLP section, by increasing the availability from 65 per cent to 80 per cent, the modelling predicted that a 31 per cent increase in monthly production was achievable.

Outcome: The mine worked closely with the relevant original equipment manufacturer (OEM) as well as with its employees to ensure a higher availability (80 per cent) and achieved the predicted 31 per cent increase in production. The outcomes from this analysis were also applied to the LP sections on the mine and the importance of the critical machines, availability was stressed to the OEMs.

Logistics process

In order to maximize productivity it is important that the logistics surrounding the mining method is fully understood. The logistics study⁵ that was conducted incorporated both changes in tram distances as well as the specified OEM bucket capacities in order to determine the tonnage that could be moved per hour by:

Two 3 t LHDs

Two 6 t LHDs

Two 8 t LHDs.

From this information the average effective utilization⁶ over a period of a month was plotted and compared to the section's best achieved utilization.

Figure 16 illustrates the results of analysis that was done on the sensitivity of the LHD bucket capacity to tram distance.

⁵ A comprehensive simulation was done on the logistics using Arena™ Modelling. The study examined the effect of tram distance as well as bucket capacities.

⁶ Effective utilization is the machine Utilization multiplied by the machine availability

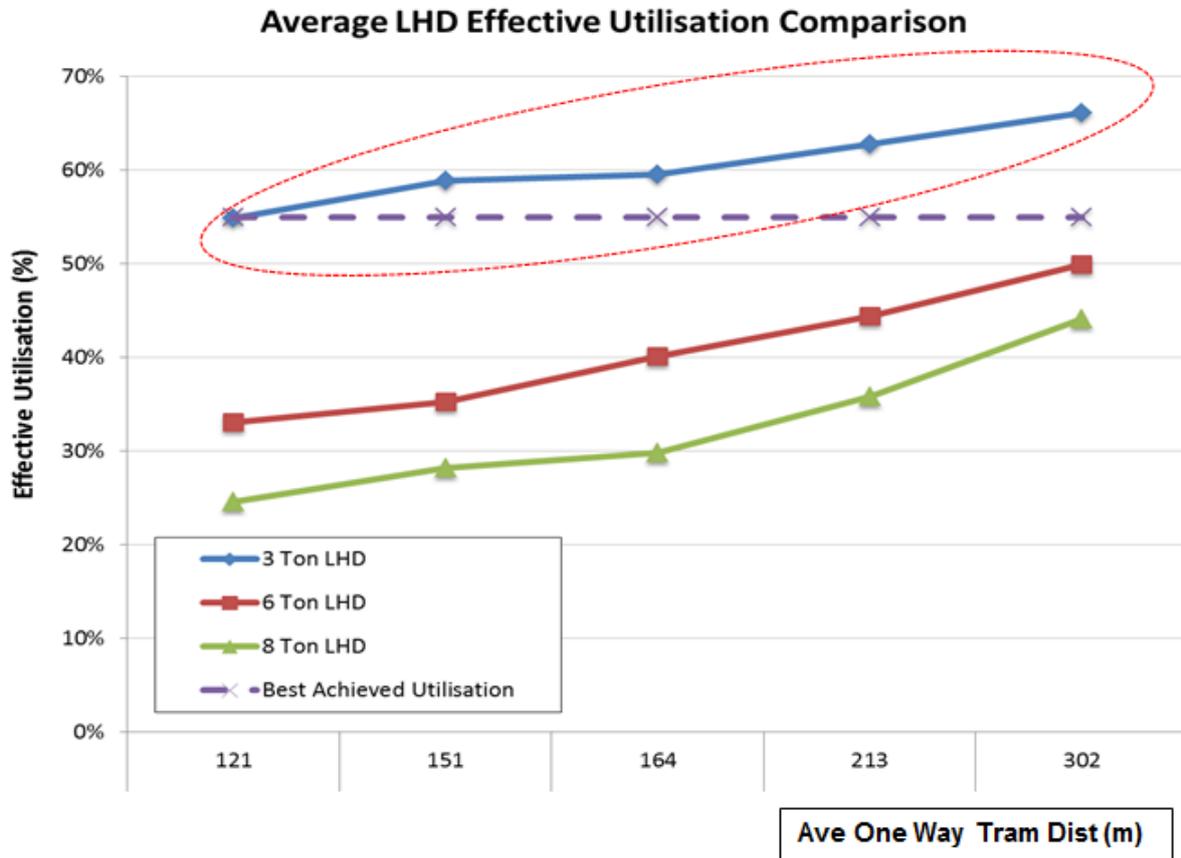


Figure 16-LHD effective utilization

The analysis showed that a 3 t LHD was a major constraint, which in turn had a marked effect on the tonnage moved (which was exacerbated by longer tram distances) and ultimately destroyed value.

Outcome: A decision was therefore made to replace the 3 t LHDs with LHD with larger bucket capacities in both the LP and XLP sections.

Low-profile Mechanized mining vision

Based upon the results achieved for the mechanized mining methods a vision for a full mechanized system going forward was developed, which is outlined in Figure 17.

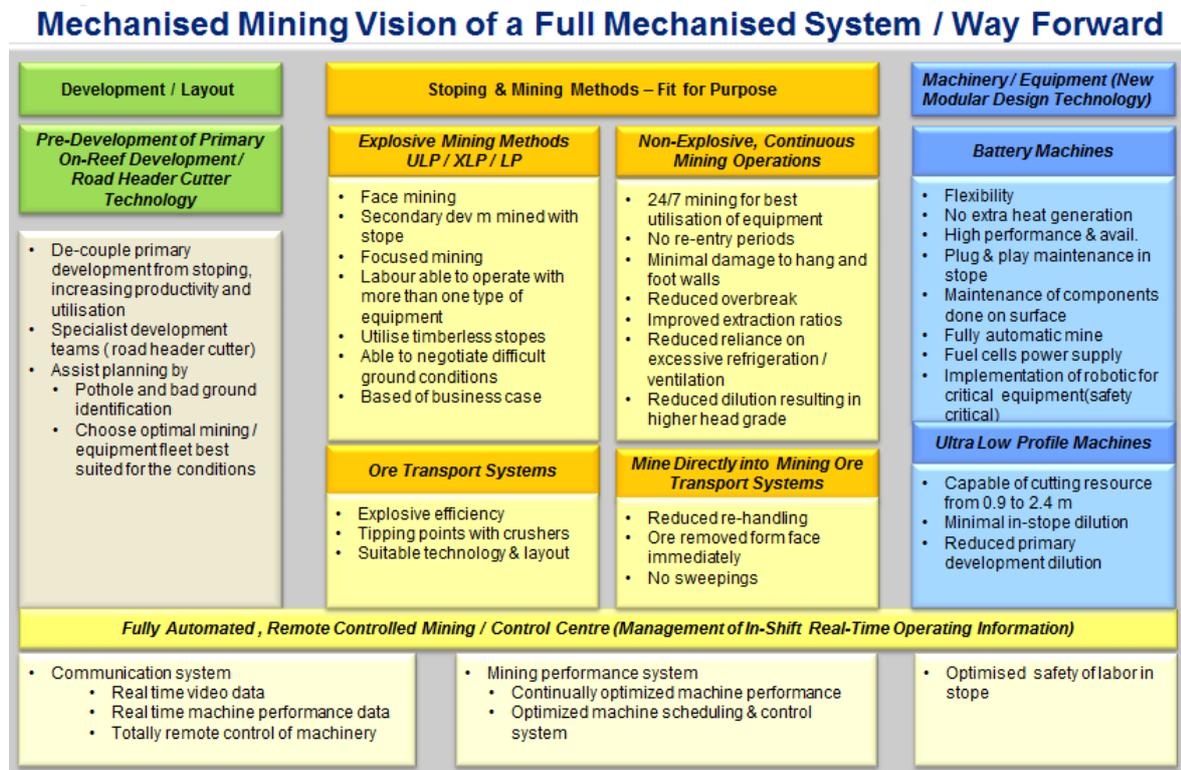


Figure 17-Mechanized mining vision

New layout

Based on the physical observations that were conducted on Anglo American Platinum's current operations as well as on the optimization work that was carried out on each mining method, a new layout has been proposed (a graphical representation of the pre-development concept is given in Figure 18 and Figure 19) incorporating the abovementioned design criteria.

The pre-development layout is initially separate from the stoping activity and later forms an integral part of the stoping layout through the establishment of raises and winzes which feed the strike belt drive. The layout focuses on an on-reef primary development structure, thereby ensuring that all the necessary services and infrastructure are in place prior to stoping. The layout incorporates pre-installed mining tips, services, and infrastructure services. To assist with this rapid development a mobile crushing unit has been developed to enhance the forward movement of the entire system.

Raise and winze dimensions have been developed to cater for various combinations of mechanized equipment and therefore not limiting the potential extraction of the mining block. The layout requires that four raise lines should be active, the first with the primary development, the second for ledging, the third for stoping, and the fourth for sweeping and vamping, as is illustrated in Figure 18.

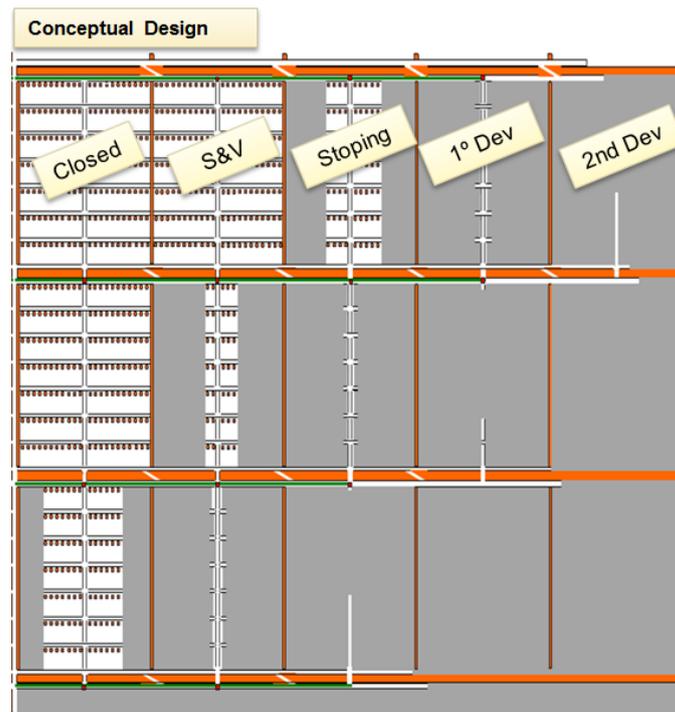


Figure 18-Conceptual design of a continuous mechanized mining system

The layout creates a safer and more productive working environment through the following:

- Separates the primary development from stoping activities
- Separates the gully development and stoping activities (pre-development completed ahead of stoping), thereby ensuring fewer people in the stope)
- Ability to predict ground conditions and potholes timeously
- Reduces the number of redevelopment delays
- In previous mining methods the movement of the tips was problematic and unreliable. The belt design currently hampers the logistics between stopes and sections; the design alleviates this by placing the belt in the footwall

- The design also guarantees the correct placement of tips
- Layout ensures a higher face availability, thereby ensuring a higher consistent average stoving efficiency
- Concentrated mining for 8 – 10 months, allowing for more permanent workshops and waiting places.

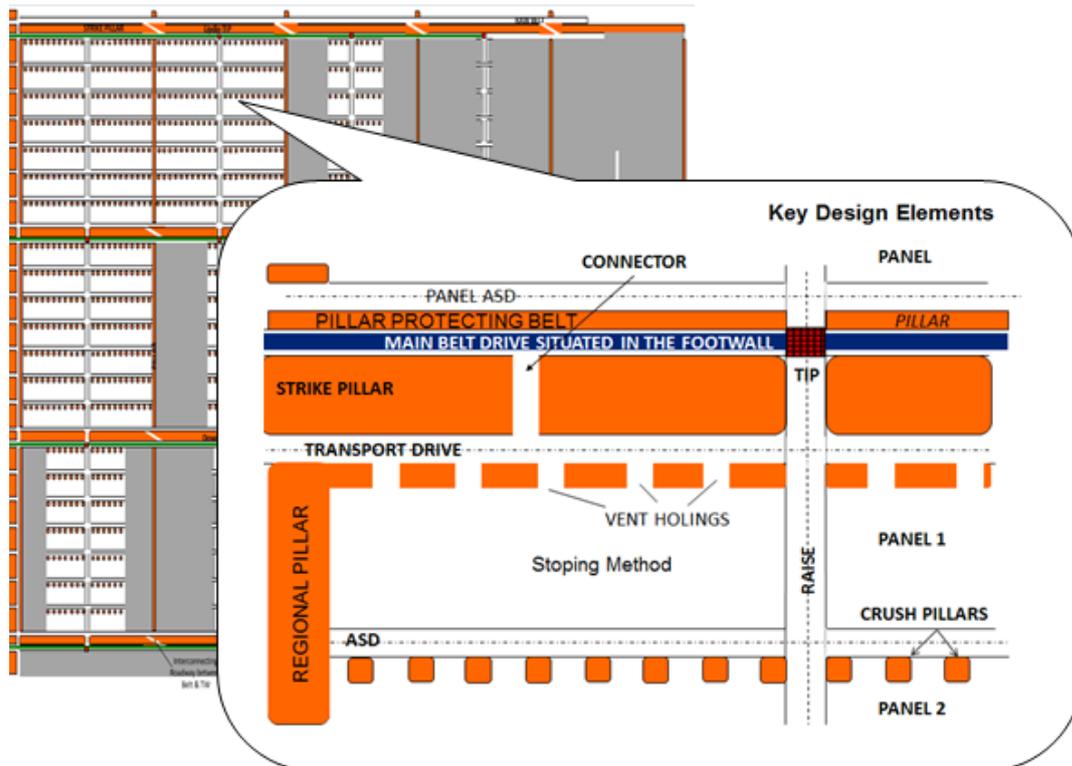
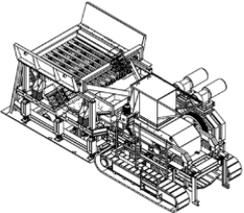
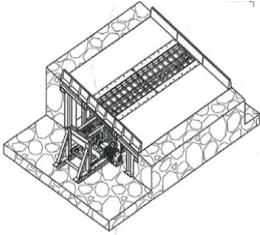


Figure 19-Detailed design of 20 m XLP breast mining section

Table III provides a brief description of the key design elements of the new layout and looks at each elements contribution in terms of safety and productivity.

Table III-Key Design Elements of the new layout

DESIGN ELEMENT	SAFETY	PRODUCTIVITY
Pre-developed and proposed stoping layout	<p>Minimized interaction between machinery and personnel</p> <p>Designated areas for labour, machinery and handling lines</p> <p>Create safe operations through the reduction of personnel in the 'high risk zone' of stopes</p> <p>In-stope remotely operated equipment</p> <p>Minimize travelling, people and machinery in an excavation due to development of designated drives for travelling and for the belt</p>	<p>Pre-developed layout ensures logistics infrastructure is ahead</p> <p>Tips are always in place</p> <p>Separate pre-development and production tipping points</p> <p>Max distance of face to Tip isn't exceeded</p> <p>Designated crew and fleet for primary development (focused mining)</p> <p>Better appreciation of geology due to pre-development being well ahead of stoping</p> <p>Separate primary and secondary development (in conjunction with stoping), checkerboarding, increasing productivity and utilization</p> <p>Specialist development teams</p> <p>Assist planning (better geological Info)</p> <p>Improved m²</p> <p>BetterFace availability</p> <p>Construction crew is part of the dev. crew</p> <p><u>Raiseline</u></p> <p>Optimal tramming distance of LHDs resulting in a better utilisation of the LHDs due to multiple tipping points (updip and downdip tips resulting in less congestion in the raiseline)</p> <p><u>Tips</u></p> <p>Tip remains for approx. 7 months</p> <p>Ore handling line transporting ore from primary dev. and stoping continuously</p>

DESIGN ELEMENT	SAFETY	PRODUCTIVITY
<p>Mobile Crusher</p> 	<p>Safety standards</p> <p>Mine Health and Safety Act – Act 29 of 1996</p> <p>SANS 10104</p> <p>ISO 7731: 2003</p> <p>EN 954-1:1998</p> <p>AFRS GUIDELINES</p> <p>SRMP GUIDELINES</p> <p>Dials and gauges are clearly visible</p>	<p>Design reduces/eliminates re-handling of big rocks</p> <p>Mobile crusher unit</p> <p>Modular design ensures that major components can be easily replaced</p>
<p>Double-sided tips</p> 	<p>Designed to create a safer environment around tip</p> <p>Safety standards</p> <p>Mine Health and Safety Act – Act 29 of 1996</p> <p>SANS 10104</p> <p>ISO 7731: 2003</p> <p>EN 954-1:1998</p> <p>AFRS GUIDELINES</p> <p>SRMP GUIDELINES</p>	<p>Double-sided tips therefore accessible either side of the raise</p> <p>Handle large LHDs without any delay</p> <p>Quick, easy/cost-effective tip moves</p> <p>Major components are easily accessible</p> <p>Tips are always in place</p> <p>Pre-dev. and production tipping points are separated therefore reducing congestion</p> <p>Max. distance from yip isn't exceeded</p>
<p>Ventilation</p>	<p>Equipment to use low-sulphur diesel</p> <p>Sufficient time to ensure the necessary ventilation infrastructure is in place prior to stoping</p>	<p>Ventilation-on-demand system</p> <p>Machines equipped with catalyst and particulate filters and Tier 2 type diesel engines</p>
<p>Rock mechanics</p>	<p>Pre-development layout provides the ability to predict ground conditions and potholes timeously</p>	<p>Development and stoping are separated ensures that the support always meets the support requirements</p>
<p>Transport drive</p>	<p>Designated drive for machinery (strike pillar separates the two drives)</p>	<p>Due to pre-development roadway quality can be assured resulting in better</p>

DESIGN ELEMENT	SAFETY	PRODUCTIVITY
		tramping speeds and fewer breakdowns
Belt drive	Designated drive for the belt and for mine personnel to travel through	Dedicated area for the belt Services run Strike pillar protects the belt

Conclusion

The core strategy of Anglo American Platinum is to conduct its business safely, cost-effectively, and productively. From the analysis that was done, it can be concluded that mechanization within Anglo American Platinum will have the following benefits:

Safety

- Minimized interaction between machinery and personnel
- Personnel are removed from risk area (zero harm) through the implementation of automation/robotics, –thereby ensuring that the operating personnel manage the mining process from a safe place
- Educated workforce, highly trained and highly knowledgeable, able to recognize risks/dangers
- Improved underground conditions through the introduction of well-controlled hanging- and sidewall conditions.

Productivity and cost-effectiveness

- Higher production levels and greater efficiencies can be achieved using mechanized equipment
- Where the production per half level is <math><1\ 800\ m^2</math> the rand per ounce costs of the two mechanized mining methods are comparable to the costs of the conventional mining method (450 m² per crew). However, the mechanized mining methods exhibit a short ramp-up-required to reach steady-state production, thus resulting in a more favourable overall NPV when compared to the conventional mining method, which required a longer ramp-up in order to reach steady-state production
- Another consideration is the further upstream benefits regarding the treatment process cost implications.

Based upon the analysis and optimisation work that was done, a layout incorporating Pre Development is being proposed.

Benefits of the pre-developed layout include:

- This logistical layout caters for numerous proven mining methods as well as conventional application
- The pre-development layout will identify any major potholes/ geological features and due to the number of faces still allow the optimum faces to be stoped based on the mining method
- The pre-development option will also ensure better face availability when compared to the traditional mining methods through the introduction of a central raiseline, thereby allowing for double-sided mining (increased IMS)
- Ensures optimal tram distances within the section through the introduction of multiple tipping points with a one-way tram less than 200 m
- New layout supports a continuous mining operation based on the predevelopment being 3 raiselines ahead of the stoping in the sequence of holing the raise, preparing the ledging in the second raise whilst stoping in the first raise
- Dedicated tipping points for pre-dev and stoping
- Footwall tip: belt situated in the footwall in order to accommodate the tip and grizzly via a spoonfeeder, thereby creating a continuous belt extraction system
- Layout supports concentrated and dedicated mining within a section by divorcing the pre-development from the secondary development and stoping activities
- Primary development and stoping are fed into a common belt extraction system
- Equipment can be re-used throughout the continuation of the mining system (leapfrogging of tips as well as the movement of crusher and spoonfeeder).

However, it is also important to be aware of the following:

In order to achieve high production rates it is essential that the development is at least three raiselines ahead of the stoping.

In order to ensure efficient and profitable mining into the future mechanized technologies and alternative approaches to mining are required. Through the use of detailed modelling and analysis, Anglo American Platinum has been able to develop a new mining layout as well as provide sufficient evidence that mechanization is a mining method that can provide safe, productive, and profitable ounces. Applications of this thinking are already being applied at two existing Anglo American operations, with further roll-out envisaged.

References

Anglo American Platinum Limited. Building Foundations for the Future through Mining. Anglo American Integrated Report, 2011.

Cambitsis A., and Lane G., 2012. A framework to simplify the management of throughput and constraints. *Internal white paper*, Cyst Corporation.

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Petr commenced his mining career at the Odra Mine in the Czech Republic in 1986 after completing his Mechanical Engineering Degree at the Ostrava University of Mining and Metallurgy. Petr joined Anglo Platinum in 1991 following the completion of his doctorate on the design of cutter heads for hard rock mining conditions. He is currently responsible for managing all of the New Mining Technology (NMT) projects within Anglo American Platinum, including the development of new technologies and layouts for the hard-rock mining industry. His scope of work is inclusive of the financial evaluation, implementation, and roll-out of New Mining Technology projects within the group.



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George graduated from WITS mining school in 1985 and was a graduate mining engineer with Anglo Gold in Welkom. He transferred to De Beers, worked at Cullinan and Namdeb mines till 1997, progressing from mining graduate through to mine overseer, pit superintendent, and finally head of mine projects and planning at Namdeb. He spent 8 years as a management consultant locally and internationally, before joining Cyst in 2005.

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