Can research, development and innovation extend the life of the PGM Mining Industry

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Abstract

Some recent public reports have warned that South African Platinum Group Metals (PGMs) Mineral Reserves based on conventional drill and blast technologies will be depleted by 2030 and Mineral Reserves supported by mechanised mining methods exhausted by 2035 (Turner 2016). The South African mining industry is currently considering research and development as a means to find more efficient, modern and cost effective ways to mine. The mineral industry looks to mechanisation, non-explosive rock breaking, automation, and continuous mining as the panacea for its problems with the goal that results from Research and Development activities will be capable of extending PGM Mineral Reserves beyond 2042.

However, based on previous experiences the innovation, design and implementation of new technologies have proved to be extremely involved in South Africa's narrow-reef environment, generally achieving lower than planned productivity at higher than budgeted costs. Although the development of innovative mining systems based on new technology is critical for the continuance of the South African mining industry, the necessary change management to support the implementation strategy is even more critical.

This paper discusses the strategies and research initiatives, as well as considers some of the requirements regarding change management in order to ensure that the PGM mining industry is in a position to continue mining operations beyond 2035.

Introduction

Mining in general, and South African hard rock mining in particular, is associated with risk. Narrow reef mining entails risk from fall of ground, geological discontinuities (potholes), fires, and other hazards to the mineworker via the actual mining process. However, another risk that is influencing the South African mining industry is the every apparent risk of mine closure due to economic factors and social and statutory constraints. In June 2017, AngloGold Ashanti announced the potential closure of two shafts and the retrenchment of nearly 9000 jobs. In July 2017, Bokoni Platinum, a joint venture between Anglo American Platinum and Atlatsa Resources, gave notice of its intention to retrench 2651 workers as Atlatsa decided to place the mine on care and maintenance. Two months later, Impala has announced that some 2500 (EWN, 2017) workers may lose their jobs at its Rustenburg operations. This latest announcement signals the most recent blow to the mining industry (Star, 2017). The Chamber of Mines of South Africa (COM) warns that "research suggests 200,000 job losses by 2025 could affect 2,000,000 people indirectly" (COM,

2017B). Even more disturbing is the claim by two platinum executives, Potgieter and Griffith (2017; 2017) providing opening addresses at the August 7-8th (2017) Rapid Underground Mine and Civil Access conference that 70% of the operating platinum mines were operating at a loss.

These concerns affect the entire spectrum of employment in the mining industry from the general labourer to top management; from students just entering university studies in the field of mining/metallurgy to mineworkers with decades of experience; from surface operations exploiting coal and iron ore to underground gold, manganese, chrome, and Platinum Group Metal (PGM) operations.

In the past, labour was inexpensive and plentiful and combined with the narrow nature of the orebodies, and this led to labour-intensive mining methods (Figure 1). Many of the deposits were shallow, conducive to short travelling distances to the working face, moderate stope temperatures and high productivity. This is no longer the case – the reality is medium to deep level mining involves travelling through two or three shaft systems with associated travelling times of the order of 1.5 hours in each direction. A recent study on a platinum operation indicated actual face working times between 2 hours 10 minutes and 5 hours 30 minutes with an average stope working period of 4 hours 22 minutes. This equates to stope face times of less than 50% of the total working shift.

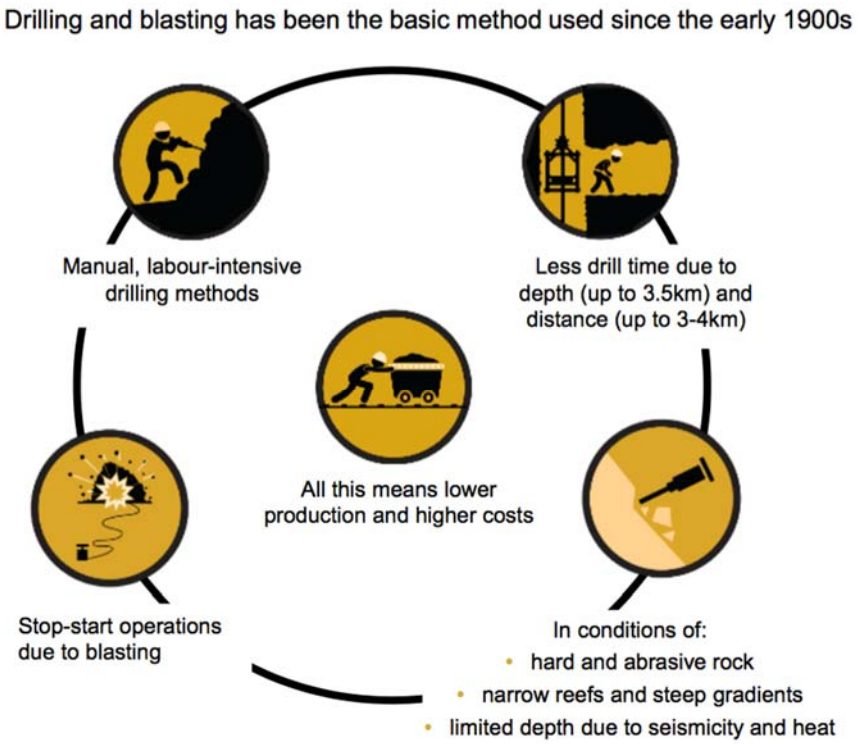

Figure 1. Traditional Conventional Mining Method (Macfarlane, 2016).

The above-highlighted concerns are in context with a labour force that is highly unionized with demands for significant increases in wages; a regulatory environment that is often viewed as over-zealous in regard to safety stoppages, onerous social and community responsibility; combined with double digit annual increases for electricity tariff and diesel for a number of years (Figure 2). All of these issues are coupled with concerns such as the future availability of water and changing of the environmental regulations.

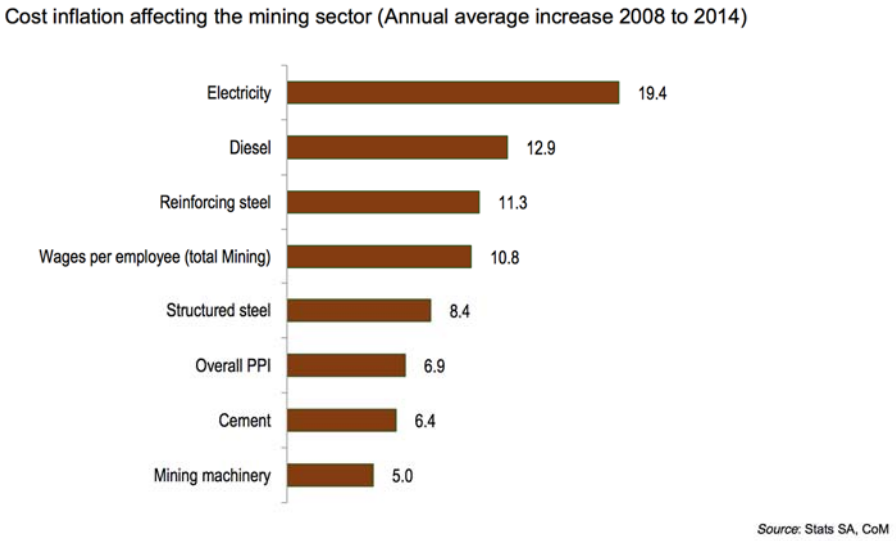

Figure 2. Cost inflation affecting the mining sector (annual average increase 2008 to 2014) (COM, 2015).

The view of the author is that the South Africa mining industry (employment and mineral output) within the next 15 to 20 years will be a fraction of its current size unless significant changes are made with immediate effect. National initiatives, such as the Phakisa Programme, are taking far too long to mobilise and in the author's opinion lacks the required commitment by the mining fraternity, (government, owners/management, unions, and academia). The South African mining mindset must change – unfortunately, too many affected and interested parties still don't understand the severity of the problem!

One of the possible reasons for the lack concern maybe the overall consistency of mine production (Table 1). 2015 and 2016's total PGM production indicates an increase of previous years production outputs. ~~which indicates that production tonnage has remained relatively constant since 2012 barring the strike affected 2014 period with production ranging between 254t and 276t PGM.~~ However, Table 2 and Figure 3 indicate that the Platinum industry has shed some 25,000 jobs since 2012, while Figure 4 demonstrates that the Rand - US Dollar exchange rate has enabled the Rand/oz Platinum price to slightly increase since 2008 despite a decline in the real US$/oz Platinum price since 2011. Over this same period cost inputs have nearly doubled with

the average overall mining inflation estimated at 8% (Griffith, 2017) with employee earnings increasing some 193% since 2005 (Schwikkard, 2016).

Table 1 South African PGM production and sales

Year	Production	Local sales		Export sales		Total sales	
	tonnes	tonnes	Value R'000	tonnes	Value R'000	tonnes	Value R'000
2004	286	–	3,786,133	260	29,527,109	260	33,313,242
2005	303	–	4,969,108	259	33,481,439	259	38,450,547
2006	309	–	11,829,608	267	53,614,207	267	65,443,816
2007	303	–	13,172,114	262	65,573,441	262	78,745,555
2008	276	–	13,448,280	223	77,904,355	223	91,352,635
2009	271	–	4,322,869	251	53,459,307	251	57,782,176
2010	287	–	7,892,570	244	65,894,341	244	73,786,910
2011	289	–	10,619,219	244	73,234,047	244	83,853,266
2012	254	–	8,285,235	211	60,918,939	211	69,204,174
2013	264	28	8,886,103	239	75,348,535	266	84,234,637
2014	189	29	10,644,402	202	66,860,760	230	77,505,163
2015	276	32	11,149,886	254	82,988,098	287	94,137,984
2016	264	31	11,093,572	251	85,318,461	282	96,412,033

Source: Department of Mineral Resources

Table 2: Employment by commodity: 2004-2016

Year	Gold	PGMs	Iron ore	Copper	Chrome	Manganese	Diamonds	Coal	Aggregate and sand
2004	179,964	150,630	7,142	4,042	6,765	3,243	21,186	50,327	4,080
2005	160,635	155,034	7,492	3,746	7,894	3,335	22,033	56,971	5,210
2006	159,782	168,530	8,859	3,993	7,899	3,333	19,686	57,777	5,133
2007	166,064	186,410	13,857	4,241	9,796	3,239	19,471	60,439	5,834
2008	166,423	199,948	13,257	3,523	12,279	3,976	18,474	65,484	6,427
2009	159,926	184,162	13,728	3,366	10,966	5,003	11,601	70,791	6,852
2010	157,019	181,969	18,216	3,032	13,982	5,879	11,467	74,025	7,009
2011	144,799	194,745	22,360	3,237	16,911	7,460	12,047	78,580	7,122
2012	142,200	197,752	23,380	2,533	19,762	8,685	12,332	83,244	7,719
2013	131,738	191,260	21,127	2,930	18,358	9,842	13,579	88,039	7,510
2014	119,007	186,864	21,794	2,853	18,658	9,971	15,356	86,106	7,421
2015	115,055	187,756	20,760	2,805	18,470	8,657	17,481	77,773	7,525
2016	116,479	172,444	16,490	2,366	15,514	7,240	17,978	77,506	7,602

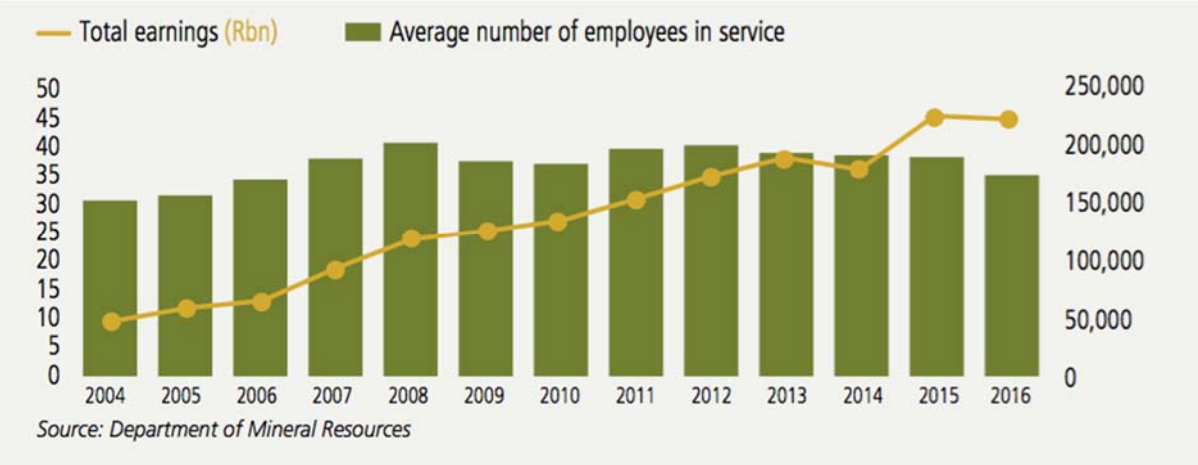

Figure 3. Total earnings and average number of employees 2004 -2016 (COM, 2017).

Figure 4. Platinum price Rand/oz and US$/oz (COM, 2017).

Over the past seven years some platinum operations have closed or have been placed on care and maintenance, for example, Blue Ridge Platinum, Smokey Hills, Everest, Crocodile River, Lonmin K4 Shaft, Impala 17 shaft, Leeuwkop, and Eland Platinum. Price Waterhouse Cooper (PwC) states "Platinum is on a knife-edge" (September 2016). The previously mentioned closures combined with the recent announcement of closures and restructuring signifies an industry requiring change.

South African Initiatives

One of the initiatives being led by the Chamber of Mines of South Africa (COM) is its Modernisation Programme, which looks to drive technology innovation through research and development in a holistic manner, adopting a systems and people-centric approach and includes all elements of mining – including reporting structures, skill development, and change management (COM, 2017B).

Figure 5 depicts the results of a recent COM study and presented by Turner (2016) indicating the tonnages to be mined from South African platinum mining companies based from conventional, mechanised and continuous (24/7 mechanised) mining operations. Figure 5 shows that by 2030 PGM tonnage sourced from traditional mining will largely be depleted; similarly, PGM tonnages sourced from mechanised mining sections will be exhausted in 2035. The Modernisation Programme suggests that through the continued implementation of mechanised mining to continuous (automated) 24/7 operations, the PGM mineral reserves could extend beyond 2040.

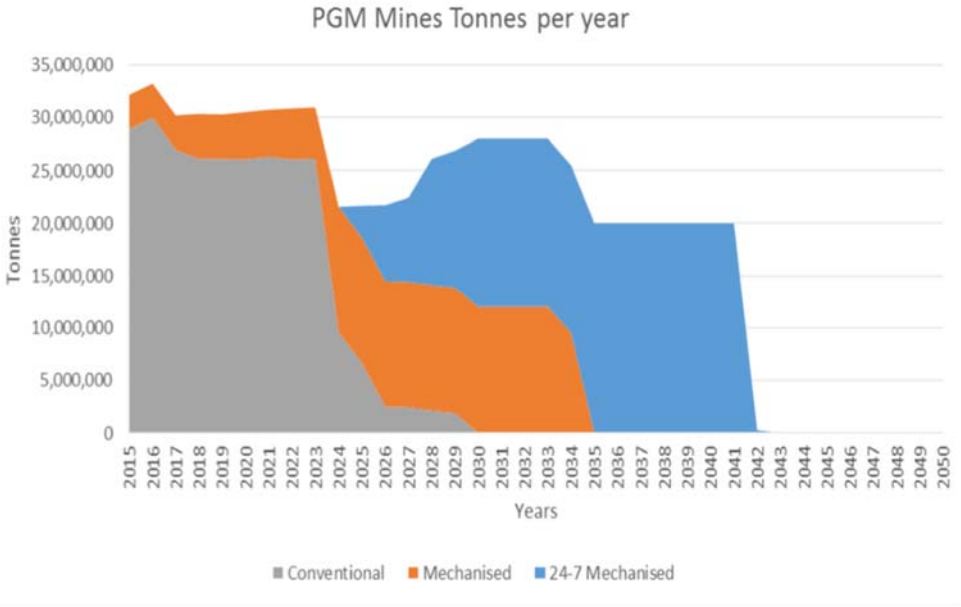

Figure 5. PGM mined tonnes per year based on mining method (Turner, 2016).

The COM initiative looks to extend mine life, preserve mining employment, improve safety and health, and allow mining of lower grade deposits and deeper mineral resources. The COM further states "a low-grade mine with a current conventionally mined life expectancy of some four years, using semi-mechanised methods, could extend operations to 15 years and, with full mechanisation (Figure 6) and 24/7 operations, to as much as 25 years" (COM, 2017B).

The platinum mining industry has also investigated mechanisation as a means to improve productivity and reduce unit costs. The current mechanisation initiative has made some progress but is not conclusively successful (e.g. Lonmin's experience). The implementation of mechanisation in the narrow-reef environment requires favourable geology with up to 50% of the mineral resources being potentially unsuitable for mechanised mining systems (Rupprecht and Rapson, 2004) and the mechanised mining systems requiring a considerable amount of capital. Albeit the above comments, mechanisation should be able to propel the industry beyond 2030 with continuous 24/7 operations further extending platinum mining operations to beyond 2045. Anglo American Platinum Limited has stated that it doesn't ever envisage developing another conventional platinum mine in South Africa with any future expansion linked to mechanisation (Griffith, 2017).

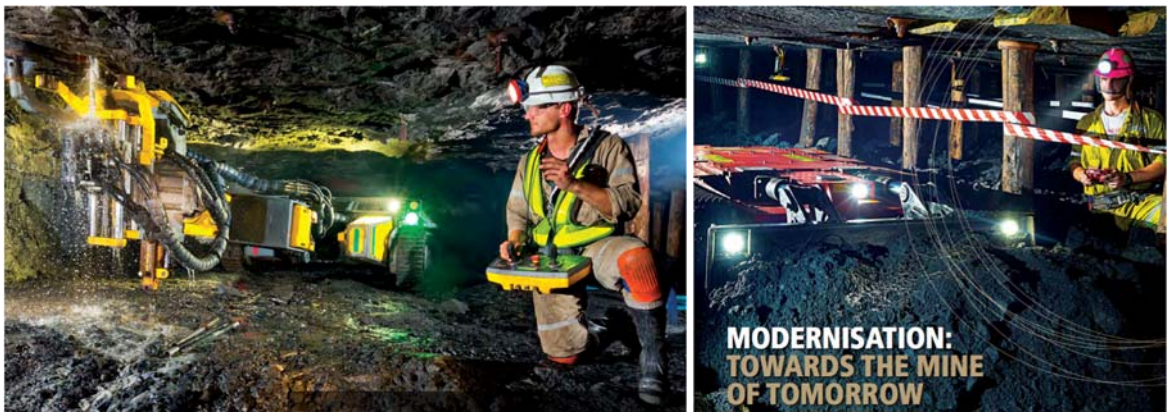

Figure 6. An example of mechanised mining (COM, 2017A and 2017B).

Current research and development thoughts around modernisation of the platinum industry are to obtain quick wins over a three-year period; improving mechanised drill and blast to realise improvements within 10 years, and finally achieving 24/7 continuous operations to support the industry beyond 2045 (COM, 2017B).

Phase 1, which proposes maximising conventional mining through modernisation to achieve the best results as possible. One could argue that much of the research and innovation requirements are already known to the industry, and it is more around the improvement of current technologies. Areas of improvement must include vertical and horizontal transportation to facilitate greater face periods - improving time on the face back to 6 hours or 75% of the available shift period. The second area of interest is the stope environment – investigating means to improve the mining cycle; rock drilling, charging and blasting, support, rock removal and sweeping, and improving the overall working environment.

Mechanisation is the 2nd Phase of the research initiative. Since around 2000 on-going research and development has taken place regarding the mechanisation of the platinum industry. Review of the SAIMM Platinum Conferences is an excellent testimonial to the progress made toward mine mechanisation. However, the success of mechanisation is far from concluded. Lonmin's experience regarding the introduction of mechanisation is a good example of the complexity of introducing mechanisation to the platinum industry.

Lonmin experience

Lonmin's CEO Brad Mills (2004 -2008) was one of the initial proponents of introducing mechanisation into the South African platinum industry. Mills proposed to implement mechanisation in incremental stages, and 2004 Lonmin set a target to achieve 50% mechanisation by 2010; with robotics, intelligent and continuous mining beyond 2010. In 2010, Webber provided

a sobering update of Lonmin's progress highlighting the challenges with the implementation of XLP mining, and in 2012 Lonmin began to realise the benefits of it reversal back to conventional (Webber et al. 2010). The then executive vice-president of mining, Mark Munro, claimed that the mechanisation programme had taken Lonmin four years longer to reach full production (Faku, 2012).

In 2015, Ben Magara the CEO of Lonmin commented that Lonmin had "committed its own mistakes in the past. There had been some $2 billion in misallocated capital which was spent on mechanisation". Magara further went on to state - "The second thing is that Lonmin went into mechanisation and hoped that would turn the world around; that was another $1 billion mechanising deep, narrow, tabular, and hot orebodies, so mechanisation could not work." Magara added that by 2012 Lonmin had "then spent $500m to reverse mechanisation back to labour intensive mining" (McKay, 2015).

In 2013, Brad Mills was quoted to state (Michaud. 2013) – [he] "regrets not having pushed the firm to a process of mechanisation in South Africa." "My view was, this is a 15-year process, but you've got to get your head out of this trap. And the only way you're going to do it is to convert, mechanise, as painful as that may be."

Lonmin's 1st quarter results ending in March 2017 reported a $214m loss for the six months to end-March compared with a $6m loss the year before (Seccombe. 2017).

Anglo American Platinum Experience

In contrast to Lonmin's experience with mechanised mining, Anglo American Platinum have been pursuing mechanised mining since 2003. Between 2003 and 2005 extra low profile (XLP) equipment was trialed utilising a Room and Pillar mining method. The mechanised mining layout was then converted to Breast mining layout with production achievement largely achieving between 1500m^2 to 2500m^2. Success of the XLP trials at Bathopele between 2009 and 2011 provided the concept of utilising mechanised drill rigs, roof bolters and the dozer in the stope environment. Recent work conducted by Anglo American Platinum has provided proof of concept that a 14 panel stope layout at 10 degrees with potential to operate up to 16 to 22 degrees (conceptual). Stoping widths between 0.9m and 1.2m appear to be viable utilising ultra low profile (ULP) mining equipment. Cash operating costs per ounce for ULP mining is lower than conventional mining with productivity per labourer greater than conventional stoping (Smith, 2017). Of course results from trials (proof of concept) must be considered with care. However, all indications are that when mechanisation is deployed in new mine areas with specific layouts then mechanisation may prove to be more efficient. Some Thirteen years later, narrow reef

mechanised mining in the platinum industry is looking operational effective and over the course of the next seven to 10 years with further improvements in machinery, IT, management systems and human resources one may see mechanisation fully integrated in the South African mining industry.

Research Recommendations

The development of XLP and ULP mining equipment looks promising for the platinum industry, but there is more to mining than just machinery. Also, the industry still needs to consider the longevity of current mining operations that are not conducive to mechanised mining yet may continue for many years to come provided solutions are found to improve productivity and safety.

Three fundamental areas need to be addressed if the South African mining industry is to reverse the current trends of declining output and low or stagnant productivity:

- Labour-related issues around productivity and efficiencies
- Shift duration
- Research and innovation and its role in addressing industry needs, and the efficient transfer of this new knowledge.

Currently, the mining workforce is lucky to realise 50% of their shift time on the working face. This underground shift time is in contrast to surface mining, which targets 94%. Technology and its appropriate development is admittedly a broad target and could include a host of research areas. For example, geology, geophysics, exploration techniques, geotechnical engineering, mine planning, mine valuation, engineering, mechanisation, drilling and blasting, material handling, ventilation and cooling, logistics, beneficiation, environmental, mine closure, etc. are all areas under consideration for research funding. But, more importantly, it is critical that key areas are identified for research. Rather a critical few are selected rather than a multitude of small projects, and the time frame to develop this research must be viewed as taking a decade rather than a few years to achieve (Rupprecht, 2016).

Labour-related Issues

New technology on its own will not overcome the negative features of the prevailing work culture. Labour issues must be addressed before any new technology is introduced (Anglo Platinum is investigating this in their current Proof of Concept stope at Tumela). It is apparent that the mining industry requires a different way of organising work and there appears to be a gap between theory and what is happening in practice underground. Historically, South Africa mining has been dependent upon cheap labour to facilitate narrow tabular mining. Labour is no longer cheap, and yet many management teams seem to be unaware of the need for a paradigm change. The current

mining work practice remains inefficient and requires a radical change to increase productivity. The paradigm shift is necessary to move towards a creed that - One should get paid to work and produce quality tonnes - not just attend work.

That said, there seems to be a gap between the reality of working underground and the theory of mining i.e. how management believes the job is carried out. The critical question being 'is the work structure conducive to mine safely and productive?' Having the workforce operate in hot, humid conditions is not conducive to safety or productivity. As with many standards, there is a gap between what should happen and what happens underground.

Risk-taking is part of the occupational culture of the mining industry. Many mine workers take for granted the dangers and discomforts of mining and have developed ways of coping with them. Technology on its own will not overcome the negative traits of the current work organisation and occupational culture.

Shift time and duration

The South African mining industry is largely a mature industry and as such mining operations have progressively moved deeper underground by making use of sub shafts and tertiary shaft systems. Recent time studies in the gold industry indicate excessive travelling times in each direction, resulting in face times of less than four hours and some cases approaching only three hours. This short work period is discouraging when one considers surface mining operations are targeting 7.5-hour shifts (Ramalepe, 2016).

In 1998, the Deepmine Programme identified transportation as a key technology driver, and the research concluded in 2001 that 'in general, vertical transportation systems are efficiently designed and operated in sharp contrast to horizontal and in-stope transportation systems, which were found to be inefficient in both design and operation' (Rupprecht et. al., 2001). The 2001 findings are still relevant 15 years later, with vertical transportation appearing to have regressed in this same period.

The key point is that to achieve a 'safe, quality blast everyday' sufficient face time must be available so that the entire mining cycle can be completed in a shift with enough time to carry out planned tasks to standard and on time. Adequate time must be available so that unplanned activities can also be conducted during this same period. This requires an efficient transportation system that gets the workforce to the mining face in less than 1-hour. The author is advocating 10- to 12-hour shifts, thereby ensuring six to eight hours of face time. This would create two distinct advantages for the industry: (1) an increase in the workforce, as a crew will be able to work only three to four shifts per week, and (2) sufficient time will be available for all planned tasks to be

completed correctly, resulting in the proper completion of the mining cycle which will lead to quality tonnes.

Mechanization

Narrow reef mechanisation is critical, and one only needs to review the six SAIMM International Platinum Conferences from 2004 until 2014 to understand the volume of work that has gone into introducing mechanisation to the southern African platinum industry. Mechanization is a nondebatable area requiring further research, innovation, and development. Probably the biggest shortcoming with the development of mechanisation has been the inability of the industry to manage this collaboratively. There has been too much duplication between mining groups, a lack of proper documentation and a reliance on original equipment manufacturers to develop the new technology. A strong requirement is for the local manufacturing of mobile equipment, focused primarily on the southern African underground mining environment. There is a need to apply relevant industrial engineering principles to the mining industry while still being cognizant that mining is not a factory as inputs (i.e. the mining work environment) change on a regular basis, requiring workers and supervisors to adapt as and when required.

Infrastructure

Stope conditions must become more conducive to good working conditions. Therefore, any discussion around productivity must include providing cooler working environment for stope workers. The use of pneumatic rock drills continues to be the mainstay of the mining industry. However, the inability to supply compressed air to the driller on the stope face impacts on the drill penetration rate and thus productivity. Poor control of compressed air (air leaks) leads to reduced productivity and high electricity demand.

As mining progresses deeper and working places are situated further from the shaft the available face time decreases. Current mature mines are experiencing ~~4.5~~four hours face time which means over half the working shift is spent travelling and on another task not directly related to exploiting the mineral on the stope face. ~~Two~~ Three things must happen; (1) travelling times must significantly reduce through good transportation practices, (2) processes within the stope face must be reduced through innovation and improved technology and (~~3~~2) the industry should look to extending the shift duration similar to what is practised in the South African Coal mines. In the authors opinion sufficient work has been conducted during the Deepmine and Futuremine Collaborative Research Programmes to facilitate the change to improve stope face time.

Probably the biggest impact on the platinum industry is the human factor. Creating a multi skilled and motivated workforce will be essential for the successful transformation of the platinum

industry. This change will require the buy-in from the government, mine owners and management, unions and the workforce. Furthermore, the stope environment must be made conducive for working six plus hours in the stope, meaning that the work face must replicate a cool shallow work environment.

There must be a clear focus on improving the sustainability of the South African mining industry. Obviously health, safety, social, environment and other critical areas will need to be considered, but the primary focus of the research must be about transforming the industry. Management of the research programme and industry liaisons must be fully bought-in to this process.

Summary and Conclusions

Over the past three years, the platinum price has maintained its Rand per ounce price yet the cost of operations has doubled. This is a trend that is not sustainable and requires dramatic improvements in mine efficiencies or the PGM basket price. If the platinum industry wishes to continue beyond 2030 or even 2040 a long term research and development programme must be undertaken to improve mining efficiencies, reduce manual labour, reduce operating costs and address the human resource constraints currently encountered by the South African Mining Industry. In the short term, immediate improvements in transportation, material handling, stoping and development systems, and environmental conditions may sustain the industry long enough so that material in roads can be made in mechanisation and continuous 24/7 operations.

The effort cannot be relinquished by the mine owners/houses to others such as consultants, original equipment manufacturers (OEMs), government, academia, or unions – but it must be viewed as a team approach with the view of seeing the South African mining industry beyond 2045. Just as important as technical advance, softer issues such as work structure and payment need to change.

It is time for the South African mining industry to realise that it truly is on a “knife-edge” and it is a time to act. Some companies have already realised this and are well along the path of advancing the industry, however there remain too many passengers in the drive to modernise the mining industry and transform the mining sector truly into the 21st century.

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