Presidential Address: Are efforts to mechanize SA mines too focused on machinery rather than technology?

by J.L. Porter*

Synopsis

This paper takes a personal look, through the author's own experiences, at the implementation of innovations in the narrow-seam, hard-rock mining environment of South Africa's mining industry over the past 40 years. A number of examples are used to illustrate some of the successes and failures over this period. More importantly, the examples are used to illustrate that the bulk of the investment for these projects should have been applied in a manner that could have achieved more sustainable results.

The use of the word 'technology' in this context is also examined, as it is the author's contention that only measuring the performance of machinery fails to encapsulate the potential of the entire system describing the scope of the innovation being implemented.

These experiences and observations are projected onto the current backdrop of upheaval in the relationship between key industry stakeholders and the sustainability challenges facing areas of the mining sector in the South African economy.

The paper concludes with some opinions on where attention can be focused in order to develop new thinking that can be applied for the safe and economic extraction of the nation's mineral wealth.

Introduction

According to Statistics South Africa, the current unemployment rate is 25.5% of the workforce. This includes 10 million people subject to high levels of poverty. South Africa is currently number two on the world's Geni index, which measures the disparity between high and low income earners. Taken together, these statistics are worrying and this aspect is not lost on the architects of the National Development Plan (NDP), in which poverty alleviation is rightly a significant driver. However, if we look in another, more positive, direction (below our feet in this instance), it is reported in the Chamber of Mines' South African YearBook, 2012/13 that the country's total metal and mineral reserves 'remain some of the world's most valuable, with an estimated worth of R20.5 trillion ($2.5 trillion)'. Now, two and a half trillion is a big number by any standard. To put this figure in to some perspective, it would equate to a pile of US$100 bills, covering the entire surface of the largest allowable rugby pitch, including the in-goal area, to a depth of 5.5 metres!

Unemployment and poverty facts are painful, yet these are some of South Africa's vital statistics that cannot be put aside. What possibility is there to reconcile the issues of, on the one hand, having been endowed with mineral bounty beyond imagination but on the other that current public and (in some areas) industry perception is that there is a lack of ability to bring the potential mineral wealth to account for the long-term benefit of the nation? This is a complex question and I will attempt to answer only a relatively small part in this paper; which focuses primarily on how changing the way people do work can lead to greater success in re-engineering the mining methods used in the industry.

Most industry followers understand the significant role that mining plays in the economy (Figure 1 and Table I):

- ➤ Contribution of R2.1 trillion to GDP in the last 10 years
- ➤ 11.9% of total investment in the economy (2012)
- ➤ 24.7% of the Johannesburg Securities Exchange (JSE) and R1.9 trillion of its market capitalization (2012).

Maintaining and creating new jobs in mining can clearly be tied to the potential of bringing these future resources to account. To consider the solution to sustainable mining (and by association sustainable employment) as a perpetual round of cost cutting or productivity improvements and restructuring can only address the matter of short-term survival. In some situations this is important and unavoidable. Using the platinum sector as an example, Figure 2 indicates that many of the platinum mining operation are currently not profitable. If South Africa is looking at how to use our total mineral resource to create work, perhaps there are some metaphorical

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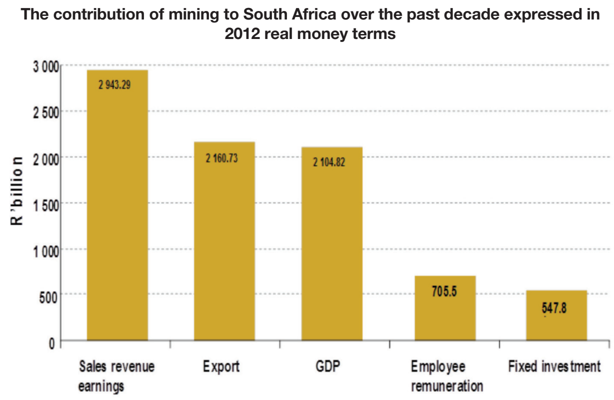


Source: Chamber of Mines Statistical unite

Figure 1—Mining's contribution over the last 10 years

boxes that need to be broken open. In this regard, recognition must be given to those projects that are pushing hard for fundamental changes to either the mining methods employed or the new generation of machines that are being used to mine the rock (ore).

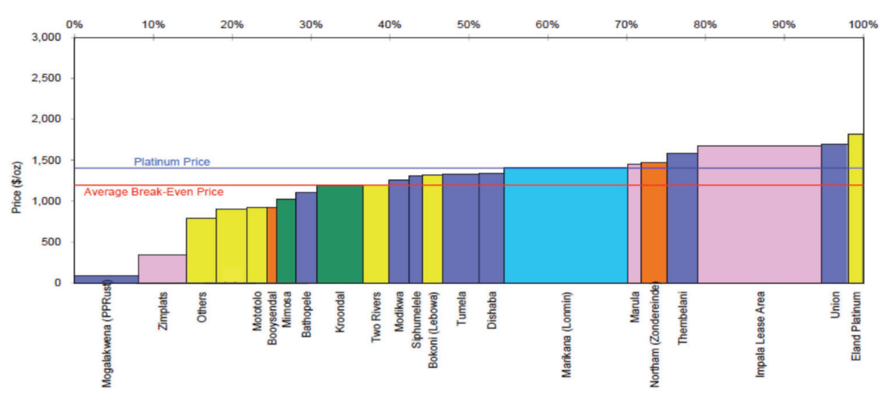
In today's politicized social and economic environment, poverty reduction through job creation must also include a discussion about opportunities tied to job preservation after the mines have closed. The infrastructure that mining creates long outlasts the life of the mines themselves. The skills created by the mines also outlive the mining operations. Why are these assets not turned to better account, perhaps by more aggressive intervention by Government to create tax incentives that stimulate small/medium industries built on the infrastructure and local skills?

Table I

Ten-year financial trends, 2004 through 2013 - top 40 companies

$ billion	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**
Aggregated income statement										
Revenue	512	525	539	435	325	349	312	249	222	184
Operating expenses	-350	-340	-311	-246	-217	-208	-176	-141	-141	-129
Adjusted EBITDA	162	185	228	189	108	141	136	108	81	55
Amortization, depreciation and impairment	-97	-86	-42	-34	-31	-57	-19	-12	-16	-15
PBIT	65	99	186	155	77	84	117	96	65	40
Net interest cost	-15	-6	-6	-7	-6	-6	-5	-3	-4	-3
PBT	50	93	180	148	71	78	112	93	61	37
Income tax expense	-30	-25	-48	-38	-22	-21	-32	-27	-16	-9
Net profit	20	68	132	110	49	57	80	66	45	28
Adjusted net profit excl. impairment	43	99	143	111	57	80	81	66	45	28
Year on year increase / (decrease) in revenue	-2%	-3%	24%	34%	-7%	12%	25%	12%	21%	67%
Year on year increase / (decrease) in adjusted EBITDA	-12%	-19%	21%	75%	-23%	4%	26%	33%	47%	90%
Year on year increase / (decrease) in net profit	-71%	-49%	20%	124%	-14%	-29%	21%	47%	61%	133%
Adjusted EBITDA margin	32%	35%	42%	43%	33%	40%	44%	43%	36%	30%
Aggregated cash flow statement										
Operating activities	124	137	174	137	83	104	95	77	58	41
Investing activities	-125	169	-142	-79	-102	-126	-67	-38	-23	
Financial activities	-3	21	-28	-35	10	14	36	4	-11	-10
Free cash flow	-6	11	76	70	19	38	44	40	27	19
Aggregated balance sheet										
Property, plant and equipment	712	701	601	511	467	402	371	262	224	196
Other assets	544	544	538	432	334	274	284	192	148	120
Total assets	1 256	1 245	1 139	943	801	676	655	454	372	316
Total liabilities	624	563	482	387	354	339	329	217	178	151
Total equity	632	682	657	556	447	337	326	237	194	165

Note: All income statement date presented excludes Glencore marketing and trading revenue and costs



Source: J.P. Morgan Estimates – April 2014

Figure 2—Platinum mining industry break-even analysis (cash cost plus maintenance capex)

Figure 3, which is copied from the National Development Plan, indicates a matrix of which areas can indeed stimulate job creation through state intervention, but also identifies challenges pertaining to employment. Somewhat disappointingly, it classifies mining as '*Good for growth but not great for jobs*'. Admittedly, this is a simple diagram describing complex interrelationships, but I believe that this does not correctly express the full breadth of employment opportunities. When viewed in conjunction with the Fraser Institute 2012/2013 Annual Survey of Mining and Exploration Companies, this is particularly worrying as Fraser ranks South Africa 76th out of 96 jurisdictions in terms of current mineral potential (assuming current regulations and land use restrictions). Read together, the future of mining in South Africa does not seem to be synonymous with job creation.

So much for the 'doom and gloom': There are many areas in which the country and industry can be rightly proud and in which there lies considerable promise for the future. Between 1994 and 2014, households with access to clean drinking water had increased from 62% to 93%; in 1994 only 36% of SA homes had electricity, while today it is 84%. Current and future levels of investment in infrastructure, while arguably late, also bode well for the mining sector. There are real drives to increase the number and quality of engineers to service industry and there are signs that Government and industry are coming together to address the perilously low levels of research and development (R&D) activity in the South African mining industry.

The unfortunate incidents and industrial disputes over pay and conditions of employment in the last 18 months have had one positive outcome. They have brought into the broader public debate terms like 'mechanization' and the ability of the industry to change its processes in some significant fashion. The number of calls from media representatives received by the Centre for Mechanised Mining Systems at Wits University has increased some 300% over the same time span. I consider this to be a positive outcome because the more people are discussing the issues, the more minds there are considering solutions to the many technical and social challenges.

The title of this address clearly requires some explanation, especially in the context of what has been presented so far. What is meant by words like 'mechanize', 'machinery', and 'technology'? How does the title of the paper link to job creation? These two questions can be addressed through a statement of the issue being discussed

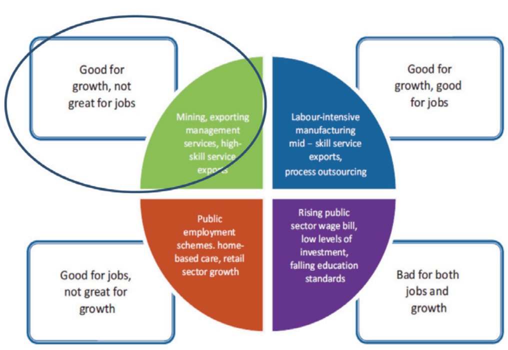


Figure 3—NDP and job creation matrix

and some clarification on terminology. What is clear is that there is much greater scope for innovation and the way that technology can be successfully implemented. More successful projects will accumulate to address, in some part, the job preservation/creation needs. I will illustrate, with examples, the underlying arguments before concluding with some suggestions, on where future thinking and work could be directed.

In summary

- ➤ South Africa faces considerable challenges in alleviating the real threats of unemployment and poverty result from weak economic growth and urbanization
- ➤ On the upside, South Africa is richly endowed with many assets in terms of metals and minerals, agriculture, its oceans, a young workforce, and an increasingly mobile middle class
- ➤ The opportunity in the mining industry lies in finding ways to better leverage understanding of human behaviour to bring to the fore more successfully implemented technologies
- ➤ A further opportunity lies in considering what else can be done beyond the immediacy of direct mining jobs, such as leveraging the legacy of mining infrastructure, as well as developing mining capital goods.

Background

So, if South Africa is estimated to have the world's fifth-largest mining sector in terms of GDP value and possibly the largest by dollar value of metal and mineral resources, why does it appear that there is currently so much pessimism in terms of our ability to bring these assets to account?

'JOHANNESBURG (miningweekly.com) – Data released *on Monday by Statistics South Africa (Stats SA) statistician-general Pali Lehohla has revealed that output from South Africa's mining and quarrying industry had contracted by 24.7% in the first quarter of 2014, as the sector battled subdued commodity prices, low productivity and a prolonged standoff with labour*.'

Headlines such as this are clearly not assisting the cause, but this example highlights the importance of platinum in the overall metal and minerals contribution to the economy. This is further demonstrated in Figures 4 and 5, which show how the SA mining industry has both grown and changed since 1980. The point here is that while many people have the perception that the SA mining industry has declined because of the gold sector, it has in fact continued to grow and thrive in other commodity sectors. The challenge for platinum is best demonstrated in Figure 2, where only the mines below the red line make a real contribution – and that was before the recent wage negotiations were concluded. As a result of excessive cost increases in recent years, the majority of SA's mineral wealth remains sub-economic, and this is further compounded by geological, geotechnical, and metallurgical complexity combined with declining productivity due to increasing depths.

Is this an undeniable fact of life or a condition for which the country is able to find solutions? Obviously, the answers to these questions lie partly in history's lessons and partly in our ability to see future solutions. Presidential Addresses

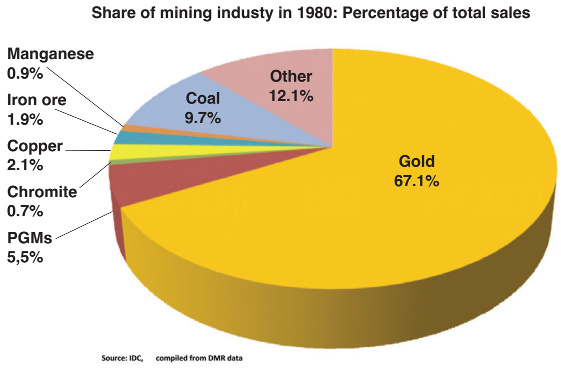


Figure 4—Percentage breakdown of mineral sales, 1980

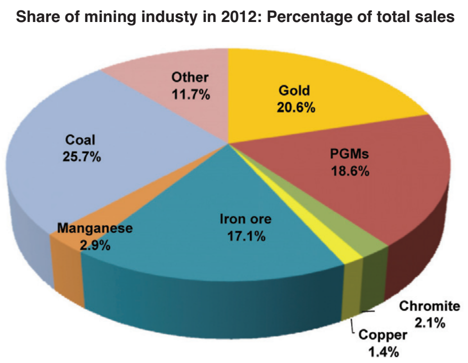


Figure 5—Percentage breakdown of mineral sales, 2012

over the history of the SAIMM are littered with dire warnings of pending 'doom' due either to technical difficulties (e.g. poor metallurgical recoveries or increasing risks due to mining depth) or the challenges of establishing a new deposit of economic interest. (The possibility of 'fracking' for gas in the Karoo is a current example.)

There is a clear and consistent track record of South Africans successfully rising to the challenges of the day.

However, the mining sector cannot just assume that in some miraculous way it will once more resolve its challenges. The global and regional economy, politics, and technology have changed and are becoming more complex over time. If the industry is to play its role in alleviating poverty through job creation, then all stakeholders must make a concerted effort to find innovative ways to envisage viable outcomes. In the past, the South African mining industry has been a recognized innovator in areas ranging from seismicity to winder rope design, mine refrigeration, and extractive metallurgy.

As a final justification for finding successful innovations to change the way the mines function (work – refer to the definition of technology) and using the platinum sector as an example; consider that between 2000 and 2012 the platinum group metal basket price per platinum ounce increased at a cumulative average annual growth rate (CAGR) of 8% in rand terms. However, during the same period, industry cash operating costs per platinum ounce increased at a compound annual growth rate of between 15% and 18%. This is all before the damaging labour dispute and resultant increase in wage bill of 2013/14.

Figure 3 also contains a very significant insight. Many of the mines that are below the blue line are 'new mining' initiatives. Admittedly, Mogalakwena is an open pit operation. This has important implications in that moves to mechanize the platinum industry in the early 'noughties' are coming of age economically, due mostly to the large escalation of input costs. Broadly, the consensus is no longer about whether we should mechanize, but more about where and when to mechanize. Never before has the national imperative been greater or more focused on overcoming a wide range of challenges.

Almost by definition, and as a result of the increasing pace of change, the solutions needed in the mining industry are going to be more complex and the speed with which the solutions must be successfully implemented through managing change must also increase. Therefore, the question:

'Is there too much reliance on devising 'silver bullet' machines rather than developing new systems by which we achieve faster implementations through a better understanding of how to improve results through people with known technology?'

As mentioned above, scanning through previous Presidential Addresses (as all Presidents have done in their respective turn!) covering the last 40 years specifically, over 90% refer to costs issues; 80% mention research (usually in the context of needing more of it), and 84% look to technology and innovation in a forward-looking context. However, less than half make reference to people or investment in human capital. Where people are mentioned it is usually in the context of cost or labour relations matters. Perhaps this is indicative of the broad thinking over this period? Experience in the Centre for Mechanised Systems has indicated that a generational knowledge gap has opened. This means that much of the knowledge gained in the 1970s and 1980s through extensive research has been lost to industry. Furthermore, some of the solutions devised in those years and shown to be not economically viable may indeed now be viable, due to the pace of technology change having driven:

➤ Miniaturization of instrumentation
➤ Improvements in the properties of materials
➤ Advances in digital communication
➤ Economic factors
➤ Society's acceptance of the importance of safety and environment performance.

With the benefit of hindsight and reflecting on conversations, workshops, and conferences as well as direct involvement in numerous 'innovation projects' over the past 20 years, I have come to the realization that the slow pace of successful technology intervention and associated change management is a result of a faulty scoping and project resourcing process that results in the disproportionate application of time and money to the 'machine' and not to the 'technology', which includes the machine. In other words, through honest attempts to keep total project costs low, there is a tendency to make sure the funds are in place for the design and building of the next best 'mousetrap' but not for the 'soft' issues. This often results in the implementation phase running out of time or budget to provide for properly designed implementations. It nearly always fails to allow for developing correct training and communication to all affected stakeholders. Unfortunately, 'affected stakeholders' often means the shareholders who have put up the funding for the project. To substantiate this statement and set the scene for the next section, some explanation of terms is required. The English language serves a useful purpose (one hopes!) in communication, but there are times when its success in being the language of business is its own worst enemy. As individuals and as teams, there is a tendency to develop a preferred set of terminology (by example, look to your children and the names that families give to everyday activities – I'll leave this example right there, as we all know where this is going …). Some simple definitions are required. These are not slavishly copied from the dictionary, because they are my own usage, and so the meaning and emphasis have relevance later.

- *Mechanize*—the action of replacing some or all aspect of human labour (work) in a process by the use of machinery, e.g. an excavator, thereby improving safety and productivity. However, machinery can also be used to improve the conditions in which a human works (e.g. refrigeration plants)
- *Machinery*—an artifact, tool, or a collection of human engineered parts that together are used to improve efficiency (performance) of human effort e.g. an axe or a bicycle
- *Technology*—the purposeful application of information in the design, production, and utilization of goods and services, and in the organization of human activities. It is derived from the Greek tekhnologia, meaning 'systematic treatment'. [At this point, use is made of an excellent description from a business dictionary , as it suits the purposes.] Generically, technology can be divided into five categories:
  - *Tangible:* blueprints, models, operating manuals, prototypes
  - *Intangible:* consultancy, problem-solving and training methods
  - *High:* entirely or almost entirely automated and intelligent technology that manipulates ever finer matter and ever more powerful forces
  - *Intermediate:* semi-automated or partially intelligent technology that manipulates refined matter and medium-level forces
  - *Low:* labour-intensive technology that manipulates only coarse or gross matter and weaker forces.

In other words, technology can be said to be the way that people get work done – simple; and that is the meaning of technology used here.

As mentioned previously, some of the concepts discussed in this paper are to be found both in history and in how people envision or perceive, or are able to perceive, the future:

About history

An unfortunate reality of mining is that we work with wasting or depleting assets. It is clear that for listed companies to retain their value or asset base in the eyes of the investment community, ongoing interventions are a critical component of the business model, by way of:

- Exploration for more resources
- Acquisition of resources or reserves
- Cost control or cost cutting arising from combinations of weak commodity prices, lower grades, or escalation
- Productivity or 'sweating the assets'(ROC)
- Mechanization to support one or all of the above interventions.

In South Africa, there have been periods of exceptional exploration, investment, and development as represented by the development of various metal and mineral resources: for example in the Witwatersrand Basin gold and associated goldfields; the Kimberly diamond mines upon which much of this nation was so painfully built; the Witbank coalfield that has provided much of the energy for homes and industry. These investments have, in large part, enjoyed substantial world-class mining lives, not only because of their geological setting but also because of the vision of entrepreneurs, researchers, Government, and, importantly, the commitment of labour. However, for various reasons beyond the scope of this paper, South Africa's research capacity to service new challenges in the mining industry is sorely depleted. It is unlikely that we will see another 'Project Deep Mine' for several years.

About the future

In part, the reality here stems from the human mind's ability to make predictions. It would seem that one of mankind's enhanced survival traits is the ability to construct forward-looking scenarios and then make critical risk-based comparisons between the scenarios to determine an appropriate course of action.

Isaac Asimov, the revered science-fiction author, made a stab at describing life in 2014 back in 1964. In a New York Times article 50 years ago, Asimov called his vision 'Visit to the World's Fair of 2014'. Now it is, in fact, 2014 so we can all be very clever with the benefit of hindsight!

Asimov's predictions fall into two obvious categories (it is worth reading the whole article):

- Those that have come to pass (he predicted the global population in 2014 would be 6.5 billion (actual, 7.1) billion and the population of the USA would be 350 million (actual, 320 million)
- Those that do not (levitating cars)!

Predictions about technology's future are almost always doomed to failure. For example, according to George Orwell's '1984', by now the population should have become a society of brainwashed drones toiling under constant surveillance for faceless overlords. Clearly, that has not happened – but, wait a second …

There is clearly a third category:

- Technologies that are indeed feasible today – but are not yet commonplace.

Asimov's predictions illustrate three lessons for those who would attempt to predict the future.

- First, almost every new technology takes longer to arrive than sci-fi writers (or engineers for that matter) imagine. Work undertaken by COMRO shows that it can take between 20 and 30 years for a new technology to become mainstream in mining operations

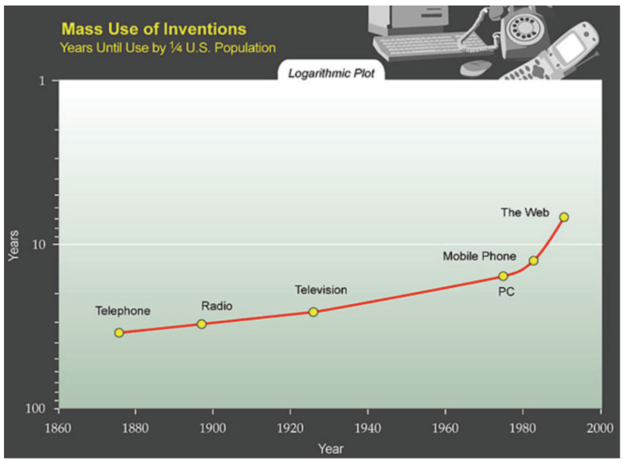


Figure 6—Speed at which society adopts innovation

from date of first conception. However, this does not hold true for consumer products, where emotion 'need-to-have-the-cool-gizmo' is a driver of the buying habit. Figure 6 shows that it took approximately 35 years from first concept to product maturity for the telephone. However, the mobile phone took a mere 12 years, and the www a blistering 6 years!

- Second, it is not possible to be all-seeing and hit all the big ones; the history of technology is framed by enormous zigs or zags – consider, for instance, the Internet – no one saw that one coming. By the same token, has the mining industry fully absorbed the impact of digital migration and miniaturization?
- Third, many attractive or logical developments never materialize, thanks to our own human failings. The fault is not in our engineering but in human nature, politics, or economics.

What is the opportunity?

There is a clear 'golden thread' running through the discussion. This common denominator has to be people, but it very much depends on a point of perspective as to whether people, as a common denominator, are a threat or an opportunity. Seen in terms of safety exposure, management workload, reluctance to change, cash costs, etc., people can easily be seen as a 'the problem' to sustainable business. These are probably the most cited reasons for putting machines to work underground, thereby mechanizing various parts of the mining process. In recent years, several projects at South African mines and universities, the CSIR, Carnegie Mellon in the USA, and several universities in Australia have researched the possibility of jumping directly from manual to automated mining systems.

It is my contention that by viewing people as the 'problem', any efforts to improve the rate at which safety and productivity innovations are implemented will be fatally flawed. It certainly does nothing to alleviate poverty and unemployment amongst the youth.

In summary ...

- A historical mind-set going back many decades views the role of labour as a 'problem to be managed'
- Machinery does not equate to mechanization or even automation without the context of both systems design and, specifically, people
- To say that the mining industry needs innovative technologies actually means that the industry needs new and innovative ways for people to perform work
- The decline in fundamental research capacity in the country means that this has to be re-built before we have local capacity to resolve domestic business and technology issues. Employing only offshore research facilities does not resolve the entire matter when implementation is domestic
- South African's inherent ability to 'make a plan' and keep the job going will no longer be sufficient to ensure survival
- We are not able to reliably predict the future in engineering terms
- The speed with which the mining industry is able to devise and deliver new ways of working (technologies) is unacceptable. It is suggested that there has been insufficient research into the emotional triggers that make people want to use a new technology. This requires a change to long-established habits.

Reference cases

My career could be described as spanning both 'pre-technology' and 'post-technology'! and yes, this does mean that I discovered another way of getting work done successfully. The change happened when I was preparing a presentation for what was Gold Fields of South Africa in 1998, a little over halfway through my current career. It led to the moniker, described below and used at the time, of '40:40:20'. [''Moniker' in this context means the 'nickname' (40:40:20) given to represent the meaning of the circles shown in Figure 7.] The question posed to the presenter at the time was: 'Why do you think that some technology projects succeed but most do not?'

Before explaining the moniker, a basis for the discussion needs to be established. I will use examples selected from projects on which I have worked over the past 40 years. They are presented as anecdotal evidence to colour the following discussion and do not follow the rigour of a full case study. The list of projects is also not intended to be exhaustive but is presented in order to establish that I have had ample opportunity to learn from my mistakes. More importantly, to provide the breadth of experience for a formula, for what may

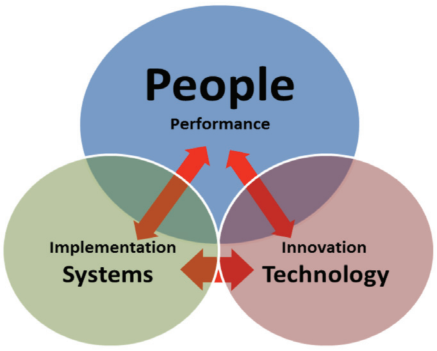


Figure 7—Basis of the 80:80:10 Moniker

result in a successful project outcome, to be developed. Also, the degree to which I was involved in the projects varies but can generally be described as having been either a hands-on involvement or instrumental in the project initiation and management. The list represents projects ranging in value (money of the day) from the tens of thousands of rand up to several hundred million rand, and varying in complexity from local testing of a product to mine-wide implementations, major capital project construction, to market-driven technology product development:

1. Multiple types of blasting barricades
2. First use of LHDs in underground reef pillar extraction
3. Multiple types of hydraulic props
4. New types of timber pack support
5. New types of elongate support
6. New scrapers and scraper winches
7. Emulsion rock drills (95:5 and 98:2)
8. Various types of stope face drill rigs
9. High-pressure water jets
10. Diamond wire cutting of ore
11. Electronic detonator blasting systems
12. Pre-conditioning of deep-level stope faces
13. Semi- and fully mechanized development
14. Semi-mechanized stoping methods
15. Design of alternative stores and maintenance management and delivery systems
16. Backfill systems design and implementation
17. Underground tracking and communications options
18. Vertical shaft-sinking projects
19. Decline sinking projects
20. Establishment of an international company delivering mining technical systems and services
21. Design, development, and implementation of the first corporate-wide, on-line mining technical system servicing over 2 000 concurrent users
22. Various experimental computer system (PlanIT Optim, MineServ)
23. Establishment of a materials flow properties testing laboratory at Wits University.

The first thought that probably comes to the mind of most readers is: 'OK – how many were successful?' Well, I am not going to air all of the dirty laundry but let's just say that there are enough T-shirts in the cupboard. There was one new technology introduced that was very successful – and that was the use of glue to fix ventilation brattice controls to the hangingwall of the stopes. However, I now suspect that the success of implementation had something to do with the smell of the glue …!

Unfortunately, together with the information in Figure 6, this does illustrate a critical element of human nature. A new technology will be successful if people can plainly see that it is to their individual or collective benefit/advantage. The second aspect is that these technologies work to establish new habits!

Four cases have been selected to illustrate that when deciding on how to resource a project, the relative focus of resources/effort is the deciding factor between success and failure:

1. High-pressure water jets
2. Semi-mechanized (hybrid) mining methods
3. Computer systems development
4. Mechanized capital development for production build-up.

Also, these four examples indicate that the role of behaviour and habit play an important function in determining success or failure.

High-pressure water jetting for stope cleaning

This project involved the installation of water jets powered by a 55 kW electric motor (Figure 8) in the underground stopes. The objective was to use the focused energy of the high-pressure jet of water to assist rock removal on-dip during the stope face cleaning portion of the stoping cycle. The technology was based on equipment used in the china clay mines. No changes were made to the mine designs. Some work was done to modify the face layout to maximize the benefits.

➤ *Need*—To achieve faster, more efficient face cleaning, but no impact on other stope cleaning bottlenecks, such as advanced strike gullies, was considered

➤ *Technology*—Regarded as simple, jetting guns were sometimes dangerous in the hands of an inexperienced operator. The logistics of moving the heavy pumps between stopes proved problematic as a rigger was required in some instances

➤ *Technology transfer*—It seemed to just happen! The supplier delivered the pumps and production officials had the units underground before engineering knew that cables needed to be installed. Operators were trained on the job for as long as the trainer deemed necessary

➤ *Surprises*—Eye injuries (due to foreign bodies) went through the roof initially. Given that the gold is very finely disseminated in the reef, there was a view that the mine call factor was negatively impacted due to the gold being blasted into support packs or into footwall cracks. Subsequent research indicated that this was not a cause of significant gold losses.
Not unsurprising was the increase in mudrushes and the under-design of main shaft pump and mud handling facilities.

➤ *Habits!*—Was an early success with most people, as it reduced manual effort and removed workers from unsafe areas. However, the habit of working to complete a task and then going to the 'station' meant that there was no real improvement in tonnage output.

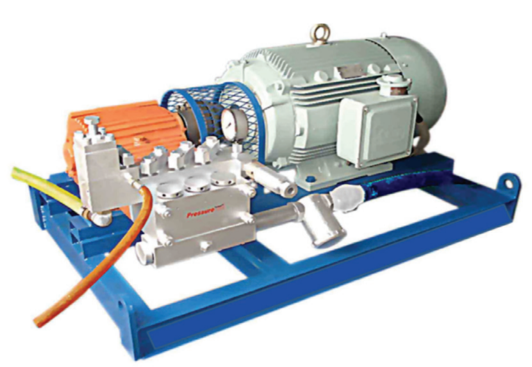


Figure 8—55kW High pressure water jet pump

As a result of this work. significant numbers of pumps were deployed across the gold mining industry as the immediate objective was achieved. Stope face cleaning efficiency improved by between 20% and 30%. However, that did not necessarily result in more blasts, and significant remedial work had to be done on safety training, control of mudrushes in ore passes, and ensuring that water handling throughout the whole mine was kept in balance. In-stope energy consumption effectively increased by 33% because there were more 55 kW motors running. There was no upfront systems analysis or risk assessment.

Hybrid mining methods

There were several significant projects on various gold mines in the 1980s and 1990s that used load haul dump (LHD) machines to transport ore from the stope face to the hopper or tip. All other aspects of the stoping system were considered conventional.

- *Need*—Due to the physical characteristics of the reef horizon, such as thickness of the orebody, dip of the reef, faulting, etc., ore removal using LHDs offered greater flexibility in the mining method than traditional scraper-cleaned advanced strike gullies
- *Technology*—Used existing equipment, and the biggest single issue was dilution from the deeper and wider strike drives sized for the equipment

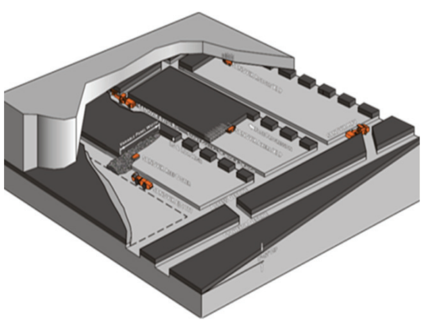


Figure 9—Semi-mechanised, in-stope mining system

- *Technology transfer*—Not complicated, because existing technology was employed. However, having a sufficient number of experienced artisans that were prepared to work underground was problematic
- *Surprises*—Dilution of gully waste into the ore was the single biggest factor that counted against the method. Also, working through the older mine infrastructure made logistics a challenge in terms of supporting the mechanized operation. The high cost per ton stoped was the metric used rather than the more system-wide cost per ton milled
- *Habits!*—Not readily adopted by many employees as the initiative was perceived as replacing stope workers. Machine breakdown or availability became a stock excuse for not achieving planned performance.

Computer systems design

Mainframe computers were first installed in the South African mining industry by JCI in the 1970s, but it was only in the 1990s that improvements in personal computers and software languages really started providing the tools for engineers in mining (note: not just mining engineers). While computer aided design tools had been improving through the 1980s, it was only in the early 1990s that they started to be adopted widely, facilitated by international APCOM conferences, etc.

- *Need*—There were no appropriate design and scheduling tools for the tabular hard-rock mining as found in the Wits Basin and Bushveld Complex. All plans were paper-based and for life-of-mine plans it would take many months to compile just one scenario (if they existed at all)
- *Technology*—This required the development of database techniques that allowed for full data manipulation in a 3D graphical interface providing an on-line environment available to handheld and mobile devices. South Africa pioneered much of this work in mining

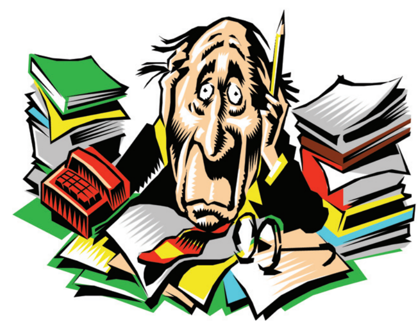


Figure 10—Mining by numbers

- *Technology transfer*—In several instances the rollout of complex computer systems was seen as part of a change management process as well as an ongoing performance improvement initiative. Considerable effort was invested in training and implementation, but unfortunately many senior managers got left behind
- *Surprises*—More senior management tended to be left behind by the technology and could not demand performance from younger engineers driving the systems. This facilitated the advanced levels of mathematical complexity used by the mining industry, to simulate all aspects of the operation: an innovation in its own right
- *Habits!*—The tools that all the cool guys want to be into …
  The ability to create virtual mining environments with virtual dashboards led to the unfortunate notion that operational control sits behind the desk.

Mechanized capital development for production build-up

All large underground mine development projects are faced with a common problem (there are lots, but one in particular is discussed here) in terms of the length of time in which there are large cash outflows before revenues start to accrue from the production build-up. This means that the critical path to full production enjoys a lot of focused attention.

- *Need*—At what was called the Freddies No. 1 Shaft Project (Tsepong North), attention was given to how quickly the development crews could be recruited, trained, and brought up to full productivity in the safest way possible

- *Technology*—While development was done by drill rigs (initially) and LHDs, the key to the successful execution of this project was the way in which the crews were allowed to select and hire their own members

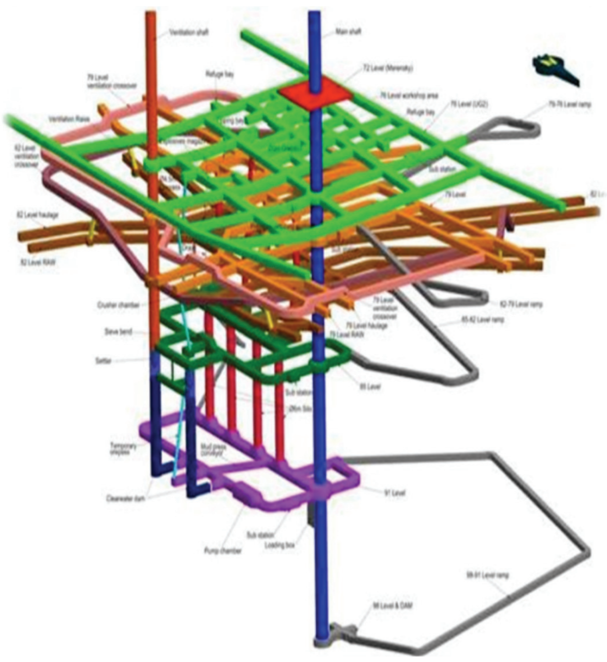


Figure 11—Illustration of a complex underground development infrastructure ahead of cash-generating activities

- *Technology transfer*—Recruitment was done on a top-down basis. Crews were on-site going through induction and training up to two months ahead of deployment. They felt part of the mine even before going underground. Teams competed against one another in training, which ultimately found expression in competitive face advances
- *Surprises*—How wrong the recruitment of the shaft operating teams turned out to be, due to ingrained habits learnt at a similar (but different) shaft. The high level of bonus earned by the competing development crews
- *Habits!*—At the outset an attempt was made to consciously build self-directed teams. The winner was drilling (coaching and training) the crews during days of surface preparation before allowing any production work underground. Constructive competitive behaviour and systematically repeated routines created habits rewarded through team recognition and incentives.

In summary

- The examples quoted above have all yielded their own lessons that have lent to the learning process over the course of a career
- All four examples have a common theme of machines either built or procured for specific purposes in the mining process
- Irrespective of the nature of the machine, it is essentially the technology (how the machine was used) that is the differentiator of how success was either measured or recognized
- All efforts to mechanize come to naught if the people are not involved and do not see that they have something to gain. This does not have to be financial gain, but can be peer recognition given in a constructive context.

Discussion

The format of the moniker is:

X:Y:Z

where

X = an expression of the total effort expended in conceiving, scoping, designing, and building the engineered component of a project normally measured and expressed in monetary terms. This can also be conceived as the 'machine'

Y = an expression of the total effort expended in the implementation of the project through training and change management processes also expressed in monetary terms

Z = an expression of the total effort expended in coaching the leadership of the technology in terms of how to motivate usage and demand performance by the executive, measured in monetary terms.

$\mathbf{X} + \mathbf{Y}$ = the technology

$\mathbf{X} + \mathbf{Y} + \mathbf{Z} = 100$

100 = the entire system

The 'As- Is' moniker

With reference to Figure 7, it is clear that there is no area of overlap between the systems 'circle' and the technology 'circle'. This is intended to signify that the technology has not been designed and implemented in the context of a systems engineering approach. This was reflected in the water jetting example, where the machine was purchased and installed without due thought to unintended consequences.

Further, we see that there is considerable but separate overlap between people and systems and people and technology. This is simply because people design both the systems and the technology. This has resulted in the technology not being used either correctly or effectively, as was the situation in the use of LHDs in the hybrid stoping method.

Now unfortunately, this is where opinion engineering has to come in to the argument. While the author has made assessments over the years as to the relative spend ratio between X, Y, and Z, it has not been done in a rigorous manner and ideally should be the subject of formal investigation. However, there is sufficient confidence to be able to state that in the majority of projects that cannot be classed as successful, the ratio of application of effort or spend on the project is approximately:

80:10:10

It is clear from the moniker and Figure 7 that everything is out of balance.

The 'To Be' moniker

If we now refer to Figure 12 we see that all three circles have come together, pulling towards the centre of gravity of the system. The implication is that with a complete and detailed understanding of the whole system, the people designing the technology are better able to envisage unintended consequences of their technology and take the appropriate risk mitigation steps. This the author experienced firsthand in the exceptionally successful production development build-up in the above example. The more complex the system, the tighter the three 'circles' should be overlapped. This is expressed in the computer systems design example. The intensive involvement of user groups at all levels of the client organization brought together detailed business process knowledge with the technologists where a common language and understanding was achieved. If one accepts the author's definition of technology – being the way that work gets done – then it becomes very obvious that the better a team is able to describe through systems engineering how the work is to be done, then the better able they are to design and build the technology solution.

As per the argument concerning the 'As-Is' moniker, there is sufficient confidence to be able to state that in the majority of projects that can be classed as successful, the ratio of application of effort or spend on the project is approximately:

40:40:20

It is clear from the moniker and Figure 8 that everything is now in a much better balance. The tighter the circles overlap the more 'balanced' the system becomes. Importantly, the executive leadership and all senior stakeholders have put in time and effort to be part of and understand the technology. Greater ownership throughout leads to shared values of what is 'in it' for the team. This is the fundamental trigger to creating good work habits and ensuring that change management is embedded in the organization. Another interesting feature of the red dot in Figure 8 is that it also represents the space in which real-time operational control happens in a manufacturing setting. If the business has not achieved a sufficient degree of business integration and management maturity to have all three circles overlapping, then it is unlikely that advanced monitoring and control systems would be truly effective in running the business processes more efficiently.

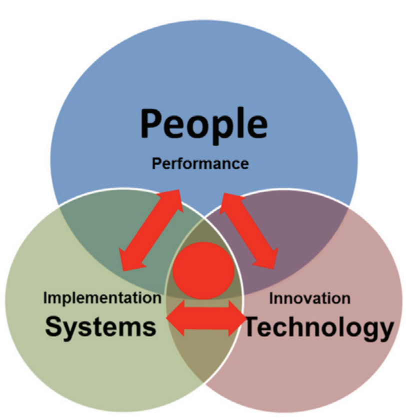


Figure 12—Basis of the 80:80:10 Moniker

In summary: why technology often fails (and what to do about it)?

Recall that failure here relates to not being able to change the way that work gets done. This is linked in turn to a failure to change the behaviour of people. Changing the behaviour of people is not about going through an engineering process to identify all of the mechanical and technical considerations. It is fundamentally about understanding how you want people to behave; then using industrial psychology tools and processes (such as understanding the power of habits) to introduce new habits that are triggered by activities in the work environment and rewarded in a manner that is clearly recognized (and even appreciated?) at an individual level.

The above is easy to write down but not at all easy to achieve – if it were, there would be fewer supervisory positions! It is the author's belief that the use of the 40:40:20 moniker as a guide in the design of how a new innovation should be implemented will both speed up the implementation and increase the probability of achieving a sustainable success. Success, as measured by changes in people's behaviour. Additional aspects that are also important considerations are:

- *Systems engineering*—The mining industry still suffers from a 'siloed' approach to project design. Time spent on analysing and designing the full range of business processes in terms of systems engineering will assist the project team to develop new habits. In addition, should any changes be made they can be subject to proper risk analysis for unintended consequences. This last point (unintended consequences) is an almost inevitable outcome of making changes to systems if there is little upfront analysis (the Y component) of the initial system to be impacted by a technology intervention
- *Human factors*—As engineers we tend to avoid the important task of doing a thorough design for people systems. In fact, some engineers avoid people altogether and do not appreciate robust debate – seeing this as unacceptable conflict! There are growing bodies of knowledge in industrial psychology circles that provide incredibly insightful tools for managing team dynamics and influencing behaviour. An example of recommended reading is 'The Power of Habit' written by Charles Duhigg
- *Organizational maturity*—It does happen that there are instances where the project is not aligned appropriately with the parent organization. This occurred with the strategy to grow the technical systems company by establishing international offices. The parent organization did not have the requisite systems or processes established even though the subsidiary had the ability and experience in its ranks
- *Stakeholder analysis*—Are the main sponsors of the project truly committed for the long haul? Remember that with most projects there are periods of pain (lots of it) and not a lot of gain. This question is particularly pertinent with shareholders who have an imperceptible financial risk 'pain threshold' and little stamina. I speak with the authority of being a shareholder …

New CEOs have been appointed in over half of the top 40 global mining companies (Table II) in the past two years at a time when operating environments and the social licence to operate mines have never been more difficult. Is this a further reflection of inappropriate metrics and the difficulty of managing the interface between short-term results and an industry that requires a steady hand and a long-term imagination?

Conclusions

It seems to me that linking the above discussion back to how the mining industry can find innovative ways of sustaining and creating employment has to cross the path of the 'Markets'. Increasingly globalized operations add complexity and risk. Corporate executives can sometimes be caught in the grip of faceless investors who have little truck with employment issues in the southern end of Africa. There is no doubt that there is merit in quarterly reporting, but not if short-term focus hurts longer term sustainable job and value creation.

In a recent article in the *Harvard Business Review*, Gautam Mukunda made the observation that the pursuit of quarterly returns has '… become so powerful that a recent survey of chief financial officers showed that 78% would give up economic value and 55% would cancel a project with a positive NPV – that is, willingly harm their companies – to meet Wall Street's targets and fulfill its desire for 'smooth' earnings.' Is the drive for quarterly reporting another example of a 'habit' that has unintended consequences?

It is patently difficult to list a set of solutions to some of the challenges discussed above, and even new ideas that can be investigated in order to shed new insight are a tall order. To check this you only need to come up with what you think is a unique thought and then go to Google. It is very humbling! Nonetheless, in closing, two questions must be addressed:

'What is the most basic outcome of investing in technology and how is it recognized?' and 'How does this all relate back to job creation?' The answer to the second question then takes the reader all the way back to the introduction section of this paper. An investment in a new technology – according to the author's use of the word, is an investment in the way that work gets done and, critically, the behaviour of people is changed appropriately. An important premise to this statement is that presumably the investor wants to have that work done more safely or more productively

In emerging markets, many countries are seeing labour costs rise way above the rate of inflation. In South Africa, for example, labour costs currently range from 20–25% of total production costs for modern, mechanized and opencast mines, to 50–60% for the mature deep-level underground mines. Worker demands for increased salaries and wages, safer working conditions, and improved conditions of employment have continued to plague the industry, and it is estimated that South Africa's mining industry lost more than US$1.4 billion in the 2012 –2013 financial year due to disputes related to these demands. While workers may aspire for higher real wages, during weak commodity price cycles the dialogue should be focused on achieving productivity improvements to pay for these gains. In contrast, a notable and sustained decrease in labour productivity has been experienced in the country. Research by CoMSA, for example, indicates that since 2007, labour productivity in the gold mining industry, expressed as kilograms produced per employee, declined by 35%. Clearly, this is not a sustainable situation and feeds the perception mentioned earlier that 'labour is the problem'.

The following are what I regard as potential avenues for exploring opportunities for a more rapid deployment of technology in general, plus some specific areas where additional employment creation could be possible:

Table II

Top 40 mining and exploration companies

Name	Country **	Year-end	Name	Country (**)	Year-end
OJSCALROSA*	Russia	31 December	Jiangxi Copper Company Limited	China/Hong Kong	31 December
Anglo American plc	UK	31 December	KGHM Polska Miedz Spolka Akcyjna	Poland	31 December
Antofagasta plc	UK	31 December	Newcrest Mining Limited	Australia	30 June
Barrick Gold Corporation	Canada	31 Decembeer	Newmont Mining Corporation	United States	31 December
BHP Billiton Plc/BHP Biliton Limited	UK/Australia	30 June	NMDC Limited	India	31 March
Cameco Corporation*	Canada	31 December	MMC Norilsk Nickel	Russia	31 December
China Coal Energy Company Limited	China/Hong Kong	31 December	Polyus Gold International Limited	UK	31 December
China Shenhua Energy Company Limited	China/ Hong Kong	31 December	Potash Corp. of Saskatchewan, Inc.	Canada	31 December
Coal India Limited	India	31 March	Randgold Resources*	UK	31 December
Consol Energy Incorporated*	United States	31 December	Rio Tinto plc/Rio Tinto Limited	UK/Australia	31 December
First Quantum Minerals Limited	Canada	31 December	Saudi Arabian Mining Company (Ma'aden)*	Saudi Arabia	31 December
Fortescue Metals Group Limited	Australia	30 June	Silver Wheaton Corporation	Canada	31 December
Freeport-McMoRan Copper & Gold Inc.	United States	31 December	Sumitomo Metal Mining Company*	Japan	31 March
Glencore Xstrata plc	UK	31 December	Teck Resource Limited	Canada	31 December
Goldcorp Inc.	Canada	31 December	The Mosaic Company	United States	31 May
Grupo México S.A. de CV	Mexico	31 December	Uralkali	Russia	31 December
Impala Platinum Holdings Limited	South Africa	30 June	Vale S.A.	Brazil	31 December
Industrias Penoles S.A.B. de CV	Mixico	31 December	Yamana GOld Inc.	Canada	31 December
Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Co. Limited	China	31 December	Yanzhou Coal Mining Company Limited	China/Hong Kong	31 December
Inner Mongolia Yitai and Jaingxi Copper	China/Hong Kong	31 December	Zijin Mining Group Company Limited	China/Hong Kong	31 December

*Refers to companies which were not included in the 2012 analysis
**Refers to the country of primary listing where shares are publicly traded

- The government of any country only has people, land, sea (water resources), agriculture (including forestry), and the contents of the Earth to bring to account for the benefit of the population. The debate on resource nationalism is one to be encouraged, as it keeps the interests of the mining industry front and centre with the interests of Government and organized labour
- South Africa does not have 20 or 30 years to identify and develop brand-new mechanized or automated solutions to access and recover many of its mineral resources. Perhaps a renewed focus on inventions that have already been researched, but with a view to applying them in new ways technologically, should be undertaken in the context of recent developments in the areas of:
  - Materials engineering
  - Miniaturized instrumentation
  - Digital communications
  - Greater risk adversity
  - Improved commodity prices
  - Energy conservation
  - Industrial psychology

Viewed in the current climate of social awareness and global economics, this may very well produce a different outcome

- By the same token, old methodologies applied in an innovative way are clearly an underdeveloped opportunity. For example, selective blast mining as a technology has evolved enormously in recent years, and if applied to in-stope narrow-reef orebodies can change the economics by an order of magnitude. Furthermore, the author, in collaboration with Dr Mike Roberts, has determined that there may be mining designs that can increase total gold extraction from deep mines by adopting a retreat mining strategy
- The speed with which society and technology are changing, driven by the sheer number of people in the world, continues to create an environment in which the mining has a positive future. Taken in the context of the South African industry's ability to overcome challenges, this suggests that solutions will be found to bring mineral assets to account as well as creating employment opportunities
- One of the core issues to overcome is the pace at which the industry is able to devise, implement, and manage innovations that have a lasting impact on performance
- The theme of this paper is to suggest that the pace can be increased with appropriate focus on innovation projects that:
  - Develop a common language
  - Move from 80:10:10 design to 40:40:20 planning
  - Nurture new-style leadership
  - Understand the culture of decision-making (risk-taking)
  - Leverage multi-stakeholder collaboration
  - Can accommodate orebody-specific solutions
- Quicker turnaround in the implementation of new technologies must recognize that people's behaviour has to change as a result of the new technology investment
- Employment and job creation cannot be viewed solely in the classical context of 'on-mine' work. If, for example, the industry came together with Government to structure incentives that:
  - Promote mining capital goods manufacturing – upstream beneficiation (e.g. car manufacturing for export)
  - Exploit mining developed skills and trades within infrastructure remaining after mines close to promote small industry, agriculture, etc.

Then services and support to the new wave of innovations will drive demand for more technicians to be trained. This also drives tertiary employment in technicons and universities.

Make no mistake that there are significant challenges to overcome but I, for one, look forward to them in the remaining years of my career.

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