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A framework for the introduction of mechanized mining

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The paper describes the issues that should be considered when introducing mechanization to a mining operation. In South Africa, traditional methods of mining are well entrenched after more than a century of mining. To successfully change from these methods requires an integrated holistic approach that considers all aspects of a mining operation including setting of objectives, selection of personnel, recruitment, training and remuneration policies, organizational design, mine design, equipment selection, maintenance philosophy, standards and procedures, and monitoring and control. The paper makes reference to experience gained during a variety of on-mine case studies in drawing generic conclusions and making recommendations.

Introduction

This paper focuses on the issues pertaining to the introduction of mechanization in an underground narrow reef hard rock mine typified by, but not solely restricted to, platinum mining in South Africa. In the context of this paper, mechanization refers to any machine, process or activity that reduces the human effort required to break or move rock or material in a mine. The following mechanization technologies, among others, have been implemented in South African platinum mines with varying degrees of success:

- Trackless equipment for narrow reefs
- Conveyor belts
- Rock cutting technologies
- Drill rigs and jigs
- Hydropower systems
- Monorail transport systems.

Not all of these technologies can be considered as having achieved pervasive use, which is an important indicator of successful implementation. Those that have been widely applied often do not perform at their full potential, as the case studies will illustrate.

Drivers of mechanization

An in-depth understanding of the drivers for increased mechanization is important to ensure that mechanization is not adopted for the wrong reasons. The reasons that are proposed for embarking on mechanization are increased productivity, improved safety and reducing the incidence of low-skilled work.

Increased productivity

Improving overall productivity (not just labour productivity) is probably the most important driver for increased mechanization. Increased mechanization does not necessarily lead to lower unit labour costs. Rather, increased skills are required, resulting in higher paid labour, albeit with fewer workers being required. Fewer numbers of underground workers have important benefits such as easier transport logistics and lower fixed labour overheads.

For a narrow reef environment, the key to maximizing productivity is the integration of technologies and the resulting higher face advance rates[1]. High face advance rates result in reduced face length or improved output, which results in much better utilization of a mine's labour and infrastructure resources. Less face worked leads to better supervision and control and makes it easier to introduce yet more technology, which in turn leads to further increased face advance rates. All this leads to a self-reinforcing cycle of activities, which result in reduced cost as depicted in Figure 1.

There are also other benefits for the overall quality and efficacy of the mining system that are less easily quantified but that lead to improved productivity. These include improved communications and environmental conditions underground.

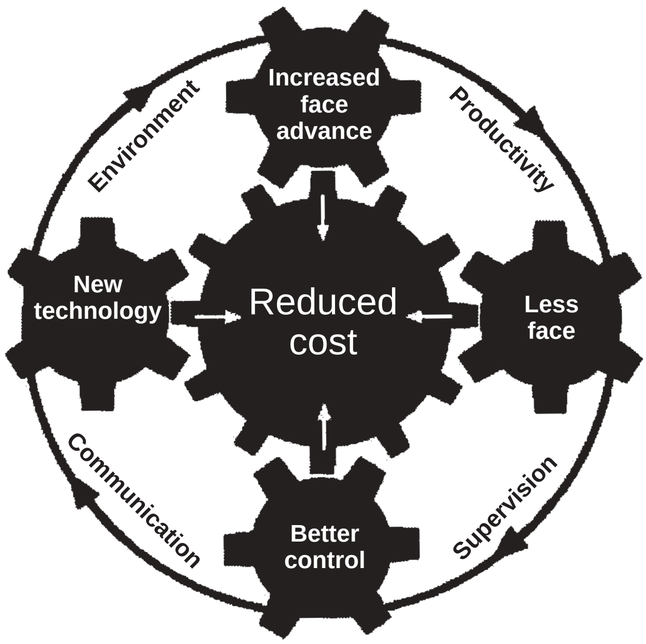

Figure 1. Impact of increased face advance rate

Face advance rates are a function of the planned cycle, the days available for mining, the advance per blast and the lost blast rate expected. One of the keys to improved face advance rates is to reduce the lost blast rate. Past work[2] has indicted that for a 1:1 planned cycle, as much as 30 per cent of the planned blasts can be lost when using conventional technology and work practices. Any technology that can significantly reduce the lost blast rate will lead to improved face advance rates.

Improved safety

While the introduction of machines and remote control systems have the potential to remove people from often very dangerous areas of the mine (e.g. drillers moved away from the high risk proximity to the face) and hence significantly contribute to reduced accident rates, the widespread use of machines gives rise to other risks that must be fully understood and managed.

Reduction in the reliance on low-skilled work

One criticism often levelled at any form of mechanization is the replacement of labour by machines and its resultant social consequences. Mechanization can, however, be a powerful driver of increased investment in education and training at all levels of the workforce, with concomitant positive socio-economic benefits. An important consideration is that, while the number of people employed on mines may decrease, the numbers employed in secondary industries such as manufacturing and service industries will increase in order to meet the increasingly high technology demands of mining companies. The overall result of increased mechanization is therefore often increased opportunity within the broader mining industry.

Barriers to success

Sustainable technology change, such as the introduction of mechanization, is often difficult to achieve in mines. The reasons for this are not necessarily any technical inadequacies in the technology itself, but rather 'soft' issues or barriers to technology implementation that may include[3]:

- *Organizational and institutional factors*—The pace of technological change is usually faster than the rate at which organizational changes can be assimilated and institutionalized. This poses a problem as employees have to be sensitized and prepared for change, and organizational systems and procedures have to be modified to deal with the changes. A mine's capacity or ability to absorb new technology is influenced by the level of prior, related knowledge and expertise (i.e. basic skills, shared language, technological acumen, and functional specialization).

  Organizational culture has a significant influence on the efficacy of technology transfer. A culture of action orientation, risk taking, receptiveness to both internal and external breakthroughs, and a high tolerance for failure should be present. In the mining industry this issue is complicated by the often short tenure of senior management on the mines, who may be unwilling to support long-term mechanization development when they will not be in a position to enjoy its benefits.
- *Human factors*—People are key to successful mechanization implementation. This implies that people involved in the implementation process have to be:
  - Informed about the implementation process
  - Appreciative of the benefits of mechanization
  - Consulted about their needs, concerns, perceptions, attitudes and expectations
  - Trained and mentored to understand and apply the technology to its fullest extent.

  When new technology is imposed on mines without ensuring internal receptivity, it is bound to fail. A very real factor influencing successful implementation is employee attitudes or perceived resistance to change. Early and significant employee participation in the planning and implementation phases is a critical precondition for fostering a positive attitude to technological change.
- *Integration with other mine systems*—The most advanced technology does not necessarily produce maximum benefits, whereas integration of technology with the rest of the mine does. Integration requires effort and resources going well beyond specific technology acquisition and training. Redesigning and restructuring the entire system in which it is utilized obtains the optimum performance of technology.
- *Communication factors*—Many technology transfer problems can be attributed to ineffective information exchange between providers and users. A considerable amount of attention should be given to reducing communication barriers.
- *The nature of the technology*—An important determinant in successful implementation of new technology is the nature of the technology. The more concrete the technology, i.e. the extent to which the technology is understandable, demonstrable and unambiguous, the greater the probability of success. People-embodied technologies are therefore more difficult to implement than are product-embodied technologies. The degree to which mechanization is demonstratably supportive of a mine's unique needs and strategic goals will have a huge impact on the success of the technology.

Case studies

The following case studies illustrate the many and varied challenges in implementing new technology:

Conveyor belts

Recent developments in shallow hard-rock deposits have accelerated the use of conveyor belts for rock transport. In particular, the trend in the platinum sector is to follow chrome and sometimes even coal practice and to apply belt conveyors in dip, strike and apparent dip applications.

Recent research[4] has found that, on average, conveyors installed as primary underground material handling systems operate at less than 60 per cent of design capacity. What is also evident is that this is probably not a poor achievement, given the constraints under which these systems operate. While there is a tendency to blame poor conveyor design for the low utilizations achieved, closer examination of the problem typically reveals that it is rather poor design of the overall rock-breaking and transport system that is responsible for poor overall utilization.

Conveyor belts are continuous flow devices that operate best when fed with well-graded constant feeds. The choice of belt width is governed primarily by the maximum lump size of material to be transported. The nature and shape of the material has an effect on the maximum inclination that may be used. Throughput is achieved as a result of the combination of width and speed.

Constant feed to a conveyor belt is difficult to achieve in platinum mines where the system for moving rock from the face to the conveyor feed point is by means of LHDs, which are essentially batch conveying devices. A quasi-constant feed onto the conveyor can be achieved by introducing surge capacity between the LHDs and the feed point of the conveyor. This solution is, however, limited by the practicality of providing large excavations at the head of each conveyor. Another approach is to feed the conveyor with small frequent loads rather than large infrequent loads. This may, however, be at odds with a desire to use the biggest possible LHDs for mining efficiency reasons in room and pillar applications.

Lump size can be controlled by the application of grizzlies or feeder-breakers at conveyor feed points. Feeder-breakers are not easily applied in platinum mines because of the hardness of the rock, and grizzlies are the most obvious option. This does, however, require that some arrangement for the sorting and secondary breaking of large rock at each conveyor feed point. The practical complications of achieving this sometimes lead mines to dispense with grizzlies and to load large rocks directly onto the conveyor. This results in severe belt, idler and chute damage and significant conveyor down time, which is then often blamed on poor conveyor design.

Many mines transport more than one product on a belt and many transport three or more. While common in industrial applications and process plants for many years, it must be remembered that these applications are generally characterized by short conveyor lengths and large surge capacities. Long series belts with little or often no surge capacity take longer to clear before changing products. The lack of surge capacity significantly degrades the throughput of the system. This is often attributed to a lack of performance of the belts themselves.

This example illustrates the complexities involved in implementing a new technology in an existing system. In this case, many of the difficulties that have been experienced in the operations of conveyors belt systems in platinum mines have little to do with the conveyors themselves: rather a lack of attention to the systems-related issues in the overall breaking and moving of rock has led to the rock transport system performing below initial expectations.

Lessons learnt:

1. Overall system (mine) design is as important as individual equipment design.
2. Integration of differing systems has to be taken into account.

Impact mining system

The case study for the Impact Mining System (IMS), a non-explosive rock breaking system, was well documented in a paper[5] presented at the 5th International Symposium on Mine Mechanization and Automation, Sudbury, Canada. The following points were made:

The IMS was under development for some 20 years. It underwent extensive pre-production trials in 1989 and 1990 and has been commercially available since 1991. From 1991 to 1992, four systems were purchased by a major South African gold mining company and since then extensive full production trials were undertaken. These were suspended at the end of 1997.

The overall strategy for the IMS implementation was laudable and included most elements required for success. Its benefits were well communicated and demonstrated (through the pre-production trial), its design was well-integrated into the existing mining system, extensive well documented training and maintenance manuals with job descriptions were prepared, detailed cost benefit analysis was undertaken, full and all encompassing monitoring and reporting was implemented and a champion was identified at the early stages of the project.

Its less than optimal performance during the full production trial was due to two main factors. Firstly, it soon became evident that the technology was not totally appropriate for the geotechnical environment in which it was installed. The IMS requires some weakness in the rock (usually mining induced fractures) that it can exploit. In this case, there were large areas of ‘hard patches’, that is areas where no weakness existed. An extensive geotechnical investigation was not undertaken prior to its introduction, which would have identified the problem. Nevertheless, such technical problems could be overcome by, for example, the introduction of a more powerful hammer. The fact that it was installed in the worst possible conditions was part of a philosophy of the time of ‘if it works here it will work anywhere’. The converse of this is that, if it does not work, the negative reputation gained slows down the rate of implementation and could even in extreme cases kill the technology.

Secondly, and much more importantly, human and organizational problems proved to be much more intractable with the following issues negatively affecting performance:

- Although initially there were champions, staff turnover resulted in these champions disappearing. The fact that champions tended to be situated in the head office environment meant that there was a powerful ‘not invented here’ syndrome on the mine
- The infrastructure and culture of the team remained the same as the rest of the mine. An appropriate culture for drill-and-blast mining was not appropriate for the IMS
- Training was always limited due both to a high turnover of staff, and to the cutting short of training periods due to production pressures
- The knowledge held by the developer was not effectively utilized
- There was no effective independent technology facilitator to liaise with the equipment supplier, developer and the mine and to ensure that technology transfer plans were implemented.

The trial certainly confirmed the validity of the factors that influence successful implementation of mechanization, particularly the dangers of introducing new technology in the production environment without first addressing the organizational and cultural issues.

Lessons learnt:

1. Primary focus must be on human and organizational issues.
2. Do not underestimate the ‘not invented here’ syndrome.
3. Always consider the geotechnical environment wherever rock and machines interface

Narrow reef trackless mining

Recent developments in trackless equipment have resulted in the development of low profile machines, which are more suitable than their larger predecessors for the shallow dipping narrow tabular orebodies prevalent in the platinum industry. The tendency has been to apply this equipment in mines laid out entirely on-reef utilising room and pillar or hybrid mining methods. Where reef dips exceed the operating envelope of the equipment, apparent dip layouts have been used.

There is little doubt that, if the correct equipment is matched to the correct mining environment, there are significant safety and productivity advantages that ultimately result in lower mining costs. However, whether due to the limited exposure of South African mine design engineers, production personnel and management to trackless mining, or the particular challenges related to the use of trackless equipment in narrow orebodies, these advantages have not always been realized.

In order to have the best chance of successful implementation it is important to establish an appropriate environment for the planning, implementation and use of trackless equipment. Based on past experience, the following areas are considered to be key during implementation of trackless mining systems, whether to existing or new mines:

- *Management*—Many attempts at mechanization in South African mines have failed due to the appointment of a manager with inappropriate experience with regard to the important issues related to the implementation and use of mechanized systems. It is unlikely that management will drive issues that they do not fully understand and appointment of a suitable person is essential for implementation success
- *Holistic design approach*—Mechanized systems should not be looked at in isolation but as a part of a larger mining system. Each part of the system must integrate smoothly with upstream and downstream systems for the full advantage of mechanization to be realized
- *Selection and training*—A proper selection and training procedure should be followed for all personnel involved in the planning and operation of a mechanized mine. This includes management, planning and maintenance personnel and operators
- *Equipment selection*—A comprehensive equipment selection process should be followed in order to ensure that the correct equipment is selected for each task
- *Availability and utilization*—Detailed design of shift cycles should include consideration of both production and maintenance requirements in order to fully optimize the availability and utilization of the equipment.
- *Maintenance philosophy*—An appropriate maintenance philosophy should be developed and full service schedules drawn up for each machine. Equipment suppliers should be consulted during this phase to ensure the equipment is serviced at the correct intervals. Well-serviced reliable machines will give better availabilities.
- *Mine design*—Suitable mine designs should be developed in which the selected equipment can operate efficiently. Issues such as footwall infrastructure versus on-reef infrastructure should be considered particularly carefully.

It is clear that for successful implementation of trackless vehicles, a broad range of issues need to be considered. Failure to address all of issues adequately, including human resources, technical design and operational planning, may well result in sub-optimal implementation and put at risk the potential advantages of mechanization.

Lessons learnt:

1. Selection of an appropriate leader (champion) is vital to the success of any mechanization implementation project.
2. Proper design and planning work must be carried out.
3. Stringent selection and training procedures must be implemented for operators, maintenance personnel, planning personnel and management.
4. Careful planning of production shift and maintenance cycles is essential for high availabilities.
5. Benchmarking exercises against similar operations are extremely helpful in determining the potential pitfalls.

Proposed framework

A number of best practices for technology implementation have been identified in previous work[6]. These should be considered as they may provide important insight into issues that can influence the successful mechanization of a mine. Previous work has indicated that the following generic issues are relevant to success or failure in implementing new technology:

- *Perceived value/benefit of the technology*—People who make decisions about acquiring technology for mines do not choose technology per se; they choose the beneficial results of the technology. In all the known successful cases, the technologies were highly recommended by competent and respected third parties other than suppliers or mines. The technology was much more credible when a neutral party endorsed it.

  The classic financial measurements, such as NPV, IRR or payback periods, are often not enough to assess the cost benefits of mechanization. Although these financial criteria remain important, other non-financial criteria must also be considered. As examples, these could include:
  - Safety
  - Flexibility
  - Time to production start-up
  - Risk
  - Labour availability and skills level.

Where various mechanization options exist, a four-step approach should be adopted to assist in this multi-criteria decision making process[7]:

- Step 1: Identify the criteria to be used
- Step 2: Weight the criteria
- Step 3: Identify the options available
- Step 4: Calculate the best option based on the weighted criteria.

As most criteria require some expert judgment, this process should never be done in isolation but rather by adopting a team approach using a variety of appropriate experts.

One of the options considered should, wherever possible, be a known base case, typically current conventional mining practice. This comparative-type approach tends to be more accurate than a zero-based approach.

- *A culture supportive of technology transfer*—Excellence in mines depends on the quality and commitment of their employees and requires developing and communicating a shared set of values. The technologically orientated mine's value set should include the role of technology in the organization and the emphasis on creativity and commitment to quality. The following human resource management practices have been associated with successful implementation of complex technology and an innovative working environment:
  - Training of employees in the new technology
  - Gaining employee commitment to change by involving them in the implementation process from the outset
  - Changing the infrastructure, structure and systems to cope with the anticipated changes
  - Anchoring the new behaviour in the culture by adapting the reward system.

Sufficient attention to the above factors is crucial because if new technology is imposed on mines without ensuring receptiveness, it is bound to fail.

- *Consultation and participation*—Technology implementation processes can be improved by building, developing and maintaining solid, respectful, long-term relationships between all stakeholders, both internal and external.
- *Technology implementation as part of a broader strategic plan*—A focused technology implementation strategy should broadly determine the direction of the mine's technology transfer effort and the criteria against which the effort will be appraised. Such an implementation strategy and its relationship to the mine strategy should be given serious thought. The technology implementation strategy should be seen as an explicit element of the mine's objectives and strategies. Corporate top management should have an accurate picture of the technology portfolio. A mine's strategic plan would ideally be sufficiently well defined to identify the role mechanization could play in achieving the mine's goal, to provide criteria for generating and screening new technologies, and to suggest criteria for evaluating technology implementation success.
- *Improved and optimized communication*—Technology implementation problems are often attributable to ineffective information exchange between suppliers and users. Improved management of the information exchange is required to increase the success rate of technology implementation. It is also important to realize that no single best recipe exists in terms of the media that are utilized. Different types of technology and different circumstances might require different media. It is also important to make use of a variety of communication media to bring the message across. Whatever the mechanisms used to disseminate information, reduce the information overload. Focus on the end user who is generally not interested in how a solution was developed.
- *Evaluation and control systems*—The effectiveness of technology implementation is difficult to conceptualize, and so is its measurement. Some approaches are included in the following examples:
  - Surveys to question technology recipients about the application of transferred knowledge could be the best way to identify success
  - Collection of testimonials and positive anecdotal information provide examples of successes that are particularly useful for justifying specific programmes and/or activities in given geographic locations.

  Various other techniques for measuring and assessing transfer efforts exist, for example:
  - Transfer audits conducted by mines by way of end user interviews at the end of every project to measure the end user's satisfaction
  - In an operations audit, an interdisciplinary team from the corporate structure performs a systematic audit of a mine's operations
- *Training and mentoring*—Technology must be applied in order for it to be of value to a mine. Training employees to understand and use new technology is critical to the success of the transfer process. The training will have a direct effect on the capability of the employee to accept and implement new technology.

The acceptance by the employee is a critical factor in the process of technology transfer and leads to the need to find ways to ensure that the employees understand the new technology. The principles associated with the application of the new technology remain unchanged for different users, but the way in which they are presented and explained must be tailored to suit each type of end user. Trainers should be taught how to transfer skills and technology, deal with cultural differences and integrate the culture of the employees into the training programme. There is a need therefore to move beyond the translation of training material and to design training programmes that contain material relevant to the users.

Employees can be trained at a faster pace than is normally anticipated; however, certain key elements must exist, namely challenge, direction and means. As employees progress in their training, personal satisfaction and recognition by the organization and by peers will provide further incentive.

Finally, mentoring is an essential ingredient of technology transfer. There is no substitute for learning from someone who has already been through the process.

- *Clear responsibilities of the role players*—A number of role players in the technology transfer process has been identified. Each one of these role players is discussed below to clarify their responsibilities/roles in the technology transfer process.

Technology developer

Developers do not generally participate in the exchange of information. They frequently perceive these activities as a waste of time and not central to the work that they do. It is, however, of the utmost importance that the developers of technology be considered an integral part of the technology transfer process. Although they are not directly involved in the technology transfer process, they should be knowledgeable and enthusiastic role players in the transfer effort and they have to be kept informed of current policies and regulations and be encouraged to participate.

Developers enhance the transfer of technology in a number of ways:

- They can communicate the importance of technology to the mine's representatives
- A large body of data exists in raw form, such as abstracts and results of trials, that is written by inventors and usually in a manner that cannot be easily understood by most readers. The data are not useful unless they have a high information (as opposed to data) content. It is suggested that the data be transformed into information that is useful to the target audience. This requires elaboration, aggregation, dialogue, brainstorming and other techniques to demonstrate the implications of the new technology
- Developers can be responsive to the input and suggestion by industrial sponsors. This input could be extremely helpful in making a development project more useful or more interesting to organizations
- Technical staff should understand that results have to be usefully packaged, should focus on the end user's needs and should be presented in an easy-to-implement form. Information overload potential should lead to a demand-driven, one-page method of communicating products/technology
- Developers should define development goals clearly because obscure or vague project goals could cause disillusionment on the part of mines who expected more from a project than was possible.

Technology transfer facilitator

The technology transfer facilitator acts as an intermediary between the developer of the technology and the mine. In essence, the technology transfer facilitator does the following:

- Takes care of the personal, organizational and cultural issues of mines in order to achieve effective technology transfer
- Screens the environment for technological opportunities that could be translated into development projects
- Identifies a technology implementation champion on the mine
- Emphasizes the relevance of the project to the mine's needs
- Demonstrates the usefulness of the development. The technology transfer facilitator should ensure that any reports to the mine are clearly and concisely written, show how the development results will affect the mine, and address practical considerations of implementation
- Provides training sessions or seminars, giving potential implementers, users and developers opportunities to interact
- Creates a climate in which problems may be addressed and solved at an early stage
- Develops the technology transfer plan, giving attention to the following items:
  - Message
  - Objective
  - Team
  - Audience
  - Media
  - Action plan
  - Cost
  - Evaluation
- Implements the technology transfer plan, attending to the following:
  - Timing
  - Publicity
  - Equipment/programme bugs
  - Staffing
  - Funding
  - Alternative action sequence

Implementers/champions

Although every technology to be transferred requires a champion on both the supplier and mine ends of the process, a champion is probably more important on the mine side. The literature shows that a primary breakdown in the technology transfer process is not within the exchange of information, but at the point of implementation. In the mining industry, identifying champions can be complex, as senior staff on mines generally have a relatively short tenure on a mine. If a succession plan is not in place, the impetus in implementation may decline, as the original urgency of the development is lost.

The role of the implementer or the technology champion is highly complex. This person would be responsible for the following:

- Considering whether technological strategies are being planned and executed
- Coordinating development with strategic organization objectives
- Ensures that the CEO and the top management team gain a better understanding of the technology transfer process, as support for invention and innovation begins at the top
- Seeing to it that effective communication takes place early and continuously throughout the life of a project.
- Acting as liaison between developers and mine employees
- Using a variety of methods to communicate information and emphazing personal interaction
- Encouraging direct contact with the developer when questions arise to ensure that important problems are addressed in ways that benefit potential users
- Ensures that top management receives development results in a form that is readily understood and digested
- Providing assistance with respect to implementing and training.

Finally, the champion is a person or a team who understands technical aspects, that is familiar with human aspects and that can communicate effectively with end users or the workforce.

End user

The end users are the people who apply the new technology daily. Their responsibilities lie in:

- Verbalizing their needs
- Keeping an open mind to change
- Effectively listening to the information provided to them
- Providing feedback on the technology
- Maintaining a positive relationship with colleagues and supervisors/direct seniors
- Receiving appropriate training
- Taking part in the change process
- Giving feedback about the progress/effectiveness of the process.

Although technical problems are often blamed for implementation failure, they can be overcome relatively easily. However, if implementation is to be successful, a primary implementation focus must be the above human, communication and organizational factors.

The way forward

The South African mining industry presents unique challenges to the successful implementation of mechanization. There are many examples of failures but very few examples of outright success. To increase the success rate, which is essential to the long-term sustainability of the mining industry, requires new thinking in technology transfer practice.

Key to this new thinking is the necessity to use neutral third parties (an honest broker). Technology suppliers obviously have vested commercial interests: mining companies have employees whose future careers and indeed their current jobs may be at stake, based on the success of mechanization.

It is often only an outsider or honest broker who has no vested interests, who can remain focused on the bigger picture and the longer-term benefits of applying new technology. Such an honest broker should ideally also have been exposed to the implementation efforts of a variety of other mines, both locally and internationally.

The role of this honest broker should include the following:

- Audit current technologies and systems and make recommendations for improvement.
- Assess appropriate technologies based on pre-defined and accepted criteria.
- Manage pre-production development of these technologies and, if appropriate, arrange trials.
- Manage the process of implementation of the most promising technologies.
- Continue monitoring to ensure continuous improvement processes are in place.
- Maintain a knowledge management system to ensure the learning gained is available to future generations of mine management.

Conclusions

In order to ensure that the South African mining industry maintains and improves its position with regard to competitiveness and to safety and health, it is essential that priority be given to ensuring continuing success in the implementation of more mechanized mining methods. This requires that an enabling environment be provided in which to operate, that a thorough understanding of the benefits of mechanization is instilled in all stakeholders, and that key role players engage in building appropriate technical and managerial capacity.

It is strongly recommended that the South African mining industry investigate the adoption of the best practices outlined in this paper by testing their feasibility among the various potential users in the mining environment. This would also involve comparing success and failure technology transfer cases, to identify the relative importance of the best practices.

A number of role players with distinct responsibilities have been identified as integral to successful implementation. Respected leaders in the mining industry should take a more active role as champions of technology.

Another important factor is the need for a structured communications strategy in technology transfer. Case studies support the view that, although technical problems are often blamed for technology transfer failure, they can be overcome relatively easily. However, if implementation is to be successful, the primary focus must be on the human and organizational factors.

Finally, the role of an honest broker is emphasized in order to ensure long-term implementation success.

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