Implementation of Mechanized Roof-bolters for Low-seam Hard-rock Mining

by

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ABSTRACT

As commodity prices decrease and health and safety requirements increase, it is of the utmost importance to understand the complexity of converting the existing conventional mines to mechanized mining operations. This is necessary for the mining industry in order to remain competitive, as there are minimal numbers of new mining ventures taking place. There have been many previous attempts to do this type of conversion in the mining industry that have not been successful and also not well-documented, thus the knowledge is lost to the industry.

The intention of this case study is to understand the process followed by a specific mine in converting from a **conventional** roof-bolt installation to a **mechanized** roof-bolt installation method in an already semi-mechanized operation. The objective of many mines is to improve the health and safety of the employees who are exposed to dangerous areas, as well as to improve productivity and efficiency to ensure a more competitive position in the market. That objective also applies to this case study.

By evaluating this project through a process of interviews with role-players, based on knowledge gained from the industry and aspects that were seen as important in various other literature studies, it was possible to determine what worked, what did not work and what lessons were learned during this project that could be valuable to the industry. Through this process it can be determined which of these aspects impacted on the implementation of this type of conversion project. It is also clear that each conversion project will have its own dynamics but there will be the basic elements such as the types of equipment, human factors and management processes that will apply to most mechanization projects.

The biggest driver for the success of mechanization in the mining industry will be with regard to how to ensure job security while introducing mechanization, which does not apply only to the mine itself but to both the mining and manufacturing industries. Dwarsrivier Mine overcame this big hurdle by making a profoundly bold decision, namely that no one would lose his job. In essence, this ensured a more candid approach to making this implementation process a success.

The improvements that the new equipment brings must be understood, as well as what the consequences will be in other sections or departments of the organisation.

Setting realistic targets for the short and long term will be valuable, and allowing time for the operators to mature will give the highest return on investment in the implemented equipment.

DECLARATION

I, Cornelius Kempenaars, declare that this research report is my own work, except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to this or any other university.

Cornelius Kempenaars

Signed at ……………………………………………………

On the …………………………….. day of ………………………… 20…..

DEDICATION

I dedicate this work to my family and to my late parents. Thank you all.

ACKNOWLEDGEMENTS

I would like to acknowledge the following people who assisted and supported me during this journey, and all they have added to this work:

- My supervisor, Professor J Sheer, for his guidance throughout this research project.
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CHAPTER 1. INTRODUCTION

1.1 Purpose of the Study

The purpose of this study is to analyse and evaluate the implementation process that Dwarsrivier Chrome Operation initiated to convert from a conventional roof-support installation mine to a mechanized roof-support installation mine.

1.2 Context of the Study

Dwarsrivier Chromite Mine is situated on the farm Dwarsrivier 372KT, approximately 30 kilometres from Steelpoort and 60 kilometres from Lydenburg, Mpumalanga Province, South Africa. Located at longitude 30°05’00”E/latitude 24°59’00”S.

Figure 1.1: South Africa Map – Dwarsrivier Mine location.

The mine is located in the eastern limb of the Bushveld Complex, which comprises persistent layers of mafic and ultramafic rocks, containing the world's largest known resources of platinum group metals, chromium and vanadium. The mafic rocks termed the Rustenburg Layered Suite, are approximately 8 kilometres thick in the Eastern Limb, and are divided formally into five zones. The rocks of the Marginal Zone at the base of the succession consist mainly of pyroxenites with some dunites and harzburgites. Above the Marginal Zone, the Lower Zone comprises mainly pyroxenites, harzburgites and dunite, and is present only in the northern part of the Eastern Limb, and only as far south as Steelpoort. (ARM, Mineral Resources and Mineral Reserves, 2016)

The appearance of chromitite layers marks the start of the Critical Zone, economically the most important zone. The layers within this zone are grouped into three sets termed the Lower, Middle and Upper Groups. The sixth chromitite seam in the Lower Group (LG6) indicated by Figure 4.7 in chapter 4, is an important source of chromite ore and defines the ore body that is mined at Dwarsrivier Mine. In the Eastern Limb, in the vicinity of Dwarsrivier, the strike is nearly north-south, with a dip of approximately 10 degrees towards the west. Average thickness of the LG6 seam is about 1.86 metres in the Dwarsrivier area. (ARM, Mineral Resources and Mineral Reserves, 2016)

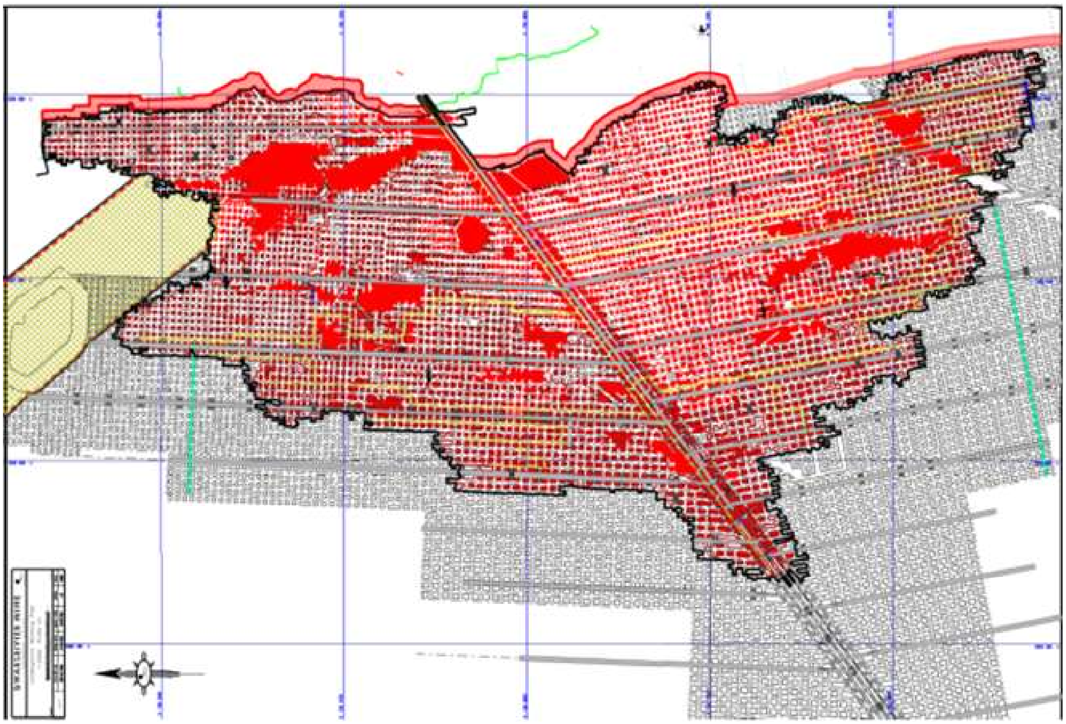

Figure 1.2: Grid layout of bord and pillar mining (Risk Assessment Report ARM Assmang Chrome, Dwarsrivier Chrome Mine, February 2013)

Figure 1.2 depicts the South Mine at Dwarsrivier showing the sequential grid layout of the board and pillar mining method making use of mechanization for all ore extraction from underground. The support pillars are 6 m x 8 m and the faces are 10 m wide. The stoping width (height of the face being mined) is 1.9 to 2.1 m which is sufficient for the mechanisation of the drilling, charging and loading activities.

To understand the rationale behind this study, one must first have an understanding of the conversion project that Dwarsrivier Chrome Operation embarked on and why the mine started this journey.

Dwarsrivier Chrome Operation is currently facing major challenges in the weakening chrome market. The lower market prices for chrome ore are forcing the company to reconsider the operational costs and to increase efficiencies. Being an employer of choice, the company has an obligation to ensure that all measures are taken to constantly improve the effectiveness of the Health and Safety system of the mine. This is done by constantly re-evaluating all risky activities and taking the necessary precautions to reduce risk and exposure to risks.

Dwarsrivier Chrome Operation is a semi-mechanized operation, where the face-drilling is done by means of mobile hydraulic face-drill rigs (Sandvik Axera 126L). These drill rigs are capable of producing 20 000 to 25 000 tons of ore per month per machine, if cycled correctly. The operation comfortably achieves 17 000 to 18 000 tons per month. The lower than designed achievement is not due to machine or machine-drilling cycle time, but to process constraints introduced by supporting processes such as logistics and roof-bolt drilling and installation.

The roof-bolt support function of the mine is carried out by means of the conventional hand-drilling method. The operation uses SECO-215-type hand drills with air legs to achieve the required roof support installation. It is known in the industry that utilizing compressed air is not the most effective method to carry out this type of activity, due to its low efficiency and large pipe and equipment infrastructure. This is more evident in a bord-and-pillar mining method, as the mine expands rapidly over a wide area. Some disadvantages of the conventional method and using air as the power medium are as follows:

- Safety of personnel is a major concern due to exposure to the red zone (red zone meaning the area where the roof or hanging is not necessarily supported to the correct standard, or not at all, or there is a possibility of loose rock dislodging from the roof, falling on a person and causing injury).

- Human endurance and strength requirements.
- Accuracy of angle of drilling and installation of roof bolts.
- Accuracy of bolt torque.
- Cycle time in the installation of roof bolts.
- Low power efficiency due to compressor inefficiency, questionable infrastructure integrity, equipment limitations and compressed-air properties.
- Large air infrastructure underground that becomes maintenance-intensive due to equipment wear or damage, and poor installations, to mention but a few.

The operation was designed and equipped with an air infrastructure to ensure effective operation for seven strike sections. This infrastructure consists of the normal steel pipelines and modular compressors on the surface. During the last few years, the mine has grown to a thirteen-strike-section mine. This expansion made the current infrastructure ineffective and caused large numbers of lost blasts due to unsupported areas resulting from a lack of compressed-air availability. An investigation was carried out to establish whether it was feasible to increase the compressed-air system but the original design did not allow for this, thus the complete air system should be completely upgraded at a very high capital cost. Such an upgrade will also not include any additional efficiency improvements regarding the roof support system.

An investigation was conducted in respect of the various options that exist for drilling support to ensure effective and safe roof support:

- New technology in air drilling.
- New electrical drilling.

- New technology in hydropower systems.
- New technology in mechanised drilling, using mobile drill rigs.

There is no new technology on the market with regard to air drilling that is sufficiently practical in this type of application. The industry is moving away from this large-scale air application due to the low efficiency and the constraints regarding the electrical supply grid of the country.

The mine and the HILTI Company tested the new HILTI waterproof, electrical percussion drill machine. Better than expected results were obtained as regards the noise levels and the weight of the unit but the penetration rate result on the 1,8 m length test hole (cycle time) was not acceptable. Safety is still a major challenge in this type of drilling method, as the exposure in the unsupported area is still high for the operator, and electrical safety is another problem.

The mine and the NOVATEK Company embarked on a test of the hydropower system that they had installed in one of the strike sections to prove the concept and obtain comparative results. The test system consisted of four hand-held units, complete with leg support, safety valves, pipes and a high-pressure pump system. Rock-drill operators were trained and the system was tested. Very good results were obtained, that is, drilling took less than 10 minutes per hole as compared to the 12 minutes per hole when using the air method. Penetration rates were very good, as mentioned, and the system was very simple to install, operate and move when required. Safety is still a major challenge in this type of drilling method, as the exposure is high in the unsupported area.

Detailed test work was conducted as regards the option of mechanised roof-bolt systems. The mine tested equipment from three different Original Equipment Manufacturers (OEMs) in this process:

- GHH semi-mechanized roof-bolter.
- Sandvik semi-mechanized roof-bolter.
- Atlas Copco semi-mechanized roof-bolter (previously tested, but not part of the scope of the study).

The mine had previously in 2008 purchased an Atlas Copco semi-mechanized roof-bolter (Figure 1.3) for the purpose of testing in a low-seam hard-rock environment. However, the results from that testing indicated that the technology was not suitable for this type of operation at that time. There is not much information available about that test work. One point that was noted was that during the test phase there was a lot of resistance to the machine from the rock-drill operators, to a point where the machine was sabotaged, which caused a number of delays. This was mainly due to a lack of communication or interaction between workers and management to discuss the reason for the test work.

Figure 1.3: ATLAS COPCO Semi-mechanized Roof-bolter

The Atlas Copco equipment also struggled with reliability problems, such as the high wear rate of wear parts in the boom area, and of sensors and hydraulic piping that caused long delays. The complexity of the technology used in the equipment played a significant role in this unreliability. The unit used many electronic sensors and cards to control certain functions, which did not work well in the underground conditions. The unavailability of these sensors and cards was a direct cause of the unsuccessful implementation. The local support of this equipment from the OEM was very limited, thus the technical skills and spares had to be sourced from the head office located in Johannesburg, more than four hours' drive from the mine.

Due to the complexity and problems and some of the lessons learned from the Atlas Copco equipment, in the second attempt to mechanize, the test work was conducted by using a GHH semi-mechanized roof-bolter machine. The main reason for selecting the GHH semi-mechanized machine at the time was based on the method of operation, which was safer with regard to the operator's position, when compared to the Sandvik semi-mechanized machine. The Sandvik machine did not eliminate the risk for the operator who is exposed to the danger zone when manually installing the roof bolt and resin capsule into the drilled hole, and thus did not address the safety requirements of this project. On the other hand, the GHH semi-mechanized roof-bolter machine reduces the exposure of the operator to the danger zone by installing a fall-of-ground, approved canopy over the operators while drilling the hole for the roof bolt and installing it. Sandvik had a fully mechanized unit under test at a mine in the region, but their results were not satisfactory, due to reliability problems concerning the rotary head used.

The test work commenced with the GHH semi-mechanized roof-bolter. In Appendix B, particulars are presented of detailed time studies that were conducted over a period to establish a comparative time for mechanized installation methods and to evaluate the performance of the equipment in actual operational conditions and under production pressure. The targeted time was 5 minutes per hole for the mechanized roof-bolter machine, compared to the current time of 12 minutes per hole, using the conventional method. The following conditions were set for the test: The machine must be operated by a mine employee and must be in an actual working section.

The GHH mechanized roof-bolter machine was operated by a mine employee who had been trained and found competent in the operation of the machine. This enabled the mine to estimate how long an operator takes to be fully competent in the operation of the machine. It also ensured that the test was done by the mine personnel in actual operational conditions to ensure realistic results.

The mechanized method of drilling reduces the risk of exposure and the number of exposures per activity and performance, thus the GHH machine was selected at the time to be the most suitable option for installation of roof bolts. This was, however, reviewed later in the project, and more detail will be given in Chapter 3.

1.3 Problem Statement

In order to safeguard the health and safety of employees, reduce operational cost and enable sustainable operations, the mining industry has to introduce new technology to improve the most labour-intensive functions on the mine.

Successful implementation of mechanization is a challenge, and there are examples in the South African mining industry where implementation of new technology has not succeeded, as was the case at Randfontein Estate Gold Mine, as stated in the project report by Brown (1995).

The skill level of affected employees (rock-drill operators) is one major concern, thus the training departments and infrastructure will be key contributors to successful implementation and operation, or not.

Continuing with the current process and inefficient infrastructure will keep the mining sector on the back foot when it comes to competing in the ore markets. Should the mining sector not introduce new and creative means to reduce operational cost (unit cost) it will face major financial losses and possible closure.

The author of this document undertook to investigate and review the process followed when converting a conventional roof-bolt installation mining method to a mechanized roof-bolt installation mining method, in order to provide some knowledge that could help to ensure that the implementation process will be a success and that the envisaged benefits can be achieved in the time allotted for implementation and be sustainable into the future.

1.4 Significance of the Study

Underground hard-rock mining has largely been locked into old technology, meaning that not much new technology has been implemented in the core activities for a very long time, but with the current social and economic pressures in mind, the mining industry has to find new and better ways to survive.

The mines are also very labour-intensive and thus the exposure to dangerous conditions is inevitable, which puts the mining industry in a very difficult position, especially in light of the new legislation. The mining industry must change to survive. Most of the older mines are still using conventional mining methods, and the existing knowledge regarding these mining methods is exceptionally good, which is a source of comfort for the management of the mines. New technology such as mechanization of face drilling, roof-bolt installation and automated loading and hauling, to name a few relevant core activities, is available and will address most of the shortcomings of the underground mining industry, therefore now is the time to adopt it. The major difficulty in this is that most of the older operational mines still use conventional mining methods, thus the mine design and layout were designed to suit that type of mining. The conversion process will not be easy, thus we need to really understand the dynamics involved when embarking on this type of project. The capital cost of the equipment is immense, and failure to implement is not an option. Managing the perceptions of people and resistance to change becomes the second major aspect. A common perception is that machines will replace humans, and if this is not managed correctly, it could have an impact on the motivation of the employees and possibly influence them to sabotage the equipment. The replacement of humans, if not done circumspectly, could cause failure of the implementation and lead to total closure of a mine. Alternative ways must be found to redeploy or up-skill those who will be affected by the introduction of machines, this is going to be the next challenge in the industry.

The vision that the mining industry will be converted to mechanization in respect of the core mining activities and in some cases become fully autonomous mining operations, to reduce the exposure of humans to dangerous and extreme working conditions, and to optimize profitability of operation, will force us to understand and streamline the process that has to be followed to ensure the successful introduction of new technology. The success of the implementation of new technology in the core mining activities will pave the way to a new generation of mining in South Africa.

There is very little literature available in the mining sector on the successful implementation of mechanization in conventional South African hard-rock narrow-reef mines, or the process that was followed to achieve success. However, literature is available in the agricultural sector, where mechanization started way back in the early 1800s but was suppressed due to the low cost of labour at the time. It is critically important that we study the various processes that have been followed in successful and unsuccessful implementation in the mining sector, so as to constantly improve our current knowledge. The challenge of implementation in the mining sector is that mines differ in layout, geography, cultures etc., just to mention a few general points, but there are basic aspects such as social and environmental matters that will to some extent be common to most mines, depending on the maturity of the mine, i.e. willingness to accept new technology and change management.

The motivation for this research is to understand the various dynamics involved in this process and to provide recommendations or share knowledge and experience for successful conversion from conventional to mechanized mining methods.

1.5 Delimitations of the Study

This study will focus mainly on the implementation of the equipment, thus examining the process followed. Selection of the equipment will not be addressed in detail but will be mentioned as part of the process. The selection of equipment in the initial stages of the process will have an influence on the implementation process and present some challenges when implemented.

1.6 Assumptions

The main assumption is that all information given during the interviews that cannot be proven is assumed to be accurate. This type of research project is highly dependent on the accurate information obtained on site from the people directly involved with the implementation process.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature findings that were used as guidance to evaluate the factors that should be considered when implementing mechanized equipment in the mining industry. The successful implementation of mechanization in the mining industry remains a challenge, especially when converting from an old, conventional way of mining to a more modern way. A limited number of these conversion projects have been documented, and it is the view of the author that companies protect their intellectual property and are thus not willing to disclose all the details as regards the trials that they as a company had embarked on. The only way for the industry to learn and perfect the process is to learn from the failed and successful projects. Mechanization is becoming more and more a reality, due to safety, environmental conditions and human aspects that must be considered.

2.2 Background Discussion

There is not much literature available on the implementation process of mechanization. However, there is literature available regarding areas that could be considered when embarking on this type of project. The focus of these papers differs, as the authors are focusing on different areas of interest. By combining these focus areas, one could create a list of important points to address during the planning phase of the implementation project. The interesting dynamics of these types of projects are that not all are the same, thus to put an exact process together would be a challenge, as the number of variables would become unmanageable.

The literature selected for this research will provide a deeper understanding of these focus areas and how they should be addressed in the implementation process of the project.

2.3 Review of Published Papers

2.3.1 *Human Factors in Mine Mechanization (Hattingh et al., 2010)*

The implementation of new equipment in many cases focuses only on the equipment and its technical performance. In the paper by Hattingh et al. (2010) it was made clear that there are other factors that determine the success of not just the equipment, but also its successful implementation and use. The main drivers of these factors are the 'softer issues', as they are called. These softer issues are summarized as: change management, leadership, skills, training, organizational structures, planning and relationships. Change management plays the major role in the successful implementation and future use of new technology. The factors mentioned in this paper will add value by establishing a guideline for the successful implementation of mechanization in the mining industry.

As mentioned, the main drivers for mechanization are normally to improve safety, improve productivity, improve working conditions and reduce costs. All of these points are linked to a human factor in some way. Mechanization will not eliminate the human factor, since there will always be an interface, whether in operations or maintenance. Thus the softer issues such as skills and training of people have an enormous role in the success of mechanization, to mention only one.

In a mechanization implementation project undertaken at Kloof Gold Mine (Hattingh et al., 2010) it was noted that the following ‘soft issues’ impacted on the implementation of mechanization:

- Equipment.
- Suppliers.
- Human factors:
  - Determining the cycle time of the equipment.
  - Training of personnel.
  - Change management.
  - Determining realistic targets for the equipment and the production section.

It is mentioned in this paper that supervision and discipline of the daily cycle were noted to be very important. This is possibly one of the most critical aspects that must be managed when introducing new technology or equipment in a production section. Neglecting to ensure that the equipment works as intended, meaning its performance and that it is fit for purpose, could be one of the reasons for failure when implementing new technology. There is a tendency to revert to outdated methods when there are problems. Supervision and a disciplined commitment to make the equipment work and ensuring that cycles and targets are met, are of high importance.

With the introduction of new technology it is often expected that there will be an immediate increase in production. In some cases that is the reason for early failure of the implementation. The focus is more on throughput rather than on efficiency. In this paper there is mention of a different way of thinking when implementing new technology, that is to focus more on completion of the cycle as intended, rather than the production. By increasing the strike rate of the cycles completed, the end result will be an increase in production. The ultimate objective of mechanization is to increase efficiency and eliminate bottlenecks in the mining process, thus by ensuring sub-process efficiency, the overall process or system efficiency will ultimately increase. With the concept of successful cycle completion the emphasis shifts to the skills requirement. This introduces the need for application of the correct skills, training and mentoring of all management, operational and support personnel.

In conclusion, the softer issues are the fundamentals for the successful implementation of mechanized mining. The selection of equipment is also important but if done correctly will be a once-off process. However, the human factors and processes are very dynamic. People are moved to other sections or replaced at times, thus the processes and systems that feed mechanization must be constantly updated and changed to ensure that the requirements of the mine and the people are satisfied for success in mechanization, including in the future.

2.3.2 *The Implementation of new Technology in Southern African Mines: Pain or Panacea (Macfarlane, 2001)*

Macfarlane (2001) briefly explained some of the factors that could limit success during implementation of mechanized equipment. The factors mentioned are: the resistance to change, unnecessarily complex technology, poor ergonomic design for equipment movement and operation, the Hawthorne effect due to the gap between management expectations and the resistance to change by the work force, and the fear of new technology. These are very real factors to be considered when establishing a basic guideline for the implementation of new technology. The change management process is very important and must be adhered to; the process selected to be followed must be examined to ensure that it will address the objective of the project and technology. Macfarlane (2001) explained "The wheel of change" process, and one of the aspects covered in this model is "Work Cycles", which is addressed in the present project. This considers not only the shift cycles of the operator and machine but also the requirement cycle of the equipment. Macfarlane's paper (2001) covers some important points such as the drilling cycle time, new cleaning cycle, equipment quantities required, number of stopes required, moving of equipment, and logistics requirements that must be taken into account when examining the work cycle of the equipment. How to combine all of these into a well-defined process or method often remains an unanswered question.

From work done by Macfarlane (2001) it is clear that the perception of employees impacts on the implementation of new technology, since the employees' perception as to whether the new technology is needed or should be implemented could cause serious obstacles. Case studies showed that technology fails not due to the technology but through a lack of buy-in from the people that are going to use it, due to miscommunication or perceptions. Involving all role-players from the inception of the project and throughout increases the success rate. There is always a degree of resistance to change in all humans when comfort zones are threatened or disturbed. This will be true even if the new solution is better than the old way. The success of implementation is directly proportional to the degree of early buy-in from the operational personnel and whether there is commitment from the personnel who will use the equipment.

Macfarlane (2001) explained in some depth the "Wheel of change" model by Malherbe (1993). The major points as shown in Figure 2.1 below are as follows:

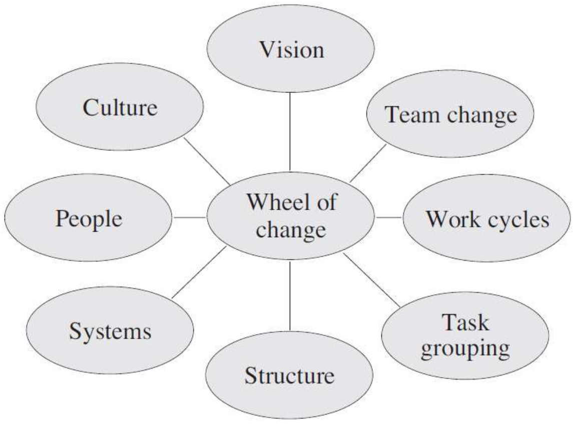

Figure 2.1: Wheel of Change

(Malherbe 1993).

Vision

The author (Macfarlane, 2001) formulated eight important questions in his paper related to the purpose of the project. These questions cover aspects such as the type of equipment, the main intended benefits, equipment fit for purpose, time frames for the implementation of the technology, the relevant partners in the project, and lastly the risks that could be encountered in respect of the technology and the equipment that has been implemented.

One of the biggest risks of failure in a project for implementation of new technology is the commitment or otherwise from the senior management. In most of the companies embarking on the implementation of new technology, the senior management are from the so-called “old school”, and in some cases do not really buy into the new ways, or they struggle to understand the new technology. If the junior personnel do not see commitment by the senior staff, it becomes very difficult to change the mind-set of the juniors so that they see the bigger picture. It is thus of the utmost importance that senior personnel are fully committed to the process and technology.

Team changes

Communication of possible team changes to the affected team members is very important for fostering a shared vision. This will give early buy-in and support of the technology.

Work cycles

In most cases, one of the reasons for the implementation is to improve on efficiencies. This is normally achieved by streamlining process and work cycles, and making activities easier and faster to execute. There are a few important points affecting the selection of equipment and the way in which the new equipment is operated, for example ergonomics, and health and safety aspects in respect of the environment and the equipment.

Task listings (grouping)

This is an important point that must be addressed, as the normal day-to-day activities will change. Different skill sets will be required in some cases. Evaluating the activities to understand how the activity will be carried out is important, since this becomes the basis of training and development of safe work procedures.

Structure

The introduction of new technology will lead to a change in the type of skills and the number of people required. Care must be taken to ensure that managers have a very good understanding of the current employee skill levels in all the relevant disciplines. This could be a problem for both operational and maintenance personnel. There might be an increase in certain required skill levels and a reduction of others.

Systems

The author (Macfarlane, 2001) indicated some systems that will be affected by technology, and these are very relevant in this research project:

- Performance management systems and incentive schemes.
- Maintenance systems and strategies.
- Procedures, codes of practice and standards.
- Emergency procedures.
- Safety rules introduced due to the new processes.
- Financial systems must be aligned to ensure that cost allocation is correct as part of measuring the performance of the equipment.
- Logistical systems – new suppliers of equipment and internal logistical handling process.
- Mine systems, which will include mine planning and production systems.

People

In this section of the Wheel of Change, skills and competency come into play. Determining the skills and competencies required for the new equipment and comparing such requirements to the current employees' skills and competencies then become crucial. In this assessment it will be vital to identify the shortcomings and the actions that are necessary to rectify the shortcomings, using the available skills. Should the shortcomings be too serious and cannot be rectified, it will be necessary to recruit the required skills from outside the company.

Culture

When implementing a new process or technology it is important that the process should be monitored and adjusted continuously. This creates a culture of always improving and optimizing the use of technology.

2.3.3 *Mechanized Bolting: On-board Drilling Automation and a Change in the Support Regime in Low-profile Mechanized Mining (Marek et al., 2012)*

The two main drivers for mechanization are safety and efficiencies (productivity). Over the last few years, legislation has become so stringent in respect of safety that productivity took a back seat to the safety of the employees. In the paper by Marek et al. (2012), the authors explored various design concepts, i.e. from very basic roof-bolt installers to mechanical props with pneumatic-percussion drilling heads, to the ultimate, completely automatic units. Various aspects, including the ergonomics related to the position of the operator, play a major role in the successful use of the equipment, showing that the “softer issues” must be taken into account in the selection of equipment. A very strong point in this paper by Marek et al. (2012) is the quality of the installation of the roof-bolt support. The ultimate goal is to install roof support to the highest possible standard the first time, and under the safest possible conditions. Two main installation methods are discussed in the above-mentioned paper, namely the semi-mechanized method and the mechanized method. In this context semi-mechanized method means there is human intervention required during the installation process of the roof-bolt. In the mechanized method there is no human intervention required as the complete process from drilling the hole to the completed installation of the roof-bolt is done through the mechanized process of the equipment.

As mentioned in this project report, the reasons for the implementation project are to improve the safety of people exposed to dangerous areas, and to increase production. The selection of a roof-bolter installation method has a direct influence on these objectives. The semi-mechanized support-installation process faces its own challenges with regard to both these objectives. On the safety side, some of the activities in the installation process require the intervention of people and do not overcome the safety challenges, as the process requires the person to enter the red-zone area. The intervention of people means that there is a pause in the installation, thus time is lost and this will lead to a decrease in efficiencies and possibly cause some quality issues.

With the full-mechanized support installation method, both these objectives, namely the safety of people and increased production, can be achieved. Firstly, the number of people required to support a face is significantly reduced as most, if not all, activities are performed by the machine and one operator. The operator is also totally removed from the red-zone area. However, it is clear that the skill level required for this machine totally differs from the skills required for the conventional method. This is where the real challenge starts in the mechanization process. This skill is required not just for the operator but for the maintenance personnel as well. The functionality of the machine is more advanced and there are many more moving parts that have to be maintained and supported when there are breakdowns. Fault-finding skills then become very important.

The fully mechanized support installation method and possible fully automated installation will therefore have a number of benefits regarding the safety of people, quality of support installed, and production efficiencies.

2.3.4 *A Framework for the Introduction of Mechanized Mining (Willis et al., 2004)*

The authors of this paper aimed to establish a basic framework of issues that must be considered during the implementation of mechanization. Safety of people and an increase in production will always be the main focus points. With the implementation of new technology there will be barriers that must be overcome. The authors (as also mentioned in the other papers) identified the softer issues to be the main barriers to be overcome. A very relevant point mentioned in this paper (Willis et al., 2004) is that the new technology must be subjected to a trial. This is in some cases overlooked and not enough time is taken to ensure that the technology is fit for the environment of the application. This is also one of the main reasons why new technology fails in the mining environment.

The above-mentioned point regarding time is important, since as much as the softer issues play a role in the implementation of new technology, so does time. If enough time is not allowed for people to familiarize themselves with the new technology, the possibility of failure is high, and in addition, if not enough time is allowed for the technology to stabilize and mature there is a distinct possibility that the new technology will not be successful. The concept of time is not addressed sufficiently.

This paper by Willis et al. (2004) also touched on an aspect that was raised in the paper by Macfarlane (2001), regarding the implementation champion or 'implementer'. The authors also raised the risk of failure in the case where the implementer is a senior person on the mine, because of the fact that such people get transferred and serve for only a short period in a certain position.

These authors provide a good framework that can be used as a starting point when developing an implementation plan. Since various authors identified similar areas of concern and focus points, it was important in the present project to determine whether these points had been considered, and whether similar difficulties were being experienced.

2.3.5 *Technology and Knowledge Transfer: Good Practice Guidelines (Willis and Ashworth, 2002)*

When implementing new technology, especially where it is in direct conflict with the way things have always been done, a careful and well-thought-through strategy of implementation must be developed or else it may fail in various ways. The paper by Willis and Ashworth (2002) presents some findings that could prevent failure in the transfer of new technology (this is described by the authors as the transfer of new technology from one party to another party by means of a managed process) if a failure in the transfer is addressed early and correctly. Factors such as the benefits of the new technology must be clearly understood by all stakeholders. The roles and responsibilities of the technology facilitator and technology champion are of critical importance. Willis and Ashworth (2002) also emphasise the 'softer' issues of the implementation process, for example culture, training, communication and the effects on the operator ('the end-user'). The authors pointed out one of the most common points of failure of most new technology transfer or implementation projects, namely communication. This creates the platform for buy-in in the early stages and throughout the process.

One of the points highlighted in this paper that has a direct connection with the present project is the matter of organizational structures. The way in which the organization is restructured in the departments directly affected by the implementation is critical. With the implementation of new technology, a new skill set is required, and if this is not available in the organization, it must be developed or brought in from outside the company. This, on the other hand, could cause social and cultural problems within the organization. The development of the people to the required skill level will take time and thus the involvement of the OEM is crucial.

As the main focus of the present project is the implementation of new technology, some important and very applicable points are emphasised in the paper by Willis and Ashworth (2002):

- Failure of new technology is not due to the information transfer (information such as the purpose of the technology, the capabilities of the technology, and the Key Performance Areas (KPAs) to name but a few) but to the implementation process.
- It can take a considerable time to completely implement the new technology and in some of the projects, a senior person is appointed as implementer. This could cause problems, as senior personnel may be transferred to different sections in the company before full implementation has been achieved.
- In some cases, the role of the implementer is seen simplistically, whereas it is actually very complex. Some of the responsibilities defined by Willis and Ashworth (2002) are as follows:
    - The agreed strategies are actually implemented.
    - Coordinate the required Research and Development (R&D).
    - Give top management a better understanding of the technology to ensure support and buy-in.

- Ensure effective communication between all stakeholders throughout the full implementation.
- Create a link between the developers and the end-users.
- Give support by means of training when applicable or required.

Normally, one of the drivers for implementation of new technology is safety, but this can be ensured or realized only if the implementation process of the new technology is completed correctly.

2.3.6 *Factors Affecting Agricultural Mechanization: Case Study on Sunflower Seed Farms in Iran (Rasouli, Sadighi and Minaei, 2009)*

The focus of this paper was to investigate the factors that affected the implementation of mechanization in the farming sector and to determine the level of mechanization adopted. For the purpose of the present research report it will be interesting to examine the factors and gauge their relevance to the mining sector.

Selection of the correct type of equipment to suit the stage of maturity of the farming community played a significant role in the success, in other words whether the community accepted the available equipment. Farm mechanization is at a very advanced stage, if one compares it to the underground hard-rock mining environment. Farm mechanization is well past the time of trial and error to obtain the correct equipment type, since one can basically select mechanized equipment from a catalogue with full specifications. It is not the same for certain activities in the mining industry. One of the challenges in the farming industry is the capital cost of the equipment and the size of the workable land. In some areas it is not feasible to mechanize, due to the scale of farming and not ~~to~~ the availability of technology.

One of the very interesting points made in this paper (Rasouli et al., 2009) is that if one looks at the 'people side' of mechanization, the farming community has made peace with the fact that human power will be used less and less, and machine power more and more. This brings the following question, namely what about employment? What does one do with all the people that were dependent on the field and hands-on work to make a living? The mindset of the farming industry is geared towards rather using the human intellectual power for monitoring, control and operational activities in respect of this mechanized farming technology. This is one of the areas where mechanization in the mining industry still has a long way to go as regards acceptance of mechanization in the workplace and the effects it has on the social environment with regard to job creation or the lack thereof.

An aspect that is common to farming and the mining industry is the scale of the operation and the feasibility of the implementation. The challenge experienced by smaller farming communities with regard to the cost of mechanization and the possible production gain is the same in the mining industry. This factor will influence the rate at which total mechanization in mining will be adopted and the humans be withdrawn from a very dangerous working environment. As mentioned above, the farming industry is one step ahead of the mining industry, as they have made peace with mechanization, therefore they will now focus on more advanced aspects that could impact their total mechanization drive, such as capital assistance for purchasing equipment, larger land to improve their production that will be mechanized, markets for high-yield products, and distribution networks, to name a few, as stated in this paper (Rasouli et al., 2009).

It is disappointing that the paper by Rasouli et al. (2009) does not provide more detail about how the people's mindset was changed to adopt mechanization, and what the hurdles were that had to be overcome in order to educate or up-skill the normal worker to participate in the role of monitoring, control and operations when using this new technology.

2.4 Conclusion of Literature Review

The golden thread evident in the papers reviewed is that the softer issues play a very important role in the successful implementation of new technology, with important factors such as recruitment, skills development, training of operators and maintenance staff, and defining their roles and responsibilities being top of the list.

The selection and appointment of the implementation champion is a vital part of ensuring success when implementing new technology - not only for the technology but from a leadership point of view. The champion need not have the most intense passion for the equipment but has to lead the change by using teams that are part of the implementation drive, and he must ensure that all processes and functions are interfaced and operational at handover. It is also evident that the selection of a senior manager to be the champion seems to be a common mistake, in the opinion of the authors.

The implementation process is very complex and there are different methods and approaches that can be followed. It is also clear that the implementer or project leader must ensure that all processes, systems and functions are interfaced. A very good approach will be to follow a system engineer’s approach. This will ensure that there is a systematic approach and no processes or systems are overlooked.

One aspect that is mentioned throughout all the papers as often much undervalued is time. The industry must guard against setting too high objectives too soon for new technology, or not allowing sufficient time for integration between people and technology. The view of the industry is that capital has been spent and there must be a return on the investment as soon as possible. There is no substitute for time spent with new technology, allowing everybody to get comfortable and confident in their own abilities and that of the new equipment or technology. Then only will the true value be realised.

Most of the papers reviewed as part of this project, in some way or another, address the aspects of affected processes and functions. The author agrees that these are aspects that must be understood in detail. A simple example that is also mentioned later in this document is that of the racing car and the pits, i.e. misalignment of the functions and impact in the process could lead to losing the race or winning the race. It does not matter how good the car is, or the driver or the track. It is very important to really spend time in evaluating how the introduction of new technology could influence the support functions, and also how improvement of the complete system due to the new implementation would impact on other functions in the organization.

To conclude, it is evident throughout these papers that people, processes and technology must be understood and integrated to a very high degree at all levels of the organization to ensure that the impact of the change is positive and generates the buy-in, and by doing that, ensures success of the implementation.

CHAPTER 3. PROJECT DESCRIPTION AND RESEARCH METHODOLOGY

This chapter provides a brief overall description of the project that is based on a case study, and the method that was followed to obtain information and data regarding the implementation project.

3.1 Project Description

Dwarsrivier Chrome Mine identified the requirement to implement mechanized roof-bolter equipment in order to address safety concerns of employees exposed to the danger zone at the work face and to increase efficiencies in the mining process. When the mine started, it began as a semi-mechanized operation whereby face drilling was done by mechanized machines. The mine went through a scoping and selection process for mechanized roof-bolting equipment that would suit the requirements of the operation. The initial test work post 2012 was done by using a GHH semi-mechanized machine, as stated in Chapter 1, but due to more advanced technology that became available, this decision was re-evaluated. The new, proven technology fully addresses the safety aspect by removing the operator from the high-risk zone by means of fully mechanized roof-bolt installation, where all the activities for installing a roof bolt are carried out from the safety of the operator’s cabin, which is equipped with a fall-on protection device that is approved for the case of a fall-of-ground incident. The Sandvik DS210L roof-bolter (Figure 3.1) was the newly selected equipment that would suit the requirements of the mine. This machine is capable of fully mechanized roof-bolt installation. This is achieved by means of a very complex drill-head assembly, as indicated in Figure 5.5 in Chapter 5 of this report. Figure 3.2 below gives an indication of the operator's position with reference to the danger zone at the face. This shows that the operator is totally removed from the danger zone and is operating the machine behind the last row of roof bolts installed. This is defined as the safe zone.

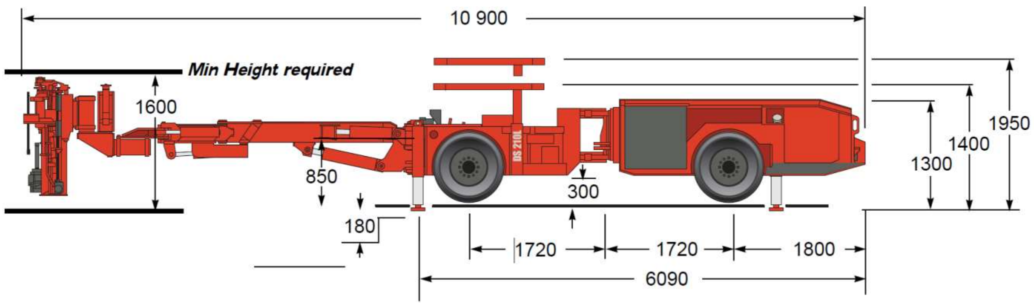

Figure 3.1: Sandvik DS210L Roof-bolter

Figure 3.2: Danger-zone Indication: Typical (Sandvik, 2015)

The objective of this project is to analyse the process that the mine followed during the implementation of this new equipment. As the need for mechanization is increasing in the mining industry, it is important to understand all the dynamics that characterize an implementation process.

As the implementation is a complex and dynamic process, getting it wrong will have a huge cost implication for the industry. Understanding what went right, what were the challenges, and what lessons were learned during the process will be the value added by this project.

Section 3.3 of this report gives an overview of the aspects that will be discussed.

3.2 Research Methodology

The research was conducted on a qualitative, single case-study basis and involved a structured approach with specific focused areas.

3.3 Research Design

The research conducted was based on a case study that included interviews with personnel in a specific mining operation. The questions focused on the objective of the implementation, the impact on people and the knowledge they gained, the processes involved and the results achieved.

- The objectives focus on the implementation of the new mechanized roof-bolter, the main reason for the mechanization, and the achievement of these objectives.
- The people aspect concentrates on labour structures, selection criteria, training and competency.
- The process aspect concentrates on the impact on infrastructure, skills, planning and maintenance systems, the role of the OEM, the

impact on operational structures and processes, as well as mine layout planning.

- The results factor concentrates on production, achievements, measurements and rewards.

The results obtained from an actual operation will create valuable information and open up areas where the current, known information is incomplete. Ultimately, the industry has to understand all the dynamics associated with the complex process when the mining method is changed.

3.4 Population and Sample

3.4.1 Sampling Method

Information gathering was done in the following ways:

- Reviewing relevant literature.
- Interviews with various role-players in the process.
- Site visits to the respective work areas.

The table below displays a selection of the people to be interviewed and is based on their involvement in the implementation process, including those who were directly impacted.

The following people were interviewed during the information-gathering process:

Table 3.1: Profile of respondents

Description of Respondent	Number to be Sampled
Mine Manager	1
Mine Overseer	2
Rock Engineer / Geologist	1
Engineer	2
Chief Safety Officer	1
HRD Manager (Training)	2
General Engineering Supervisor	3
Artisans	3
Procurement Superintendent	1
Logistics Supervisor	1
Operators of the equipment	2
Organised Labour Representative	1

The above table was divided into the following three groups during the interview process:

- People directly impacted in the process (artisans, drill-rig operators, roof-bolt operators, training department).
- People indirectly impacted in the process (supply chain, geology, mine planning).
- Management, which includes organized labour (unions), middle management, and top management.

3.5 The Research Instrument

This research information was obtained by means of a questionnaire and interviews with key personnel (refer to Appendix A). The questions focused on specific areas, as mentioned in section 3.3.

3.6 Procedure for Data Collection

Data was gathered during two rounds of interviews, where the first round was conducted in the early stages of the implementation, and the second was done approximately two years after the implementation, during which selected role-players were involved directly and indirectly in the process of implementing the roof-bolters at Dwarsrivier Operation.

3.7 Data Analysis and Interpretation

Data obtained was analysed and compared to the targets and objectives that were set at the initialization of the project, based on key areas identified as listed in section 3.3.

3.8 Limitations of the Study

The scope of this study is limited to the process that was followed during the implementation of the project. The study does not focus in depth on the equipment selection process; however, some information is presented with regard to the impact of the selection process on the implementation.

3.9 Reliability

This research project is based on the actual findings of an implementation project and the feedback obtained by means of interviews from the respective role-players in the process. In some cases, actual data was obtained from the site to verify the interview feedback so as to ensure the validity of the responses to the questions, as specified in Appendix A.

3.10 Demographic Profile of Respondents

The objective of this information-gathering process was to interview as many people as possible who had been involved or affected by the process and how it had impacted on them and their function. The actual participants in this process are listed in Table 3.1. The general manager could not be interviewed, as he left the employment of the company before the interviewing process started, but the mine manager formed part of the interview list. The information was obtained in order to gain a better understanding of the impact of the new equipment on the day-to-day activities in the various areas.

CHAPTER 4. FINDINGS OF THE CASE STUDY

4.1 Introduction

The implementation of new technology in an existing mining environment is not a straightforward process. The interface with existing processes and operational philosophies is very important.

In this chapter, the findings obtained from the formulated questionnaire (Appendix A) are presented in the respective categories and focus areas. The information shows the various aspects, namely changes to existing processes, what worked well, and what could have been done differently, based on the knowledge gained through the process.

Figure 4.1 below gives a high-level layout of section 4.2 of this chapter and the points that will be addressed.

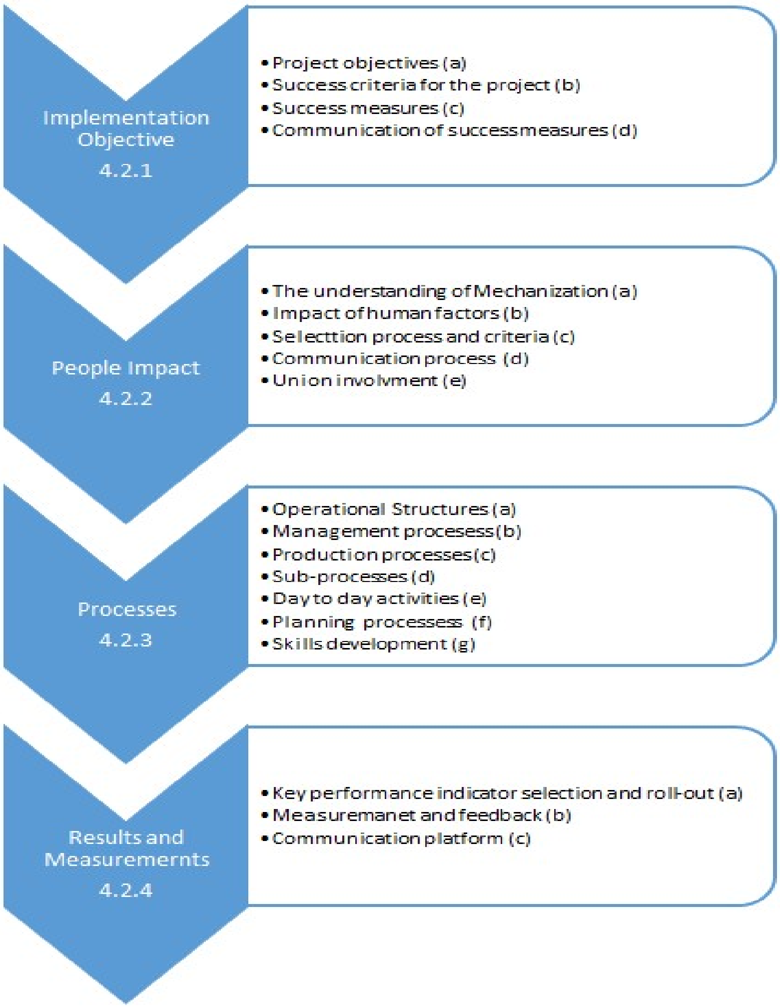

Figure 4.1: Section 4.2 layout

Table 4.1 reflects the planned list of people to be interviewed as stated in Chapter 3, with the interviews actually conducted, and the location where the interviews were held.

Table 4.1: Profile of interviews

Description of Respondent	Interview Conducted	Round of Interviews
Mine Manager	Yes	R1, R2
Mine Overseer	Yes	R1 and R2
Rock Engineer / Geologist	Yes	R1
Engineer	Yes	R1
Chief Safety Officer	Yes	R1 and R2
HRD Manager (Training)	Yes	R1 and R2
General Engineering Supervisor	Yes	R1 and R2
Artisans	Yes	R2
Procurement Superintendent	Yes	R2
Logistical Supervisor	Yes	R1 and R2
Operators of the equipment	Yes	R2
Organised Labour Representative	No	Not available

4.2 Results pertaining to Implementation of Mechanized Roof-bolters for Low-seam Hard-rock Mining at Dwarsrivier Chrome Mine

4.2.1 *Implementation Objectives*

a. *Project objectives*

The main and first objective when the project started was to reduce the number of people exposed to the high–risk zone underground. In the conventional method of installing roof support, there are four to five employees active in the high-risk zone area. This high-risk zone was defined as the unsupported roof area. The second objective was to increase the overall operational efficiency. The roof-support function was identified as one of the most dangerous activities, and was the most ineffective process, which increased the mining cycle and thus decreased production output.

b. *Success criteria for implementation*

The selection of the overall success criteria was based on and aligned with the objectives of the project, in order to reduce the exposure of employees to unsupported work areas and to increase production by increasing efficiency in installing roof-bolts, thus increasing profitability.

The project will be seen as successful when the two factors listed as objectives have been achieved. However, the duration of the period allowed in which to achieve these objectives was not stipulated by the mine in the project charter.

c. *Measuring and monitoring of success criteria*

The success indicators were initially determined to ensure that the machine performs to the designed capacity. This was measured in number of bolts per shift and the installation time per bolt. These measurements, as mentioned in section 4.2.4: Results and Measurements, in this document, did not add value to the section performance, as it was not linked to the production performance of the section. This was subsequently reviewed and the measurement was adopted as described in section 4.2.4: Results and Measurements.

The monitoring frequency was set up to be in line with the normal weekly, monthly and quarterly reporting system already implemented on the mine. The performance will be displayed by using the normal systems, such as notice boards and electronic display boards.

d. *Communication of success criteria*

Due to the importance of this project, management's communication strategy was such that it was discussed at all mass meetings that the general manager had with the workforce. In these communication sessions the detailed performance was discussed and time was allowed for questions on the topic by the workforce. The communication platform tasked for the communication was firstly via the union structures, where the union leadership engaged the workforce on the matter of mechanized roof-bolting, secondly by means of the communication briefing pack that was distributed to all employees at the mine, and lastly, as mentioned, at the mass meetings with the workforce under the leadership of the general manager of the mine.

e. *Results*

The below graph gives the number of lost-time injuries that occurred at Dwarsrivier Mine from 2010 to 2018. From Figure 4.2 it is clear that there was a huge improvement and a decrease in the number of lost-time injuries at the mine from 2013 to 2016. If these incidents, are analysed, it is found that the majority occurred as a result of a fall of ground and can be ascribed to the work on the face. The implementation of the roof-bolter started towards the end of 2013 and reduced the number of incidents, as indicated below in Table 4.2, and if one examines Figure 4.2, it clearly shows a downward trend with regard to the number of lost-time injuries.

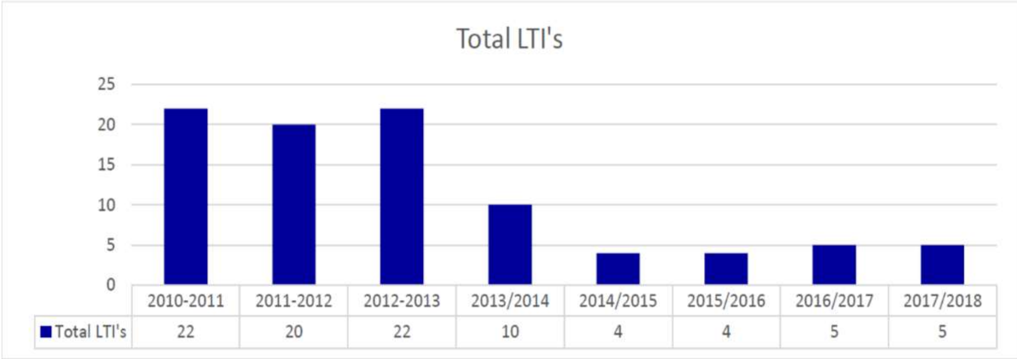

Figure 4.2: Safety Statistics

Table 4.2 gives an indication of the safety statistics pertaining to the high-risk zone, thus considering only the roof-bolt operator-related injuries that occurred in the face area. Significant numbers of injuries were recorded during conventional hand-held rock-drill operations prior to the implementation of mechanized roof-bolters. Injuries recorded were mostly hand injuries, due to incidents involving fall of ground. Safety nets were an additional safety barrier that was introduced in an attempt to minimise the impact when large rocks became dislodged due to the vibration during the drilling action. This fall of ground consisted of small pieces of rock that passed through the safety net openings and then injured the hands of the operators.

Table 4.2 below gives a breakdown of the injuries that occurred at the face during roof-bolt installation during two different periods, the first from 2008-2014, before the mechanized roof-bolt installation method was introduced, and the second period from 2014-2015, after the introduction of the mechanized roof-bolters that are displayed in the “Roof-bolter” column.

Table 4.2: Safety Statistics: Number of Incidents (from 2008-2014 and 2014-2015)

Description		Rock-drill machine	Roof-bolter
No lost-time injury	NLTI	27	3
Lost-time injury	LTI	18	0
Reportable injury	Rep	11	0
Fatality	Fat	0	0

With the implementation of the roof-bolters (2014-2015), the injuries disappeared almost completely. There was at least one rock-drill operator-related incident per month before the implementation of the mechanized roof-bolter, but after implementation there was only one every four months, and they were not due to fall of ground. The most likely injury on the face after the implementation of the mechanized roof-bolter was trip-and-fall, as the operator walks with the remote unit to position the drill bit, and due to uneven floor conditions, there were trip-and-fall incidents. This problem was addressed by means of training and setting operational rules that include the following:

- All drilling activities will be carried out from the main operator's cabin, which resulted in removing the remote units from all the machines.
- A spotter was assigned to each rig to ensure correct alignment. This was used only in cases where the operator could not see the marking.
- The spotter worked from behind a safety barrier in a safe area.

f. *Lessons learned*

- Work in a team and guard against 'silos'.

- Focus on positive flows from the project and do not shy away from the changes.

- Give assurance and stick to your promises.

- Always be transparent in your communication on the project.

- “Brag” with your project and show it to the world; the operators then take extreme pride in their job and it makes them feel important.

- Listen to your people on the ground; they know what works and what does not work

- Have regular engagements with the suppliers and ensure that they form part of the team.

- Make everybody in the team feel part of the family

4.2.2 *People*

a. *Understanding mechanization*

The interviews indicated that there was a very good understanding of mechanization with all its benefits and challenges, from the lowest level in the operation to the leadership. This could partly be because the mine is currently a semi-mechanized operation, where the face-drilling and loading practices are carried out with the help of mechanization.

Acceptance of the fact by employees that the roof-bolt activity was to be mechanized was positive, and they all saw it as adding value to their health and safety in the workplace, as well as being an opportunity for possible personal growth in the company.

b. *Impact of human factors*

The introduction and implementation of mechanization in most industries are overshadowed by the perception that there will be a loss of jobs and thus people will not be able to provide for their families. This fear was set aside as a result of the early decision that no jobs would be lost, that all employees would have employment and that in some cases there would be an opportunity for promotion. This is possibly one of the most significant reasons why this project was a success, and it can be seen in the reduction of injuries and the increase in efficiencies. The employees feel safe - safe in their workplace and safe with regard to job security.

c. *Selection criteria and process*

At the start of the mechanized roof-bolter project, a decision was taken that recruitment would firstly be done from internal labour, and if the skills and competencies were not available in the organization, only then would outside labour be considered.

A selection process was identified by using an in-house assessment process to determine the ability to be trained to the next level, using basic interview protocols. The Dover system was used to determine whether the person has the ability to operate a hydraulic drill rig. The Dover system is an Australian system that measures basic skills competency by using five modules. These modules are:

- Eye-hand-foot coordination and reaction tests.
- Size, shape and spatial recognition test.
- Two-hand coordination, movement and practical trainability test.

- Speed/Distance estimation measurement test.
- Concentration and attention in a visual field test.

The basic requirements for the operator are:

- Valid Code B national driver's license
- Physical requirements: Height less than 1,9 m, weight less than 100 kg.
- Have a valid medical fitness certificate.
- Dover A-symbol (Appendix E) with an average of 80% or a B-symbol (Appendix F) with an average of 64-79%. No C-symbols will be accepted.

An A-symbol on the ZBA (ZBA-Time Motion Anticipation) battery of the Dover assessment is of the outmost importance. If a candidate scores an 'A' result, the following is a benefit:

- The candidate is GOOD for speed and distance judgement, especially in complex situations.
- The mean direction deviation is the anticipation and estimation of speed, distance and direction of linear and curved movements. This is a complex test of movement judgement. The candidate's overall estimation ability regarding moving objects, such as other vehicles on the road, is assessed.
- The above-mentioned estimation ability is of the utmost importance where a learner is expected to work with large machines in confined areas, and the ability to control them properly is essential. This will contribute to minimizing incidents, accidents, damage to the machine, the boom and the bolting unit.

With the implementation of the mechanized roof-bolters, the rock-drill operator's function will become redundant. This means that the rock-drill operators had to be assessed and evaluated to determine whether they could be retrained to become roof-bolter operators. Through the assessment process it was clear that some of the older-generation people did not have the ability to become a roof-bolter operator. These employees were then reassessed for other activities and retained as Load-Haul-Dump truck operators, or were trained to become long-anchor installers or general underground workers.

All rock-drill operators that were affected were retrained and placed in other functions within the mine. All positions were filled from within the organization by restructuring, and moving and up-skilling employees.

Engineering personnel skills and competencies were not a real risk, as the mine is a semi-mechanized environment with basically the same type of equipment. However, the necessity for more detailed skills and competencies regarding hydraulics was clear. The number of artisans with detailed hydraulic knowledge was limited to the face drill-rig sections. Detailed hydraulic training was done by the OEM and other suppliers.

d. *Communication process*

The method used for communications during the project was based on the usual company protocols such as memos, mass meetings with the workforce by the relevant head of department, safety talk meetings, and through consultation with the relevant union leadership. The mass meeting with the workforce was the main platform for communication, as this opened the floor for frank discussion with the employees. This meeting was held with all shifts at predetermined times. In this meeting, the affected or not affected employees had the opportunity to ask questions and have a candid discussion, if there were issues that were unclear and/or more information was required.

Communication started more than twelve months prior to the implementation project. This was during the test phase of the project.

e. *Union involvement and impact*

The mine was in a privileged position that there was only one recognised union on site. A decision was made by management that the union would be involved in all relevant discussions and would be consulted regarding decisions affecting the placement of employees. Due to the nature of the implementation process and the redeployment of employees, the involvement of the union was also on a consultative basis, since all affected employees form part of the bargaining unit of the union. It was made clear that as far as possible, no employee would lose his or her job in the process.

The approach taken by management was as follows, to get employees' buy-in:

- The union was involved with setting the selection criteria and redeployment to other occupations.
- Up-skilling would come with an increased salary level, and the rock-drill operators would be the first choice if they met the set requirements, as discussed in section 4.2.2.c on the selection criteria and process.
- As far as possible, there would be no job losses as a result of the implementation process.

No one would be worse off than previously with regard to salary and working conditions.

4.2.3 *Processes*

a. *Impact on operational structures*

In the initial process of the personnel planning, assumptions were made based on the new technology and known operational method, as follows:

- All rock-drill operators were tested for up-skilling and then trained as operators for underground trackless mobile machines, or where there were vacancies that fitted the competencies of the individuals, they were redeployed to fill these vacancies.
- Drill-rig operators were trained and moved over to roof-bolter operations, based on the complexity of the equipment they operated and their basic hydraulic drill-rig experience.
- The roof-bolter operator would manage the complete bolting cycle from setting up and connection, to disconnection of the machine, thus one operator per machine was required.

In spite of the initial assumptions mentioned above about the roof-bolter operator, it was found that one operator could not manage the complete bolting cycle. Due to all the activities and the lack of skills it was necessary to add additional labour to assist the roof-bolter. The function of the additional labour was to assist with setting up the machine and carrying out other activities in respect of the roof-bolting function that support the efficiency of the bolter, for example loading the resin capsules into the resin capsule injector, as well as general housekeeping, such as hooking the power cable to the cable support and so on.

The most significant changes to the organization structures were on the rock- drill operator and drill-rig operator levels.

Table 4.3: Manning for the 14 and 7 Bord Strike

Proposal for manning a 14 and 7 Bord Strike						Appointments under MHSA
		Before Bolter		With Bolter		
Job Category	Pat/Grading	14 Bord	7 Bord	14 Bord	7 Bord	
Shift Boss	C5	1	1	1	1	Regulation 2.15.1 to 2.15.10
Miner	C2	2	1	2	1	Regulation 4.4.1
Team Leader	B5	2	1	2	1	Regulation 14.1 (i) Competent Person
Bolter Operator	B4	0	0	2	1	Regulation 8.10.(23)(1)(2) (i)(ii)(iii)(23)(3)
Bolter Assistant	A4	0	0	2	1	
Rig Operattor	B4	3	2	2	1	Regulation 8.10.(23)(1)(2) (i)(ii)(iii)(23)(3)
Rig Assistant	A4	0	0	2	1	
LHD Operator	B4	4	2	4	2	Regulation 8.10.(23)(1)(2) (i)(ii)(iii)(23)(3)
Rock-breaker Operator	A4	3	2	2	1	Regulation 8.9 (1)(i)
Blasting Assistant	A2/4	4	2	4	2	Regulation 4.4.(3)
RDO Long Anchors	A4	4	2	0	0	
Pump Attendant	A2	2	1	2	1	
	Total	25	14	25	13	

Table 4.3 shows that the production labour structure did not change the bottom-line figures, as some of the workers had been trained as roof-bolter assistants.

Engineering labour was restructured and divided up to service a 14-bord layout. Artisans were trained to be multi-skilled artisans, for example diesel mechanics and hydraulic fitters. Before the implementation of the roof–bolters, diesel mechanics were attending to the Load and Haul Dumpers (LHDs) and the Utility Vehicles (UVs), and hydraulic fitters were taking care of the hydraulic drill rigs. These skills were combined, as hydraulic skills were a more important requirement in the section. As mentioned, this was due to the number of hydraulically operated, machines, which now also include the hydrostatic RHAM LHDs that were implemented prior to the implementation of the roof-bolters. The hydrostatic RHAM machines work on the principle of a diesel engine that drives a hydraulic pump and the hydraulic pump drives four hydraulic wheel motors, thus the main drive system was based on hydraulic power. As a result, there was no increase in engineering labour underground, only up-skilling of the diesel mechanics to be more competent in hydraulic systems and fault-finding. The only place where there was an increase in labour was at the service bay on the surface. The amount of work required during maintenance of the machine is much more than for a normal face-drill rig. This is mainly due to the increased number of moving parts and hydraulic functionality of the machine. There are two artisans allocated to one roof-bolter when the machine is undergoing planned maintenance.

b. *Impact on management process*

Dwarsrivier Operation was already a semi-mechanized operation before the implementation of the roof-bolter, thus the code of practice for the trackless mobile machine, as specified by the Mine Health and Safety Act 29 of 1996, had already addressed most of the requirements set by the Department of Mineral Resources. The equipment selected was based on the same type of equipment as used for face-drilling, therefore the basic operation and engineering test requirements were the same for the roof-bolters and the face-drilling. Most of the changes to the code of practice for the trackless mobile machine were on the operational side of the equipment. The following changes were:

- Baseline risk assessment was updated and changed to reflect the new equipment and the associated risk.
- Issue-based risk assessments had to be updated to accommodate the new activities and process.
- Visibility charts ware updated.
- Brake test procedure was updated.
- Operational manuals and procedures were updated.

- Licensing process was updated.

With the implementation of mechanized roof-bolters, the risk and exposure of people to the danger zone were reduced by almost 90% and the quality of mining also improved dramatically. There was an improvement in mining height consistency, since the machine can operate effectively only in an area with a height of 2,1 m. The cleaning cycle also improved, which ensured that the roof-bolter could perform optimally.

The challenge experienced was to get all procedures approved and captured onto the document system in time to allow the training department to develop all training modules before implementation of the equipment.

Due to the modifications listed below that were done on the machine, some of the operational/maintenance procedures and methods had to be reviewed and changed.

- Remote control units – the joystick and some of the buttons had to be changed.
- Chain gears and pins –these were modified to ensure longer life.
- Stringer-head pins – these were modified by replacing them with a stronger type of pin.
- Bolt magazine loading-lever – this had to be made shorter as it was damaged during normal operations.
- Forks – had to be changed as they became bent.
- Bolting spanner – the spanner was made shorter. This was a site-specific modification to suit the ground conditions.
- Rotary actuator bolts – the bolts kept on breaking due to the speed of the actuator. An oil-flow-restriction device was installed to reduce the speed.

It was mentioned by the operational and training staff that a longer test period and having a dedicated team in a specific production section would allow for the development of more accurate operational procedures. This would reduce rework of documentation, retraining, and the risk of applying an incorrect operational method in the system at any point in time.

There were some highlights and some lowlights. The good points observed were as follows:

- The workers perceived their new environment as "caring", since they were removed from the dangerous areas and given a cleaner and safer environment to work in.
- The standard of work improved, as the operators were enabled to perform at a higher standard.
- The mining controls in respect of height and width improved and all operators experienced the same motivation to ensure that these controls were maintained.
- The positive attitude of the operators towards the new technology was excellent, and some of the lower-level employees were given promotions due to the new equipment. As part of this positive attitude, the introduction was seen as a personal development area with new opportunities.

The not-so-good points observed were as follows:

- The quality of equipment ownership (looking after and taking care of the equipment) was observed to be a concern, since the mindset of the operators who were previously looking after only R15 000 worth of equipment compared to the now R7,5 million worth of equipment was still a challenge.

- On the safety side, the challenge was to ensure that the workers still carried out the barring process as required. The mindset now was that the roof was safer and did not need barring, which is a safety concern, since barring removes loose rocks from the roof by means of a barring tool

The maintenance culture still remained a problem. The wear rate of components and life expectancies are still largely unknown in the current environmental and operational conditions.

c. *Impact on the production process*

The current mining cycle is demonstrated by Figure 4.3 below:

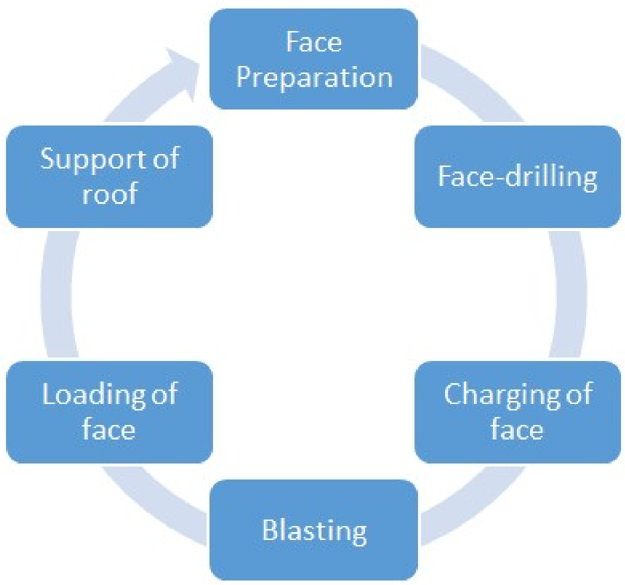

Figure 4.3: Mining Cycle

The production face consists of ventilation holing and a face, and is seen as one operational panel. The face is 10 metres wide and the ventilation holing is 8 metres wide. It is thus seen as an 18 metre working panel that must be supported, blasted, charged up, and loaded. With the conventional roof support it took one shift to complete these 18 metres. This caused the cycle to be too long, and only the next shift could prepare the face for drilling. To add more pressure to the operation, this face had to be drilled in that same shift. This put some strain on the face-drilling cycle, which reduced the ability to drill additional faces.

The introduction of the mechanized roof-bolter reduces the complete support installation time per bolt significantly. It takes three to four hours to complete an 18 metre panel. The target set for a bolter was established at 26,3 metres in 24 hours, depending upon whether there are long anchors to be installed. With the installation of long anchors, the cycle is extended, due to the manual intervention into the anchor installation. In the initial stages of the process, the cycle times decreased to a point where some of the rock-drill operators were brought back to assist with the installation of the roof bolts.

The following shortcomings were identified:

- Operators' experience impacted on the cycle time, as they were not confident in all the functions and operation of the new equipment.
- Poor preparation of the face, in this context it is:
    - 26 metres of face cleaned;
    - cleaned from sidewall to last holing;
    - barred solid and scraped clean;
    - support marked off to standard.

- Artisan knowledge of fault-finding and repairs.
- Lack of spares availability, due to modifications that were done.

The cycle time did improve slightly as a result of the addition of extra bolters into the system. This meant that there was a roof-bolter available for the installation of roof bolts at all times. Due to the additional machines, more time was spent on maintenance which, on the other hand, improved the reliability of the roof-bolters. This also allowed the maintenance staff to build up experience and confidence in fault-finding and repair.

No major operational infrastructural changes were introduced with the implementation of the roof-bolters. The only change was the initial increase of the capacity of the underground miner's store. This was done due to the number of bolts that had to be kept in stock, as the installation rate was higher than that of the conventional installation method. The logistics system was changed to allow for quick and effective transport of materials to the underground section stores. This will be discussed in more detail in section 4.2.3.d

The challenges that were identified:

- Not achieving the set targets, and the reintroduction of conventional roof support sections in the early part of the implementation.
- Maintenance and spares strategy, due to all the modifications done to the boom and head assembly of the machine.
- Lack of experience of the artisans on the boom assembly and the additional hydraulic features of the rig.

- Lack of mining discipline in all basic aspects of preparation (face cleaning, marking and charging up) on the face hampered the performance of the equipment.

d. *Impact on sub-processes*

With bord-and-pillar type of mining, the mining sections almost constantly expand. This means that the distances to the fixed infrastructure such as workshops and stores constantly increase. This has caused some constraints and delays in repair and basic maintenance activities.

One of the projects that Dwarsrivier Operation was embarking on prior to the implementation of the roof-bolters was the introduction of satellite workshops. The purpose of these workshops was to reduce the tramming of machines for repair and provide quicker support to the machines in the face. This was mainly for the drill-rig equipment, as tramming long distances caused more damage, due to the tramming limitations of the equipment. Completion of the satellite workshop project is very important for the effective utilization of the equipment, as there will be two of these types of machines in a section. Currently, when the machine has to be serviced or has a breakdown that calls for a workshop area, it has to be trammed to the surface. In some cases this takes up almost half a shift, and puts strain on the equipment.

The objective of these workshops is to do all repairs and minor services in the section and thus reduce the tramming time and out-of-face time of the equipment.

These workshops are equipped with the basic tools and equipment to ensure that all activities can be done safely and to a good standard. The location of these workshops was critical, as one workshop services two production sections. One of the biggest challenges was to ensure that both production sections and satellite work area move at the same pace. If not, it will cause the workshop to lag behind, and this, on the other hand, will cause longer tramming distances and more unwanted wear on machines.

With the implementation of the roof-bolters, the rate at which the satellite workshops must be constructed was a concern, due to the rate at which the sections move forward. The rate of section movement, looking at tip movement, increased from two sections per month to six, and in some cases seven section movements per month. To give some context to the section movements, normally in this type of mining layout the tip of the section is moved forward when the line of sight distance from the tip to the face is more than 50 metres. This means that all services such as power, water and air will be moved forward as well, but the miner’s waiting place and miner’s store move only at every second tip movement. Once the satellite work area has been installed and commissioned, this will then form part of the movement of the miner’s waiting place. The complication inherent in this is that the services in the work area will also have to move, which will include the fuel and lubrication areas, which have their own standards and specifications. This will increase the strain on the construction teams, both mining and engineering. The construction team was supplemented by the addition of a contractor construction team to assist with moving the tips and conveyor system forward. The intended strategy was to have a core mining team, and as the work load increased or decreased, so would the contractor’s team in order to compensate.

With new equipment introduced there was an initial problem in respect of the spares holding capacity and location. This was exacerbated due to the number of changes made to the machine during the implementation of the equipment. It took a while to determine and standardize on the usage, storage and supply of certain parts. Some of the same spares from the face drill-rigs could be used on the roof-bolters. This had a huge impact on the stores holding area on the surface and underground. This will be discussed later in this section of the document.

One of the biggest challenges or delays experienced by the team was the refuelling and lubrication of the equipment. This activity takes place at the face or preferably at the satellite workshop or waiting place. The challenge resulting from the introduction of additional Trackless Mobile Machine (TMM) equipment was that the current refuelling process and equipment were under strain.

The underground refuelling system works as follows:

The mine has a batching system from the surface to the main underground workshop area. From this point, utility vehicles are used with specially designed carriers and removable bulk fuel tanks to transport the fuel to the respective sections. These mobile tanks as indicated in Figure 4.4 and Figure 4.5 below, will then be kept at the satellite workshop or waiting place, and vehicles will be refuelled from them. These units have to be refilled during the shift to ensure that there is fuel at the satellite workshop for the next shift. This becomes a constraint and causes delays.

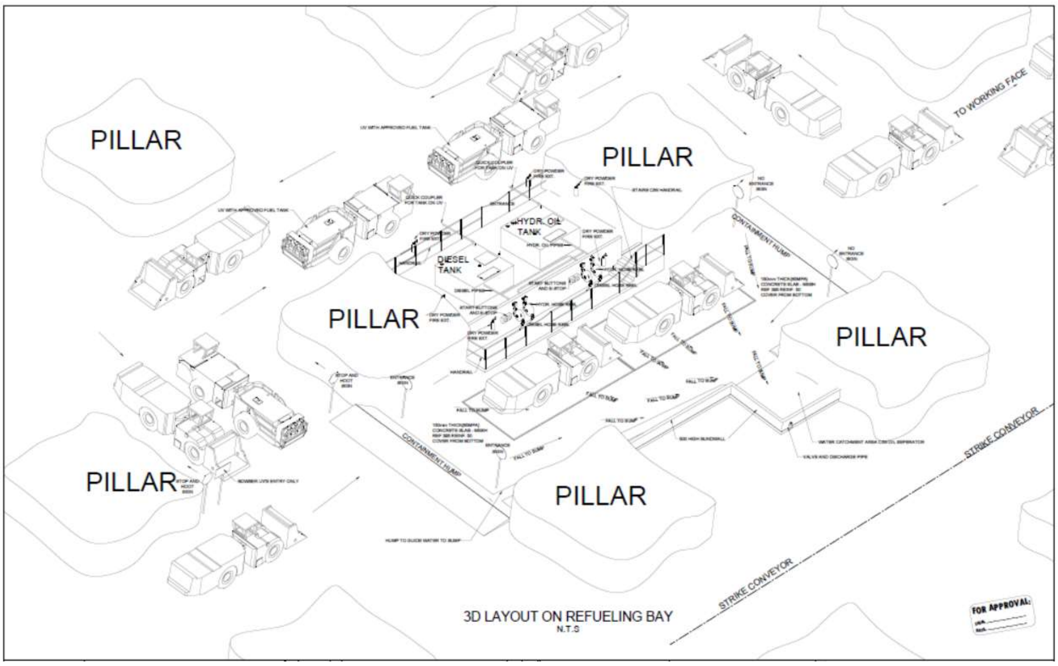

Figure 4.4: 3D Layout on refuelling bay.

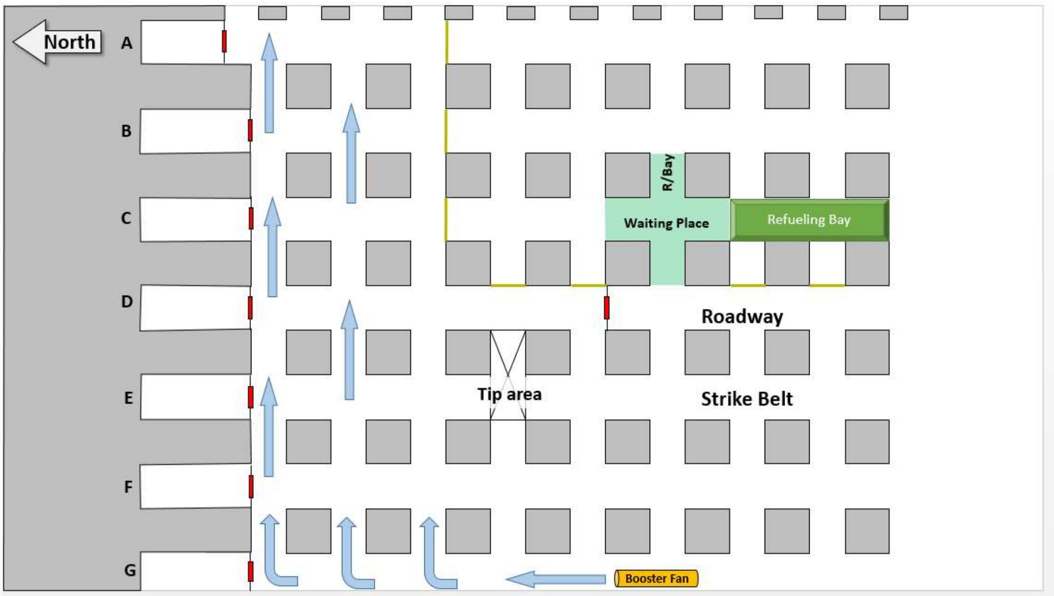

Figure 4.5: Basic strike section layout with refuel bay.

During the interview with the procurement department, which is a sub-process or department that was directly impacted as a result of the implementation of the roof-bolter machines, it was emphasised that there were challenges in respect of the inventory holding capacity (thus storage area), item packaging and transporting of goods to the sections and the planning of inventory usage by the different departments

The current holding area of the stores for roof bolts was not suitable for the increase in deliveries of roof bolts and auxiliary items for the roof-bolter process and this problem had to be addressed. This meant that the area had to increase to accommodate the increase in stock holding. The packing and delivery process was reviewed and streamlined, as can be seen from the two processes followed, namely in Appendix C, which is the old process, and Appendix D, which is the new, improved process.

Inventory planning and usage predictions also came under the magnifying glass during this project. The usage of items such as diesel, roof bolts and accessories, conveyor belt, conveyor structure and conveyor components, to mention a few, had a major impact on the planning of the procurement department. The increase in efficiency in the mining operation caused the procurement department to be at a disadvantage, since it had to reallocate and adjust the minimum stock reorder levels.

With the increase in rate of use of the items mentioned above there is also an increase in paperwork for the stores, thus the administrative load of the stores personnel increased. Reassigning activities to the team members at the store reduced this load to be manageable.

e. *Impact on day-to-day activities in the work area*

Dwarsrivier Mine's design was based on a 'bord-and-pillar' mine design policy. The typical mine design layout is shown below.

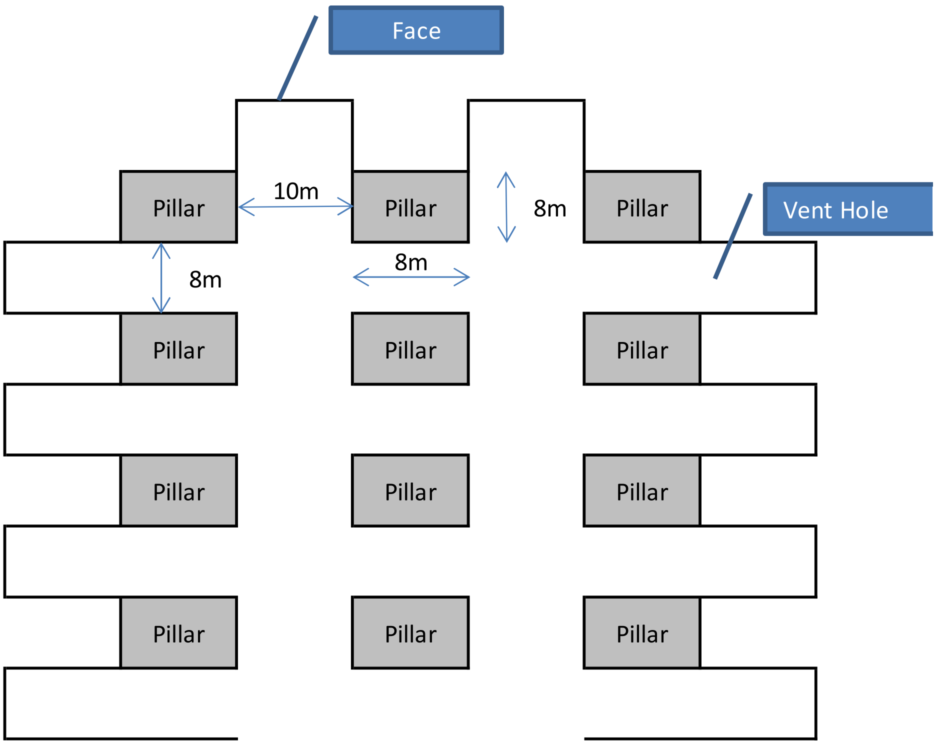

Figure 4.4: Basic Bord-and-pillar Layout

The mine design has not changed and does not have a direct impact on the implementation of the mechanized roof–bolter, as the design already accommodates mechanised face-drill equipment, thus all access ways and face entrances allow safe and effective access.

In the conventional roof-bolt supporting method, mining height has an impact on the quality of the installation but is flexible due to the type of equipment used for the installation and the manual intervention of the roof-bolt operator. With the introduction of mechanized roof-bolt installation, the equipment height is fixed. The boom and drill head assembly has a minimum height and works effectively only at a certain mining height. This equipment has a minimum height limitation of 1,6 m in a tramming mode, as indicated by Figure 3.1 in Chapter 3. The mining height ranges from 1,8 m to 2,1 m. This height is very dependent on the geology of the ore body as indicated in Figure 4.5 below. The deviations are caused mainly by reef-roll and narrowing of the reef due to features such as potholes and dykes. The mine planners had to ensure that they obtained the necessary geological data to plan the mining height and the dilution or undercutting of the foot wall of that specific mining area to ensure that the equipment could operate at maximum efficiency. This undercutting of the foot wall had an impact on the amount of waste material moved and the underground stacking of the material and road condition for the loading equipment.

The figure below illustrates the basic geological layout of the ore body mined at Dwarsrivier Operations.

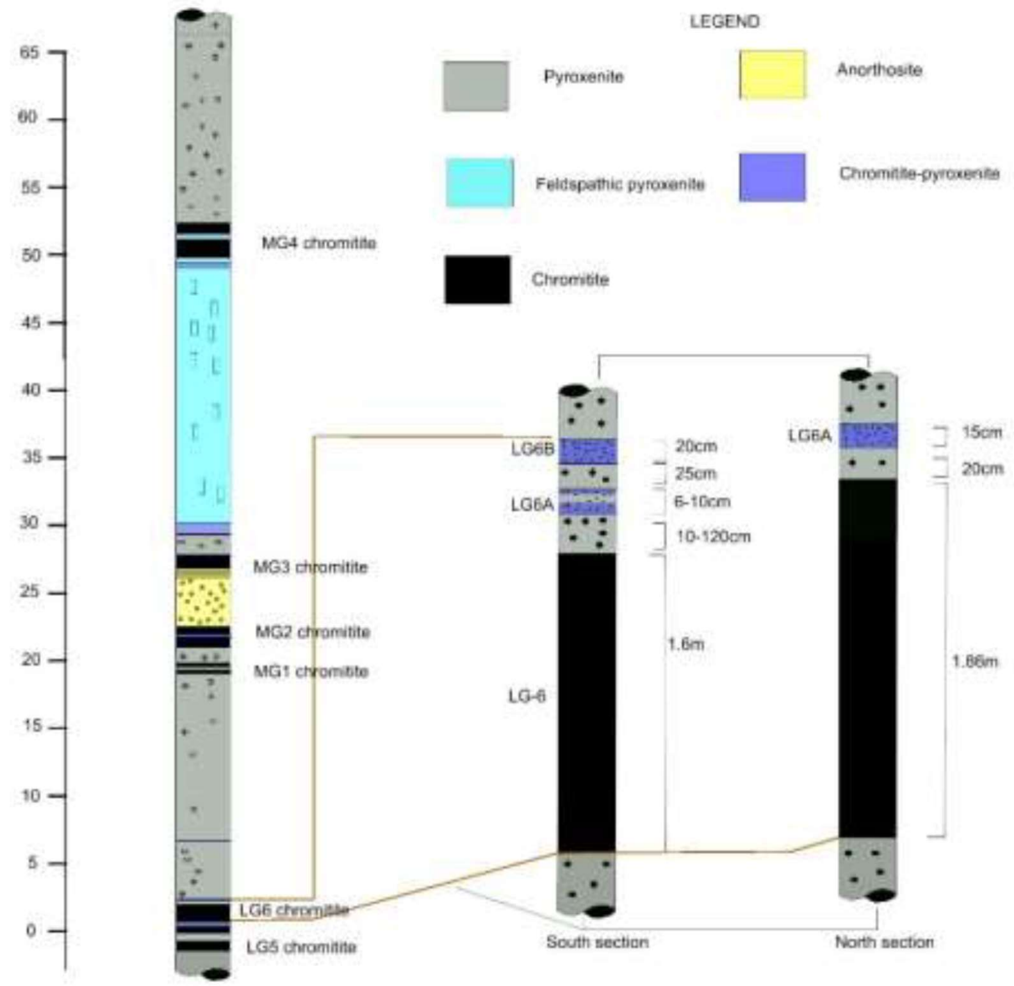

Figure 4.7: Stratigraphic Column at Dwarsrivier Mine (AMMSA, 2013)

The geology did not impact on the success of the implementation of the new equipment to the extent that any significant changes had to be incorporated. It was the opinion of the operational staff that the hanging wall was more stable and they saw fewer rock fall-outs with the new equipment. This could be linked to the fact that there was less hammer action and vibration in a given area, thus causing less damage to an already damaged hanging wall (roof). In conventional roof-bolting there will be at least two to four machines drilling simultaneously in a span of 4 to 5 metres, depending on the support pattern.

The company uses a computerised, planned maintenance system for all maintenance activities. Work activities are carried out to the OEM's requirements and time schedule. The roof-bolter equipment uses the same drive carriage as used on the face-drill rigs. The main difference in maintenance between the two types of equipment is the boom section of the equipment. This is also where most of the work is concentrated.

The scheduling and resourcing are done by the planning department, which consists of a maintenance planner and clerks for data capture. The main function of this department is to analyse data, readjust schedules, and report on recurring failures that require the attention of the engineer for rectification. No significant changes were noted in the day-to-day operation, except for the increase in workload due to additional work orders that were generated for the roof-bolter equipment.

With the introduction of the additional hydraulic drill–rigs, the labour requirement in the service workshop had to be adjusted to allow for the additional work. There was an underestimation of the workload of the artisan servicing the roof-bolter, due to the high wear rates of all moving parts in the head section of the boom. This caused an increase in time spent in the drill-head assembly area, which led to a deterioration of the carrier section of the machine. The team members were transferred to ensure that additional artisans were introduced to the service teams, as mentioned previously.

f. *Impact of short- and long-term planning*

As mentioned in section 4.2.3.d, the implementation of the new equipment had an impact on the procurement department in the long and short-term periods of procurement agreements. The increase in mining efficiencies had an impact on the rate at which certain items were used. This impacted on the forward planning and engagement with the various suppliers, and also impacted on the suppliers' transportation. Careful planning and minimum reorder levels had to be adjusted to accommodate this increase in use. In the longer term, planning in respect of diesel usage and storage also impacted on the contract values and tender negotiation. It was the view of the team that the impact of adding the next level of mechanization to the already mechanized mine with regard to the sub-processes and sub-departments had been totally underestimated.

As mentioned many times in this document, the impact on mining efficiencies due to acceptance of the equipment and increase in experience of the operators affected the mine planning department not by adding more activities but by resulting in an increase in the intervals at which these activities are performed. Measuring, reconciliation and forward planning had to be done on a weekly basis and the monthly mine planning was based on a much larger mining area after the implementation of the roof-bolters. One of the big impact areas of planning was the tip areas. It was mentioned in section 4.2.3.d that the number of section extensions increased from two sections per month to six and in some cases seven section extensions per month. This affected the mine planning with regard to the tip movements and tip excavations.

g. *Skills and development process*

The training of the selected employees started upon the arrival of the first machine. Training was divided into two basic groups, as indicated in Figure 4.8 below.

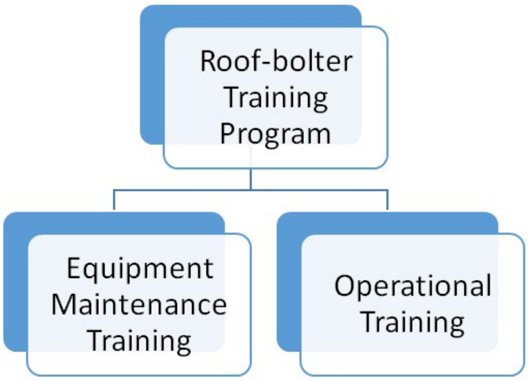

Figure 4.8: Training Groups

Figure 4.9 below represents a high-level flow diagram of the process followed to train and conduct competency assessments for the operators to be licensed to operate the equipment.

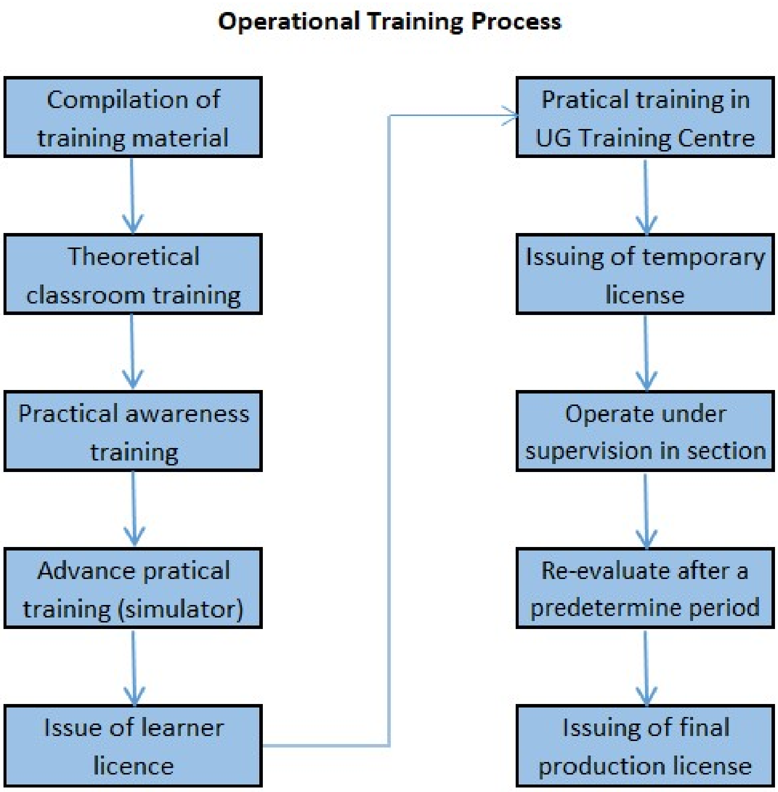

Figure 4.9: Initial Operational Training Processes

The equipment purchase agreement offered training sessions for maintenance and operation with each machine delivered. This enabled the OEM to train the instructor for the training centre and have enough time to evaluate the mine instructor in the process. There were nine training sessions.

As part of the capital outlay, a computer simulator was purchased to aid with the practical training prior to introducing the operator to actual operational conditions, and for future training of employees. The delivery of this equipment was delayed due to some software problems experienced by the manufacturer. The availability of actual machines and the late arrival of the simulator impacted negatively on the training of employees and the implementation of the new equipment in other sections.

The OEM and the training centre management developed a stand-alone physical simulator to reduce the impact of the late delivery of the computerized simulators. Figures 4.10 and 4.11 below present a view of the stand-alone simulator.

Figure 4.10: Stand-alone Simulator

Figure 4.11: Stand-alone Simulator; Remote-control Panel

This simulator simulated all 54 action steps required to install one roof bolt. Each step, if done correctly, is indicated by a light on a display panel. Figures 4.10 and 4.11 show the remote-control panel, which is exactly the same as used on the actual machine. This stand-alone simulator allowed the training to proceed and ensured that employees were competent in operating the equipment until the computerised simulator arrived on site.

Figure 4.12: 3-D Simulator

Figure 4.12 shows a three-dimensional simulator that allows the operator to view his surroundings as if he or she is in the actual machine in a work area. The operator experiences the movements and controls of the machine as if the machine is operating on the working face.

Lessons learned during the training phase:

- Do the practical awareness portion of the training before the actual theoretical training. This gives a better understanding when theoretical modules are discussed.

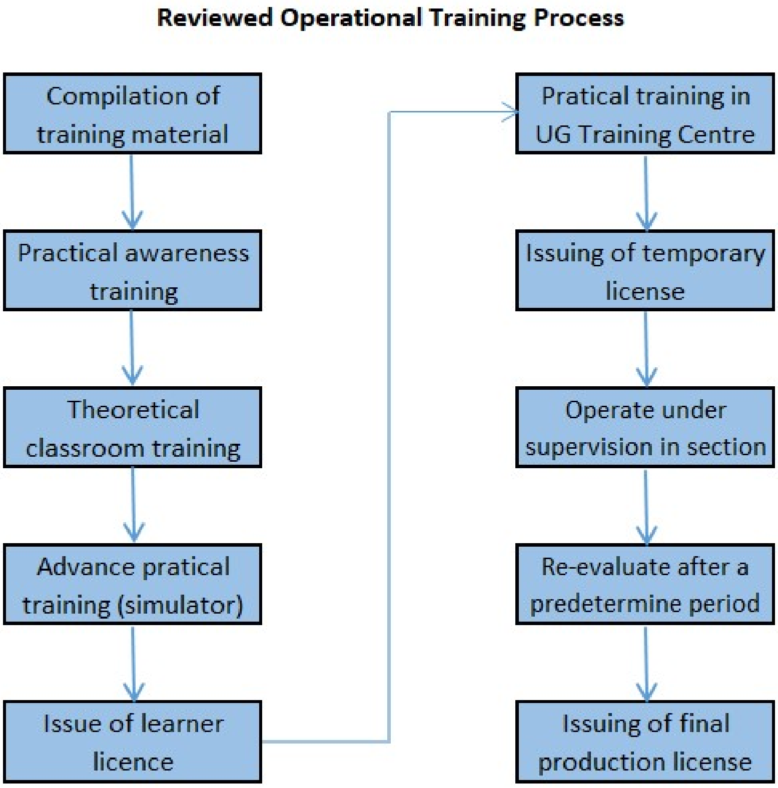

Figure 4.13: Reviewed Operational Training Processes

- Have a dedicated machine available for the training centre.
- The importance of a simulator cannot be emphasised enough, but having it on site before the actual machine will be an advantage.
- Strictly adhering to the processes that are used in the section during the training of employees is very important. There must be alignment between the actual activities (methods) on the face and the training activities in the training centre. If training is not done correctly there will be confusion when the operator is reintroduced into the production section.
- The trainer will do most of the theoretical and basic practical training, whereas the coach will be in the working area, giving guidance to workers to improve their competency

- The appointment and training of the coaches are very important. The appointment of the coaches had a very positive impact, as they adopted a hands-on approach to the training of the employees when the latter were allowed to operate in actual mining conditions. It is important that the coach be confident in the operation of the equipment. If not, it will have a negative effect on the operators and they will start operating in accordance with their own ideas.
- The selection of operators for the new equipment is also very important; one should select operators with similar experience, especially in the initial phases of the implementation process. In this case, face-drill rig operators were converted to roof-bolter operators. This meant that they had the basic skills of tramming and operating the equipment. This gives confidence in the operation of the machine and an early buy-in for all operational personnel.
- The organizational structure of the training department had to be restructured and coaches were appointed. Practical hands-on personnel on the floor at the equipment are very important when implementing new technology to help and assist the operators.

4.2.4 *Results and Measurements*

a. *Key Performance Indicator selection and roll-out*

The initial intent of the reward or bonus system for the roof-bolter machine was with regard to the number of bolts installed per hour (10 bolts/hour). This was based on the equipment's performance as well as that of the operator but caused some misalignment with production targets. The focus was on the number of bolts installed and not on the required number of production face metres supported. The result of this method was that the number of supported faces became less and thus production was running behind, due to unsupported faces. A relook and redesign was done, and the new approach was to scrutinize the required metres that had to be supported per shift to allow for a healthy production or mining cycle. The target was set at 26 metres/shift/ roof-bolter as a minimum.

The knowledge gained from setting up the Key Performance Indicators (KPIs) was that the equipment must not be treated as a stand-alone unit, but must form part of the section’s performance. In addition, its function or contribution must be clearly communicated and explained.

Continuous enforcement of the rules and communications by means of visual boards is very important, as focus can easily be lost, and this has a direct impact on a section’s performance.

b. *Measurement and feedback*

The mine generates daily reports in which the supported metres per section are recorded in the shift boss’ office and the underground waiting place. The display board at the waiting place indicates the performance of each section team, thus the respective teams keep one another accountable and the teams understand that they have to work together to achieve the target and get the reward.

As mentioned below, the feedback to the mine occurs at the monthly mass meetings and/or when there is a requirement to communicate.

c. *Communication platform*

The mass meeting platform was used to communicate the new system to all operators in such a way that they played a direct role in the performance of the section. If the faces were not supported, the operators could not drill, thus no production - no bonus. This meant that there was a direct focus on the target of the section and not on the performance of the roof-bolter.

The reward system was communicated over a period of four months to achieve buy-in and full understanding by the employees of what the impact would be on production and the bonuses paid to the employees.

4.3 Summary of the Results

One of the strong points of this implementation project was the fact that the environment was already suitable for the type of equipment, since the mine was a semi-mechanized operation. No significant changes were made to the mining method to implement the new equipment.

There was a very good understanding that the success of the new equipment depended on the quality of the people who operated and cared for the equipment. A large amount of work went into ensuring operator competency. The introduction of the computerized simulator as part of the training and exposure of the operator added value to the successful implementation of the equipment.

As mentioned, the success of the implementation was seen to be the result of the people factor. The selection process that was adopted ensured that the correct type of skilled person was selected to operate this very expensive and critical piece of equipment. As the implementation of the new equipment evolved, a real understanding of the resources required to successfully operate the equipment was realized, which led to the redeployment of the affected Rock-drill Operators (RDOs) as assistants to the operator. This meant that almost all affected RDOs were redeployed and not retrenched.

If one considers the main objective in this case, i.e. reducing the number of people in the danger zone, it has been achieved, and acceptance of the new technology by the employees was very positive.

A very important point that must be understood is the impact that this new equipment will have on sub-processes. A detailed analysis must be conducted to calculate this impact. All activities and roles must be clarified and understood in order to determine the integration points and to establish at what level this integration will be required. An understanding of what the increase in efficiencies of one process has on the additional activities generated for the supporting function is very important. This will guide the long- and short-term resource structure and planning process.

It is evident from this study that open and continuous communication with the people by means of mass meetings, display boards and waiting-place discussions is very important. This communication in respect of the performance, whether good or bad, is critically important. The topic of mechanization has always been a point on the agenda, and this was seen as a positive element, since nothing was hidden from the people.

As the operation accepted the equipment and the operators and maintenance personnel matured with regard to experience in the use of the equipment, the performance increased to a more sustainable level. At the start of the project, the performance measurements were determined for individual achievements but as time passed, it was clear that the measurements did not support the business objectives and were subsequently changed to a more section-driven achievement. It is very important to measure and incentivise the correct aspects and to not set unrealistic targets at the beginning of the project.

CHAPTER 5. DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter discusses the findings of the case study, with the emphasis on the four main focus points, namely (i) the objective of the implementation, (ii) the impact on people, (iii) the impact on processes and (iv) the performance measurements. This chapter discusses the findings in three categories:

- What the successes were in the project,
- What the negative aspects were in the project and lastly,
- Lessons learned in this project.

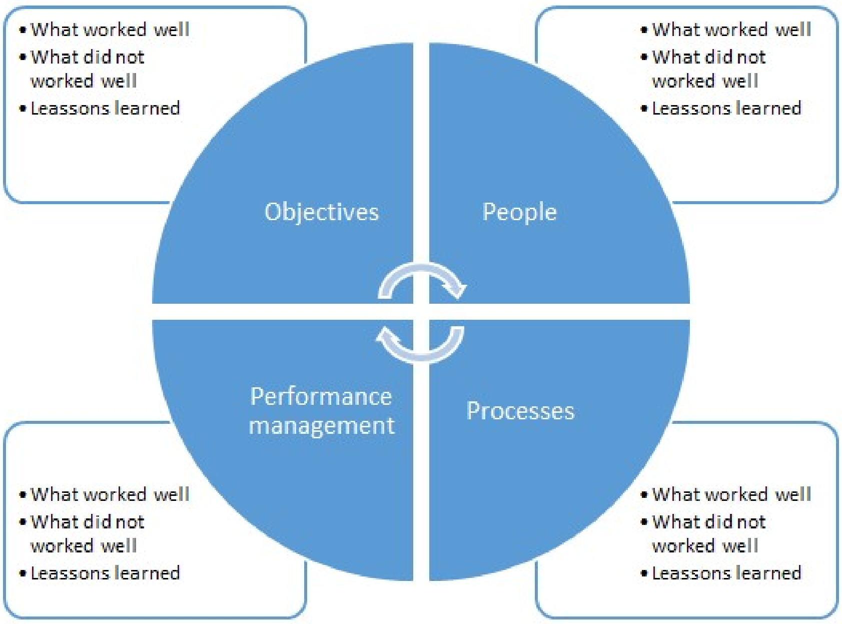

Figure 5.1: Flow of Discussion

5.2 Discussion Pertaining to Implementation Process for Mechanized Roof-bolters

5.2.1 Objective of the Implementation Project

The objectives of most mechanization projects are to improve safety of employees and to achieve overall improvement of productivity. In this case study, an improvement of the safety results was expected, as the people were removed from the danger zone and therefore one of the main objectives was realized. One interesting observation was that other small incidents started to occur, for example foot and ankle injuries. This is, in the author's view, a result of the activity list and the risks associated with the revised activities not having been analysed. Not understanding the activities and risks in respect of the new technology, and inadequate skills and experience on the new equipment, combined with environmental conditions, could be the cause of these types of incidents. In an informal conversation with two of the previous rock-drill operators who had been retrained as roof-bolter operators it was evident that the implementation of the roof-bolters had changed their lives and their attitudes towards their own personal safety. The question that was posed to them was whether the roof-bolters should be discarded and the conventional method reintroduced, in other words, would the operators be willing to go back to being a manual roof-bolter operator, and the answer was no. One operator's reason for the negative reply was that the machine had taken him away from danger and he could now work in a better mindset and focus on the work at hand and not be afraid that he could be injured. This is a very positive testimony to the impact that mechanization had on these employees.

It was also clear from the interviews with the operators that with the reduction of the safety risk in the installation of roof bolts, the focus was now on getting the work done. This had a direct impact on the rate at which the bolts were installed and thus the rate of production. This can also be seen in the graph below, which presents an overview of the increase in production and productivity at the mine.

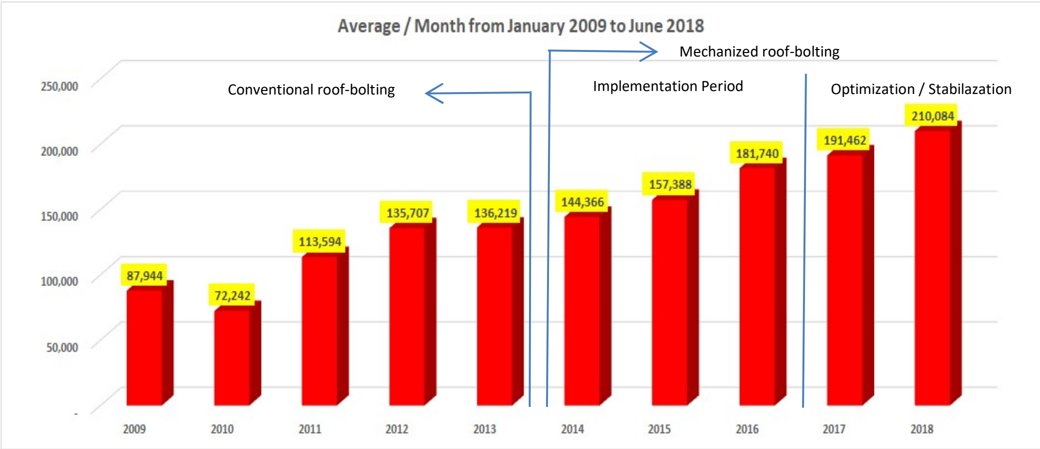

Figure 5.2: Annual Production Results: 2009 to 2018

The main production objective of the mine was to reach the design capacity of 140 kt per month and keep the performance stable. As one can see from the graph above, in years 2012 and 2013 the mine's production reached a plateau where the production could not be increased any more without doing something different. This is the point where the safety incidents were also at their highest level (refer to Figure 4.2 in Chapter 4), as more and more people were appointed to open more strike sections so as to increase the production. This was clearly not the right way to go. At this point, the decision was made to introduce mechanized roof–bolting, as the manual process had been identified during internal brain storming sessions as being the bottleneck in the process and responsible for the high number of injuries and the possibility of a fatal injury to an employee.

In 2014 there was a slight increase in production, as can be seen in Figure 5.2. This was due to running dual systems, namely conventional sections and mechanized sections, and this was the period when the operators gained confidence and experience in operating the equipment. As the machines were being commissioned and rolled out in the section, a decision was also made that the conventional method would be discontinued. The production increases were as follows: In 2013-2014 there was a 6% increase, in 2014-2015 there was a 9% increase, and in 2015-2016 there was a 15% increase in the average production per month for that year. The 15% increase can be attributed to the experience of the operators and acceptance of the equipment into the mining and operational processes. From 2016 onwards, a new production shaft was commissioned to take the mine beyond the 200 kt per month. This new mine was commissioned as a fully mechanized mine with regard to the mining cycle.

Willis et al. (2004) made it clear that by introducing mechanization, the industry would reduce the number of people in the danger area and thus reduce the number of incidents, but that other risks would be introduced that had to be understood and managed. This warning was ignored when other incidents occurred, as mentioned above.

It is of the utmost importance to analyse the detailed activity and task lists and risk-assess each task or activity with regard to environment, employee skills and experience. In many of the cases, the risk is very high in the beginning, but control measures are put into place to mitigate these risks, thus the risks will decrease when experience has been gained. It is also important at a later stage to reassess the risk and control measures to ensure effective and realistic controls.

The result of these control measures is an indication of what can be achieved once people feel safe and cared for in their working environment. The sense of safety and security engenders motivation, which paves the way to acceptance and ultimately the willingness to perform on unexpected levels.

It is the author's view that the two main objectives identified at the start of the project have been achieved and will be sustainable in the future.

5.2.2 Impact that Implementation of Roof-bolter had on People

The initial aim of the company was to reduce labour and improve efficiencies by means of the implementation of mechanization, but the labour reduction approach was abandoned very early in the initial phases of the project, and the strategy of keeping as many employees as practically possible and also improve efficiencies was adopted. The impact of this approach was positive on the employee buy-in. In the opinion of the author this was a very important approach, as the implementation of the new technology was achieved without industrial action of any kind. Normally, in cases where the livelihood of the employees is affected, there are industrial action and major delays in getting the new technology and process implemented.

Having an agreed-upon strategy on how management would obtain the necessary buy-in from the unions and affected employees made the transition easy and without labour relations problems. The approach of telling the workers "What is in it for them?" when embarking on a new technology implementation project, creates a platform for early buy-in. The purpose of the new equipment is made clear upfront, as well as what the benefits will be for the employees. It is important to clearly explain how the new technology will influence their lives. An additional benefit is that this information will create a sense of participation and ownership, thus the employees will trust the process and participate positively. In this case, due to the nature of the equipment implemented, the operators were at a higher grading level. This meant that there would be promotion for the successful operators of the new equipment. Normally there are not many opportunities for a rock-drill operator to be promoted and to earn a better salary. By addressing a basic need of all humans, namely to improve their quality of life, a willingness was created to participate as well as the drive to ensure that the new equipment would be a success. During the interviews with the operators this factor emerged as a highly motivating point that instilled in the operators a sense of pride and achievement.

Willis and Ashworth (2002) cautioned that negative perceptions could lead to suspicion and sabotage if there was no buy-in from the people. The purpose of the change must be clearly and as many times as possible communicated to all employees, in order to keep all parties informed and involved. This will reduce negative perceptions and increase the success rate.

What really benefited this implementation project was the fact that the mine had already been mechanized. The employees had a very good understanding of what was expected and how the equipment would operate in the existing environment. The management and first-line manager knew what the various challenges were regarding the existing mechanized fleet, and solutions were quick and effective. The only people who had to undergo a mindset change were the affected employees. The assistance and knowledge of operators of the existing mechanized fleet played a significant role in the change management process followed.

Willis and Ashworth (2002) mentioned the factor of sensitizing and preparing people for the coming change by way of candid communication, which is one of the factors that must be driven. People do not change as fast as technology does. If management cannot convince the people affected to be role–players and to understand the objectives, and cannot demonstrate the concept of “what’s in it for me”, success will be hard to realize. This concept came through very clearly, as the mindset of management was that as far as practical, all affected employees would be retrained or redeployed, and that layoffs would be the last option. Additionally, this new equipment could lead to promotion for some employees. This element was well communicated by the mine management in the early stages of the project.

What stood out in the case study was the very high level of commitment from management to convert to a mechanized mine. The drive to find solutions to obstacles and challenges was not non-negotiable and this came through in the bold approach of removing the rock-drill operators once the roof-bolter machine is in the section. The background and experience of the management team with regard to mechanization played a very important role, since there was alignment with the objectives of the project. The fact that there already was buy-in for the mechanization technology, due to the semi-mechanized nature of the operation, strengthened the commitment to make a success of the conversion project.

Research shows that failure of new technology often occurs, as Macfarlane (2001) states in his paper, where management is perceived to sit on the fence and not being fully supportive of the new technology. New technology must be supported from the top down to ensure successful implementation.

The mining industry is possibly one of the most unionized businesses today. The unions can be a very useful resource. Getting the unions on-board timeously in a process or project that could result in a reduction in labour adds value. The level of employees normally affected in this type of project has a direct connection to the unions.

Getting the unions to buy in to the project and its objective gives the organization a bigger voice and creates transparency in the process in the eyes of the employees. In this specific case, the union was informed at the start of the feasibility stage of the project. The objective was defined and presented, what the possible outcomes could be, and what the possible gains for the employees and the company would be. To ensure buy-in, the management team and the unions acted as one in the sense that all communication documents were signed by both parties to show solidarity and commitment from both parties. This enabled the unions to be in a position to answer all questions that came from their members that were affected.

5.2.3 Impact on Processes resulting from the Implementation of the Roof-bolter

5.2.3.1 Impact on operational structures

As mentioned, this operation is a semi-mechanized operation, thus the changes made to the structure were minimal, as indicated in Table 4.2. The structure mentioned in Table 4.2 was the final concept. The start-off structure and the final structural changes were significant. As the implementation process progressed, additional tasks and activities were identified. This again emphasized the importance of assessing in detail all the activities and tasks associated with the new equipment before embarking on structural changes. At the start of the implementation process it was assumed that the operator would be able to perform all activities related to the machine and the installation activity. This was clearly a misconception, since the operators lacked experience and skills in the early stages of the project, for example, but these shortcomings could be overcome at a later stage as the operations matured and could possibly become the subject of a future improvement project.

Understanding all the activities associated with the new equipment or technology is a prerequisite for restructuring or setting up the organization. This does not pertain just to the activities or tasks in the area where the new equipment will be implemented but also to the interfacing with and additional requirements for other levels and departments of the organization to support the new equipment or technology. Setting up the new structure by considering how it should operate only when the new technology is well-embedded could cause underestimation of the resource and support requirements in the initial phases of the implementation. The labour complement was planned as if the new technology was already embedded and not as a phased-in approach, where the skills level and experience were low. The labour complement should start off at a higher number and as the system matures and experience is gained, the labour complement can be reduced to a more effective and efficient structure. The reasoning should be to start with the envisaged final labour structure and add labour where the risk profile requires it, by adding temporary labour, or labour that can be retrained and redeployed. As the risk decreases and experience is gained, the structure is reviewed to a point where the final labour structure is established.

It was evident at the mine that the basic process and level of interface, especially the supporting functions, were in place and had been integrated for the current operational arrangements. However, the complexity of the actual operation of the equipment and the maintainability of the equipment had been underestimated or unsuspected, which led to underestimating the resources and skills requirements.

During the actual introduction of the machines into the work areas, the misalignment between the expected activities and those that were actually carried out, influenced the sectional structure. This is exactly what Macfarlane (2001) mentioned, namely that when the tasks and duties were understood, a more realistic structure was introduced. To give an example of one such activity in this case study, the activities of the operator were detailed as follows:

- Pre-start inspection of the equipment and auxiliary equipment.
- Refuelling and lubrication of the boom and the areas identified as high-wear areas.
- Ensuring that the materials are available, such as the number of roof bolts and resin that will be required for the shift.
- Tramming to the workplace and walking the route to determine the most suitable route so as to minimize damage to the equipment while tramming.
- Setting up of machine, ensuring that ground conditions are suitable.
- Positioning of head for drilling: before this is done, the operator must ensure that the correct pattern is marked out.
- Installation of roof bolt to the correct standard.
- Reloading of carousel: the operator must at all times ensure that there are sufficient roof bolts available and ready for reloading of the carousel.

- Recording of required settings and production information.
- Parking and cleaning of machine: after completing the bolts for the shift, the operator must ensure that the machine is clean and refuelled, and if possible, all high-wear points in the boom area are lubricated to ensure a quick start for the next operator.

The nature of the setting-up activity was underestimated, due to the water- and power connection requirements with regard to the mine standard of hooking the power cable to the roof bolts. The distance of the power distribution box to the face and the weight of the cable were detrimental to the time it took to start with setting up the machine for drilling. This activity took too long for one person to handle and had a direct influence on the cycle time on the face. From the last interview with the operators it was clear that this was still a problem, as some of the machines are operated by only one operator with no assistance. This has an impact on the efficiencies and is an area that must be addressed for future improvement projects.

When embarking on planning of the labour requirements for the new equipment it is very important that there should be a very good understanding of all the tasks and activities that must be carried out. In this case study it was found during the implementation process that activities such as tramming and setting up were challenging to the operator. A decision was taken to add an additional person to assist the operator with these activities. This is very important, especially in the beginning phase, as the skills and competencies are not on a high level and this factor could cause negativity towards the equipment and new processes. The lesson learnt was that a detailed activity and task list must be drawn up to evaluate the labour needs. This is also where the trial period plays a vital role, as all these activities can be evaluated, the risk assessed and time allocated, and then resourced accordingly.

One objective of this project was to increase efficiency and production output. The aim was that the roof-bolt installation time would be reduced, with an associated improvement on the overall face cycle times, meaning that more faces could be blasted in a given time. Due to equipment-related delays, the focus of the implementation team was directed at getting the equipment to perform and meet the designed bolt-installation times, and not at optimizing the overall face cycle time. During a follow-up visit to the mine it was clear that most of the critical mechanical problems had been resolved and that the equipment was much more reliable. This had a positive impact on the mining cycle, as by then the operators also had more experience and self-confidence, the results being an indication of that.

5.2.3.2 Impact on management processes

In this case study, it was clear that there was a very high level of commitment from management to convert to a mechanized mine. This fact became evident in the bold approach to remove the rock-drill operators once the roof-bolter machine was in the section. The background and experience of the management team with regard to mechanization played a very important role, and were in line with the objectives of the project. The fact that there already was acceptance of the mechanization technology, due to the semi-mechanized nature of the operation, strengthened management and the personnel’s commitment to make a success of the conversion project.

The success of the implementation of the new technology was partially due to the commitment from the top management of the company. Research shows that failure of new technology often happens, as Macfarlane (2001) states in his paper, where management is perceived to sit on the fence and is not fully supportive of the new technology. New technology must be supported from the top down to ensure successful implementation.

Due to the fact that the operations were already semi-mechanized, many of the procedures and codes of practice complied with the requirements of the Mine Health and Safety Act 29 of 1996, schedule 4. This saved a lot of time, as codes of practice and some operational procedures could just be reviewed and re-implemented by the training department.

In a totally new mechanized installation, the drafting of new operational procedures and codes of practice can be a time-consuming activity, due to the large amount of work that has to be done to get all the documentation in line with the Department of Mineral Resources' guideline requirements. The development of new codes of practice involves many resources. The guideline normally requires a drafting committee that consists of a predetermined and specified number of members of which the unions, health and safety representatives and employee representatives are a part. If procedures are not addressed early in the process, this could cause delays in the training of employees. The update or development of the baseline risk assessments can be time-consuming and must also be addressed very early in the planning process of the implementation. This includes a mine-specific baseline risk assessment, activity baseline risk assessments, as well as equipment risk assessments.

Alignment of all systems on different levels is important and must be done throughout the implementation process. Macfarlane (2001) suggested that a system engineering approach must be followed. This approach allows for all systems to form part of the process. All system requirements must be satisfied or addressed, and/or interfaced as required to ensure success. The systems in this case will be (but are not limited to):

- Maintenance system.
- Performance management system.
- Financial system.
- Logistics and procurement system.
- Measurement and planning systems.

However, the above-mentioned systems were not addressed to the required standard, since the logistics, procurement and engineering construction departments were not resourced to fully support the changes to the roof-bolt installation process.

5.2.3.3 Impact on production processes

One very important point to remember when converting to mechanized operations is that one machine will be replacing multiple hand-held drills, as in this case. In the conventional method, should one hand-held unit fail, the function fails only partially and the support function will still continue, but in a mechanized method the complete function fails. This puts the emphasis on reliability and maintainability of the equipment and sound supporting processes to ensure success. The success of mechanization lies in the effective operation of the equipment, which is a direct function of the “fit for purpose" availability of the equipment, with no downtime. It is very important to ensure that the equipment is maintained to the highest possible standard and at intervals that will ensure its reliability.

The requirement for successful mechanization in an underground operation with regard to maintenance is a well-equipped workshop, complete with a store for housing the fast-moving spares, a fuel and lubrication facility, reliable lifting facilities such as overhead cranes, working space, very good ventilation and lighting systems, a location that limits the travelling distance of the equipment, and lastly, special tools to ensure a safe and fast repair cycle. Some of the larger special tools required will be tools such as tyre handlers, percussion hand-tools to effectively tighten and loosen big bolts, for example differential hold-down bolts and wheel nuts. Hydraulic press equipment for replacing bucket bushes is important and will reduce the risk of injuries during replacement.

The availability of fast and effective responses to machine breakdowns at the face is of the utmost importance to any mining section. Transportation of artisans to and from the face or between points where breakdowns occur is critically important. The availability of effective maintenance response vehicles will reduce the down-time of the machine. These vehicles must be able to transport spares, tools and equipment to the breakdown area. There is currently a wide variety of vehicles that can be implemented. Each has its own advantages and disadvantages, and the applications vary. The work faces are in some cases as far as three kilometres from the underground workshop or even further, if there are no underground workshops. A simple breakdown such as changing a hydraulic pipe can take up to six hours, due to travelling for spares, if no transportation is provided. Continuity is very important in a mining cycle; in many cases it takes longer to get back into the rhythm than it takes to do the repair to the machine, thus valuable production time is lost. The factors that influence this rhythm are operator availability, machine set-up and control room procedures.

The underground satellite workshops or repair bays are currently in progress and will have a direct impact on reliability and quality of work done by the artisans and operators.

The operational infrastructure plays a significant role in the success of a mechanized operation. To ensure an efficient and effective mining cycle, it is of the utmost importance to arrange the handling and storage of materials in such a way that materials are easily accessible and can be moved quickly to the required location. The discipline of moving the storage area of the underground mining material and equipment as close as practical to the working face is very important in a bord-and-pillar mine environment. The other very important point to remember when planning the movement of the storage areas is the rate of consumption of the material, for example roof bolts and resin capsules, in a mechanized environment versus the rate of consumption using the old, conventional method as the turnaround time will be affected because the distance increases.

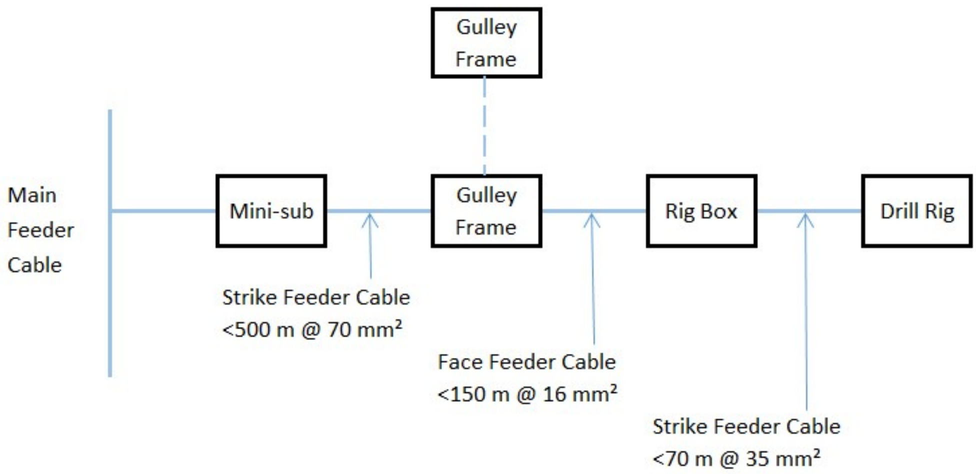

Figure 5.3: Basic Section Power Layouts

The auxiliary services such as water, power and ventilation also have a direct impact on the effectiveness of mechanization. All of these drilling machines that have been implemented operate with hydraulics supplied by electrically-driven pumps. The trailing cable is plugged into the underground electrical power reticulation (Figure 5.3). The limiting factor in this activity is the length of the trailing cable and the allowable voltage drop in the system, which could lead to electrical failures if not managed correctly. The water supply to the machine for flushing, drilling and cooling functions must be at a predetermined flow and pressure, which is determined and specified by the OEM. This, in turn, has an impact on the effective drilling and reliability of the equipment, and if not managed correctly, failures and delays will be encountered.

As this operation is already a semi-mechanized operation, moving the stores and other infrastructure is part of the mining plan, which is reviewed monthly as part of the monthly production planning cycle.

The detailed task lists of all activities are vital and include maintenance activities. The intense maintenance activities in respect of the head assembly were underestimated as regards the work load of the services personnel, as the perception was that it should be more or less the same as that of the face-drill rigs. Figures 5.4 and 5.5 give a clear indication of the difference in complexity and of the physical differences between the face-drill head assembly and the roof-bolter head assembly.

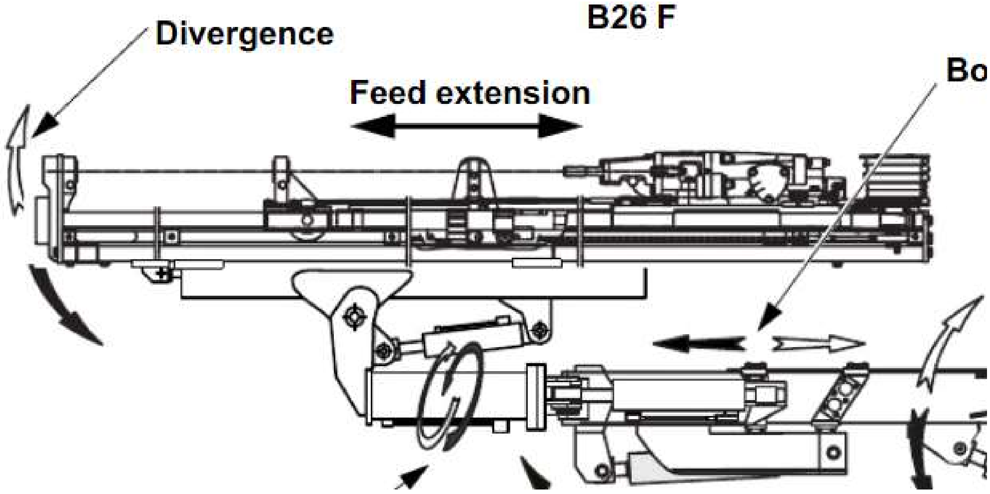

Figure 5.4: Typical Face-drill Boom Assembly

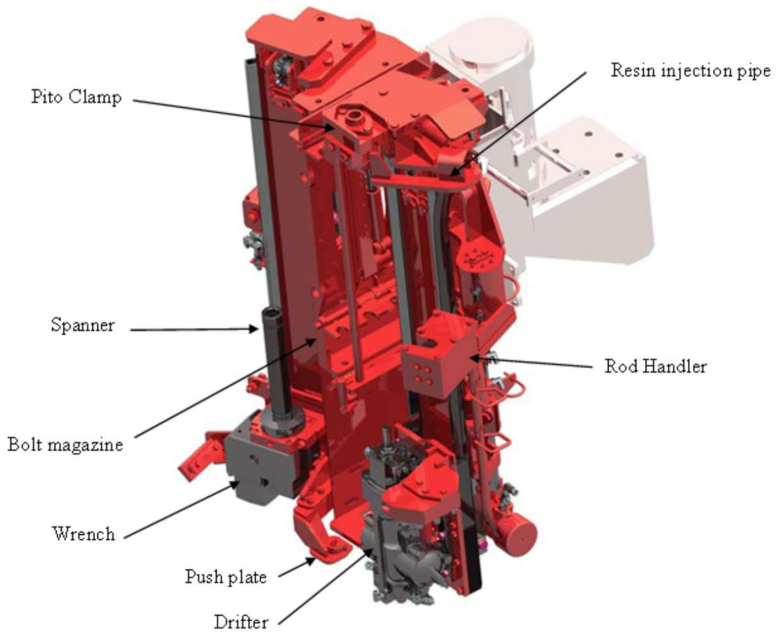

Figure 5.5: Mechanized Roof-bolter (DS210L-M) Bolting Head

The exposure of the roof-bolter head to mud and very fine material is much higher, as it drills vertically, and the flushing water drops directly onto the unit. For the face-drill unit the exposure is much less, as it drills horizontally and in some cases at an angle but the flushing water does not flow over the unit in normal operational positions. This necessitated an increase in maintenance personnel during scheduled maintenance days, as the boom section needed more attention than on the face-drill rig's boom. This in turn, put emphasis on the analysis and understanding of the complexity of each activity involving the new equipment.

The detailed analysis of all activities is vitally important and is in many cases overlooked and done as a last-minute activity. This could have negative consequences for any type of implementation project. A risk in this case study was complacency with regard to the type of technology, as the site was already a semi-mechanized site. This caused the oversight as regards the work required to maintain the equipment to the OEM's standards and requirements. What aggravated the situation was the number of modifications that were done to ensure reliability of the equipment.

Only when the detailed task lists for all activities are compiled and approved can a more realistic organizational structure be compiled, as noted by Macfarlane (2001). In this case study there were two points where this was not taken into consideration, namely the duties of the operator of the equipment and those of the maintenance personnel.

When one examines the initial results, the mine struggled to achieve 18 metres of supported face per shift as a result of multiple factors such as the inexperienced operators and unreliable equipment, to where they currently support 26 metres of face length per shift. Due to the approved availability of the roof-bolter equipment there was an improvement (2013/2014 - 65% availability increased to 82% availability in 2017/2018). This can be seen as the result of experience on both the operational and engineering sides. Hands-on experience is valuable but it takes time and commitment. In some cases, time is a scarce commodity during a successful implementation, as excellent results have to be achieved almost immediately after implementation and capital expenditure. Allowing the growth stage after implementation of the new equipment will enable the mine to enjoy stable and consistent performance of the equipment and ultimately gain the total benefit of the improvement.

It is noteworthy that the commitment that Dwarsrivier Mine made towards the workers and themselves to make the implementation work is highly commendable. The mere fact that they took the time to gain experience of the new equipment on all levels is one of the reasons for their success.

5.2.3.4 Impact on sub-processes

At the start of this project, the cycle time was affected by delays due to a lack of equipment reliability, and once the equipment was operating at the required rate, the logistical system could not supply material timeously to the miner’s store, which caused other delays. These supply delays emphasised the requirement to urgently reconsider the logistics handling process. Changes were made to the logistics handling process to accommodate this increase in installation rate. These changes can be seen in Appendix C, which shows the old system, and Appendix D, which shows the improved system. A limited number of utility vehicles and cassettes were available for executing the logistics process, so that the materials had to be offloaded as soon as they arrived at the storage area, and the vehicles had to be taken back to the stores for reloading for another section. This caused delays in turnaround times for material per section. The problem was solved by using additional utility vehicles with additional removable cassettes and reviewing the logistics system for handling of material. The number of cassettes was increased such that each section has two cassettes, that is, one at the store that is being loaded and the other at the section store that is being offloaded. The fact that the utility vehicle could then just offload the loaded cassette and load the empty cassette allowed for a decrease in turnaround times for delivering material to the sections. The control room operator took control of the movements of the utility vehicles to ensure that the empty cassettes get to the surface as soon as possible.

During the interviews with the affected departments or functions it became clear that not much thought had been given to how the other departments would be affected indirectly. In the initial phase of the project, the process mentioned in Appendix D was thought to be the only highly impacted process and had to be reviewed. This change in process had the intended impact but the other holding capacity and stock levels, reordering level, amendment of contracts, and transportation of the goods to the mine and the rate of usage had been completely overlooked.

The staffing of procurement department was not reviewed during this process and-the department is currently barely surviving due to the workload but if the problem is not addressed it will have a negative impact on the current rate of production. This success of the roof-bolter hinges on the way it is supported and not only by the production and engineering departments but also by the sub-departments and functions that enable it to perform.

The impact of one function that increases in efficiency can influence the performance of other well-performing sections negatively, and this factor cannot be ignored. As mentioned previously in the document, the rate of support increased, which in turn increased the rate of production, which then increased the rate at which the tips must be moved closer to the production faces. This will have an impact on the performance of the current conveyor belt construction crews. This was also one of the sub-functions that were disregarded in the initial phases of the project. This became evident only as the maturity and experience of the support crew increased. It is very important to investigate all activities associated with the main activity. It does not matter how small; it must be analysed to determine what the consequences will be.

Macfarlane (2001) emphasised that the logistics support systems or any other support systems must be reviewed prior to the implementation of new technology. The author also mentioned the effects that the new technology has on the work flow in a work area, and in this case study it was evident that the work flow had changed and that all processes and systems had to be fully understood in relation to the new requirements to ensure effective and efficient support so as to ensure success of the implementation.

5.2.3.5 Impact on day-to-day activities in the work area

The difference in work culture between conventional mining methods and mechanized mining methods is significant. If the difference is not managed correctly or addressed early in the project, it will hamper the success of mechanization. In this context, the work culture refers to the way in which the day-to-day activities and work flow are managed by the operational personnel. One example of this is that in conventional mining at this specific mine, before the mechanization, the rock-drill operators would support the required number of holes for the shift and then move out to the waiting place, as the construction crew had to move the infrastructure required to drill to the next available face before any work could be done. The effective utilization of the rock-drill operators was limited by the infrastructure, thus effective utilization was a challenge. In a mechanized environment it is all about the effective utilization of the equipment in the time allowed. Due to the rate at which support is installed, compared to conventional methods, there is in most cases time during the shift to start drilling and/or installing roof bolts in faces that have been prepared. This could be a bigger challenge when the operation is not already a hybrid mine, exposed to mechanized operation where equipment utilization is of the utmost importance. In this case study, the mine is a hybrid type of mining operation, where part of the mining cycle was already mechanized. The mindset of the production and processes are in place to allow the successful implementation of the mechanized roof-bolters.

During the interviews with the operators, a very interesting success factor was highlighted, namely that in the operator's view, the success of this project was in the preparation for the next shift, carried out in such a way that it would enable the next operator to get going as quickly as possible at the start of the shift. Rhythm and continuous operations are very important in mechanized mining operations. This is the most important point from the operator's side. This means that the machine must be parked in the correct place, as close as possible to the next face, clean, refuelled, lubricated, and all repairs must have been completed. This will enable the machine to start operating as quickly as possible, which on the other hand will allow for time at the end of the shift to do the same for the next operator. This method works very well at the mine and creates this mutual accountability

Willis et al. (2004) pointed out the importance of addressing the organizational and workplace cultural matters, as they will have a direct impact on the success of the new technology. The workplace cultural issues have a direct impact on the resistance to change and attitude towards the new technology.

5.2.3.6 Impact of short- and long-term planning

During this project it became evident that the policy of production planning being applied only to mining and engineering activities will have to be something of the past. The impact of mechanization on departments such as procurement and engineering construction is enormous. Some areas that were impacted were, for example, the storage capacity in the underground store for mining consumables, engineering spares, the additional diesel and lubrication requirements, as well as the increase in the construction teams to ensure that the infrastructure is in place to support the performance of the new equipment.

There must be a combined and integrated planning section between production sections and supporting sections. Currently that is not the case. By implementing this approach, the procurement department would be more efficient and provide a better service by having the materials on hand when required. That would also create more possibilities for increasing production.

5.2.3.7 Skills and development process

The training environment between conventional and mechanized mining is worlds apart. It is very important that the training personnel be experienced in mechanized mining and mining equipment. Not understanding the working dynamics of a mechanized section and not knowing how to transfer the knowledge to the operators could cause serious limitations in the success of mechanization. As far as possible, the instructor must be a specialist operator of the equipment, or have extensive experience on it, or must have received detailed training by specialists. It has been proven over the years that an operator of new equipment will learn faster from someone who already understands and is familiar with the equipment. The operator will learn by observing how the task is done, asking questions and trying the same activity under the supervision of a mentor. At the beginning of the project the mine relied on the experience of the OEM for training of the people, but as the project matured and all the operators gained more experience, the feedback from the training department was that the trust in the mine’s training officer increased to a point where the OEM’s training was stopped completely. The OEM’s training personnel were reduced gradually and in the end stopped the training completely.

In this case study it was evident that the training personnel, who consisted of a combination of various levels of employees and OEMs, were well-equipped with regard to skills and knowledge to train new operators. Willis and Ashworth (2002) stated that the employees must be trained to understand the use of the new technology and if it was done correctly, it would have a direct effect on the optimal performance of the new equipment. They also stated that the instructor had to know how to transfer the knowledge (operation and care) in respect of the new equipment to the operators to ensure success. That was exactly what happened in this case study and success was achieved.

Training and mentoring of operators in a mechanized environment are critical to success in mechanization. Willis et al. (2004) emphasized the important role that training and mentoring play in the acceptance of new technology, which is the first step to a successful implementation. Understanding the equipment's capabilities and possessing the knowledge to operate the machine to maximize its value to the benefit of an organization is where the true value lies. Value in this case is safety of people as well as profitability.

Through training and mentoring, as described in this case study, the initial support rate was 36 metres per day per section (2 x 18 metre face length) and it increased to 52 metres (2 x 26 metre face length) per day. This was achieved by having coaches dedicated to the shift, for the duration of the shift. This allowed the coaches to address operational issues at the time when problems were observed.

The fact that the operation was already semi-mechanized meant that the necessary training, skills and competencies had already been adopted and were in place. The use of additional training equipment such as simulators is a day-to-day practice that allows the operators to become more familiar with the equipment before they actually operate the machine. This early exposure to the 3-D simulators (Figure 4.11) has a tremendous impact on the confidence of the operator.

The changes that were made to the training process, as described in Chapter 4, namely to expose the new operator to a basic practical portion first, proved to be invaluable, as it made the connection between the theory and the practical side of the equipment easier for the operator. This presented an opportunity for more in-depth discussions in the training room.

5.2.4 Results and Measures

Setting up new production targets at the implementation of new technology is very complex. The tendency is to consider only what the equipment will add to the bottom line. The pitfall in this is that it does not focus on what the machine adds to the section's performance and incorrect outputs will be rewarded. For example, in this case, the production target was on the number of bolts installed and not on the required face length that was completed and ready for the next cycle. The effectiveness of the equipment improved dramatically once the focus was changed from only focusing on the performance of the equipment to also focusing on the improved mining cycle as a combined drive.

The new equipment must be part of the system and its performance must be measured as part of the complete system and not as a stand-alone unit. It must be known what impact it will have on other activities to enhance production before management sets up production targets and incentives.

At the implementation of any new technology or equipment it is very important to continuously communicate with the workers about the performance of the new equipment. This creates trust in the equipment and in management. Publicly displaying the results and having open discussions about what works and what does not work, or how the teams can move to the next level, is very important to ensure sustainability of performance. In this case study, the mine management was very frank about the performance and the problems encountered. These aspects were discussed at all the mass meetings that were held by the general manager with the work force. This paved the way for open and constructive discussions on future improvements. In the interviews with the operators, as mentioned previously in this chapter, the operators stated that they would not return to being conventional roof-bolt operators, as the new equipment enables them to grow and improve, and above all they feel safe. This has a direct impact on acceptance of the equipment and the first stage of sustainability

Macfarlane (2001) made a very important point, namely that an examination must be done of the system in which the new technology will operate, and not just on the new technology. In some cases, a benefit in one area could cause inefficiency in another, and thus the overall benefit of the new technology will not be realized.

5.2.5 Conclusion

The highlights of this study are that all the objectives that were set for the project were achieved, and that the safety improved tremendously, as people were removed from the unsupported roof area where most of the mining industry’s fatal accidents occur. This was verified by means of the interviews with the rock-drill operators who had been re-skilled to become roof-bolter operators, as they said that they felt safer in their workplace. This alone proves that this project was a successful implementation of mechanization in the mining industry.

There is always the perception from unions and workers that once mechanization is mentioned, they envisage job losses, but in this study it was not the case. All employees were accommodated - if not in the same type of position, then to a better position. The early engagement of workers in the process via the various unions played a big role in ensuring the success of the project.

Role definition is a very simple concept, and the tendency to define this to the nth-degree for all activities directly impacting on the performance of the new equipment is not a problem, but the indirect functions such as the logistics and supply departments normally do not receive the same degree of attention as the production processes, and this could cause serious flaws during implementation of new technology in the project. In this case study, a tremendous amount of time was spent on training and competency, as it should be, to ensure that all legal aspects were dealt with. As mentioned, logistics and procurement, however, were not supported in the same way, which had and will have a direct impact on the performance of the new equipment. If one should take Formula One racing as an example, the racing car is of top quality and the driver really understands how to put the car through its paces. Once the race starts and everybody pushes for good-quality performance and the best possible time, all is well until the car gets into the pits; this is where the race is won or lost. If the support function's roles are not clearly defined and they do not have the correct resources to fulfil these functions, time will be wasted and the race lost.

Two points that stood out during this case study were firstly the rate at which the operation matured with regard to acceptance of the new equipment, and secondly the time allowed for the operation to stabilize production throughout all the problems experienced. It is clear that time spent on the seat, operating the equipment, is invaluable, but the true worth of the new equipment is the result of the commitment from management to make the project work, the hard work of the engineering team to overcome the reliability obstacles, and the continuous increase in experience of the operational personnel in taking the equipment through its paces. Lastly, the support function plays an integral part in the mechanization and should therefore be regarded as part of the bigger picture.

In view of the complexity of the implementation of new technology in the mining industry, with all its legal and physical obstacles, the softer 'people issues', such as job security and feeling safe in one's work area, are the key points in attaining initial operational buy-in, but continuous success lies in the details of process and function integration, and candid communication to all.

In conclusion, top management must devote heart and soul to making the project work. Mechanization does not always mean that jobs will be lost, and maybe there will be some promotion or growth opportunities available to people. Always allow for stabilization time when setting up this type of project, do not set unrealistic production and performance targets in the initial stages of the project, ensure that the performance measurements actually measure the complete system and not just the equipment, and lastly, ensure that there is an in-depth understanding of the influence that this implementation or improvement will have on all subsystems or processes.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The objective of the project was to evaluate the process followed by Dwarsrivier Mine in converting a conventional roof-support process to a mechanized roof-support method. It is important to analyse the experience gained from this type of project and to establish guidelines or focus points that, if adhered to, will produce a better success rate for the implementation of mechanization in existing mines.

In the past there have been some attempts to make the change from conventional mining methods to mechanized operations, but with limited success. One example of such a project was the conversion of Randfontein Estate Gold Mine, which was converted back to conventional mining methods. This project was well-documented (Brown, 1995) but not all such projects were, and the lessons learnt were lost to the industry. As the demand on the mining industry increases, so does the requirement to improve and become more efficient and effective, therefore to achieve this, the need for mechanization is growing bigger and bigger. If the implementation of mechanization is done correctly, there are benefits for the health and safety of all employees and the sustainability and profitability of the company.

6.2 Conclusions

In conclusion, there were a few factors that impacted on the success of this implementation project and they are summarised as follows.

6.2.1 Impact on People

The most important driver for successful mechanization in the mining industry will be on how we ensure job security while introducing the process and this does not mean only at the mine itself but in both the mining and manufacturing industries. Dwarsrivier Mine overcame this big hurdle by making a profound decision that no one would lose his job. This, in essence, ensured that a more transparent approach could be taken to make this implementation process a success.

6.2.2 Processes and Sub-processes

All activities relating to or resulting from the new technology or equipment in all aspects of the operations must be reviewed and analysed in depth to ensure that the integration of the new equipment into an existing system is carried out smoothly. The improvements that the new equipment brings must be understood, as well as what the consequences will be in other section or departments of the organisation. This study is a clear example of where some of the sub-processes had been underestimated and undervalued, which caused a number of delays and reworks. An underestimated sub-process can be the single point of failure of mechanization in the mining industry.

6.2.3 Impact of Performance Measuring

As in most of the new implementation projects that have capital invested, the drive to get the equipment performing at the pledged production rates that were used as selling point is very important in order to ensure that a return on the investment is achieved as soon as possible. This places the emphasis on short-term performance goals, of which some could be unrealistic and unachievable, but in some cases derail the long-term strategy and sustainability of the project. This implementation project had a lifespan of three years, where the true value was achieved only in the latter part of the three years, when equipment reliability stabilised and production rates increased as a result of setting the correct long-term performance measurements, for instance measuring face length completed rather than number of bolts installed and allowing sufficient time for the operation to stabilize and mature. This is true for machine and employee. The value of setting realistic targets for the short and long term, and allowing sufficient time will yield the highest return on the investment.

6.3 Recommendations

This study showed the importance of understanding the impact on the focus areas when implementing mechanized equipment in a new or existing operational environment. The failures that occurred in this project must be seen as opportunities for growth. As there are a limited number of new ventures, the emphasis must be on understanding the dynamics of implementing new, mechanized technology in existing operations with all its operational challenges.

It is therefore recommended that when an organization embarks on a conversion-type of project as described in this case study, a holistic approach be taken, meaning that all processes must be mapped out in detail to ensure that it is clearly understood where the integration points are between processes, and that the impact and consequences of this integration are also fully transparent.

It is also recommended that the new equipment must be allowed to stabilize after implementation, and only then to pursue realistic and measurable performance targets.

6.4 Suggestions for Further Research

It is suggested that further studies be conducted to determine the magnitude of the impact that mechanization has on subsystems and processes in which this equipment is used. The following aspects should be considered:

- What will be the real cost of mechanization, if one should consider all integration aspects?
- Taking all integration activities into consideration, what will the real impact be on the implementation schedule for mechanization?

In this case study, all employees were accommodated but this will not happen in all cases, and jobs will be lost, hence the industry must find a way to up-skill affected employees to enable them to make a valuable contribution to the mechanized industry by creating jobs in that field. It is a fact that the mining industry has programmes for up-skilling personnel in the basic skills but as technology evolves, the industry must devise a plan to re-introduce the affected people to this market, otherwise the perception will remain that mechanization does not create jobs but that it destroys jobs.

The author suggests that further studies be conducted in order to determine how the manufacturing industry can counteract the job losses that occur as a result of mechanization in the mining industry.

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APPENDIX A – Research Questionnaire

This section contains two documents pertaining to the Research Questionnaire:

- The master copy of the questionnaire used. The questions are colour coded, to indicate the questions that were relevant to the five different groups of employees interviewed:
    - Operator / Artisans
    - Human resource personnel
    - Training personnel
    - Management
    - Top Management
- Examples of the two operators interviewed

APPENDIX B – GHH Roof-bolter time study

The purpose of this document is as follows:

- The GHH machine was the first mechanized machine that was used to gather information of possible drillings times under normal production conditions.
- This time study was used to compare the promised achieved targets to the actual results obtain with mine operators and in actual working conditions.
- However the machine was also monitored by the OEM during this test period.
- The results obtained were very close to the promised cycle time. ***Actual 5.3 minutes on average to the target of 5.0 minutes cycle.***

APPENDIX C – Logistics Handling Process

This process flow gives a visual interpretation of the process followed at the start of the project to deliver material to the different production sections underground.

APPENDIX D – Reviewed Logistics Handling Process

This process flow gives a visual interpretation of the reviewed process. Emphasis were on the following points during the review process:

- Reviewing the responsibilities of the different role players on the setting up of the Bill of materials.
- Reviewing the flow of these activities between the Mine overseer, Shift Boss and Miner.
- The introduction of the Control Room as integral part of the coordination of the UV operators.
- There were a number of activities identified for the UV operators and the Control Room Operator to ensure that the deliveries to the sections gets done before the material is required.

APPENDIX E – Dover Symbol “A” example

This purpose of this document is to give a better understanding of the different types of test performed for operator licensing for different types of equipment on the mine.

The following results provide guidelines for the selection and appointment:

A-symbol: A candidate has achieved an average of above 80% for each of the 5 batteries of the Dover Assessment.

The Driver/TMM Operator ***can have more than one*** (1) license type (e.g. LHD, Drill Rig, UV).

B-symbol: A candidate has achieved one or more B results per battery or an average between 64% and 79% has been achieved for each of the 5 batteries of the Dover Assessment.

The Driver/TMM operator can ***only have one*** type of license, which includes licenses for all machines within a type (e.g. Rham LHD, Aard Major LHD, GHH LHD); or

C-symbol: One or more C results per battery or an average of 63% or less has been achieved for one of the 5 batteries of the Dover Assessment. The candidate will **not be considered** for the position and/ mine operator license.

Only candidates with A and B results will be considered for TMM Operator/Driver positions.

APPENDIX F – Dover Symbol “C” example

This purpose of this document is to give a better understanding of the different types of test performed for licencing operators for different types of equipment on the mine.

The following results provide guidelines for the selection and appointment:

<u>A-symbol:</u> A candidate has achieved an average of above 80% for each of the 5 batteries of the Dover Assessment.

The Driver/TMM Operator ***can have more than one*** (1) license type (e.g. LHD, Drill Rig, UV).

<u>B-symbol:</u> A candidate has achieved one or more B results per battery or an average between 64% and 79% has been achieved for each of the 5 batteries of the Dover Assessment.

The Driver/TMM operator can ***only have one*** type of license, which includes licenses for all machines within a type (e.g. Rham LHD, Aard Major LHD, GHH LHD); or

<u>C-symbol:</u> One or more C results per battery or an average of 63% or less has been achieved for one of the 5 batteries of the Dover Assessment. The candidate will **not be considered** for the position and/ mine operator license.

Only candidates with A and B results will be considered for TMM Operator/Driver positions.