STRONG, G., TERBLANCHE, C., GÖHRE, B.J. and ANDREWS, M. A symphony of collaboration between mining and engineering. *International Platinum Conference 'Platinum Surges Ahead'*, The Southern African Institute of Mining and Metallurgy, 2006.

A symphony of collaboration between mining and engineering

G. STRONG*, C. TERBLANCHE*, B.J. GÖHRE† and M. ANDREWS†
**Modikwa Platinum Mine*
†Sandvik

Mechanized mining can be experienced as a symphony by substituting the instruments for the different machines that each perform their own function and thus have different sounds. The drill-rig is the soloist around which all the other machines must play their part in harmony. Each machine can function on its own, but productivity is achieved only when all of the machines function in a holistic manner, as the different sounds of instruments form a symphony when playing together.

To produce a symphony is to have the ability to put together all the pieces. It is the capacity to synthesize rather than to analyse. Today's managers have to apply this harmonic way of thinking to make the system of mechanized mining work. In other words each of these people must have the ability of a conductor, whose job involves corralling a diverse group of notes, instruments and performers, and producing a unified and pleasing sound. At Modikwa Mine the introduction of the MAPS (Mine Activity Performance System) has allowed management to obtain a clear view of all the activities associated with the equipment. Through synthesis the issues that hampered productivity were identified and addressed to improve production and reduce costs.

Introduction

The purpose of this paper is to share the experiences of a supplier and a customer who have achieved utilization improvements of a mechanized mining fleet by jointly analysing information garnered from the mining system. The trick was to be able to synthesize the information between mining and engineering, to view the machines as individual instruments, and to create a symphony by visualizing the activities of the machines on a single measure in MAPS. Simply put, it is not about the machines, but how they are utilized.

The analogy to illustrate the value add to labour efficiency due to mechanization would be to compare nine winch drivers and two loco personnel in a conventional system who are required to remove 2 400 m^2 of ore, with the two LHDs and one truck operator in a mechanized board and pillar section producing the same 2 400 m^2. In mechanised mining the workload of one operator has a multiplier effect on efficiency as compared with conventional mining. But if the two machines are not operating in harmony with each other, then waste and bottlenecks arise. So more can be achieved with less. Imbalances within the mining system are often the cause of failures in mechanized mining. This paper will illustrate how the 'noise' in the system created by non-harmonious processes and people can be synthesized into a symphony in which more is achieved from less.

Consecutive versus continuous cycles

In conventional mining the drilling and blasting cycle is performed after the cleaning cycle. This is done on consecutive shifts. i.e. dayshift will drill and charge the panel and blast at the end of shift. Night shift will then come in and rig up the winches to clean the panel. The cleaning must be completed on this shift, as the drilling cycle will commence in the morning. The time it takes to clean the panel is dependent on the length of the panel, stoping width, and the cleaning rate of the winch. These are consecutive cycles, and are fairly easy to manage.

When mining operations introduce mechanized equipment, they continue to think on a consecutive basis and operate around conventional mining processes - drilling, bolting, loading, and tramming are viewed as separate cycles and not as fully integrated processes in the underground mining system. In other words, for mechanized mining to succeed drilling, bolting, loading, and tramming activities should be occurring underground all the time to make the capital assets sweat. For this to happen there has to be firstly, a holistic planned total cycle in terms of which the KPIs of each individual machine and its mini-cycle are factored into the total time taken to complete a full cycle of drilling, blasting, loading, scaling, and bolting, as illustrated in Figure 1. The equipment choice should be such that the mini-cycles are of similar duration, to ensure the continuous cycling of all equipment through the total cycle. Put simply, if it takes two hours to drill an end, then it should take roughly two hours to complete each of the other cycles. Second, the availability of the equipment necessary to perform the duties has to be aligned. Little wonder, therefore, that when productivity levels are not achieved the blame is usually directed at the non-availability of the mechanized equipment during the production time of the mining cycle. But if the breakdown lasts less than an hour there is enough flexibility in the system to allow the completion of the cycle and the compliance to the plan.

In mechanized mining the challenge is to be able to plan the perfect cycle and then execute the plan. Should there be external circumstances that disrupt the plan, then

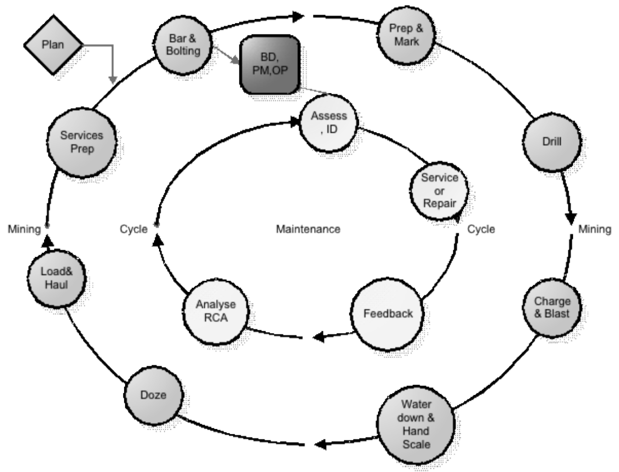

Figure 1. Continuous mechanized XLP cycle

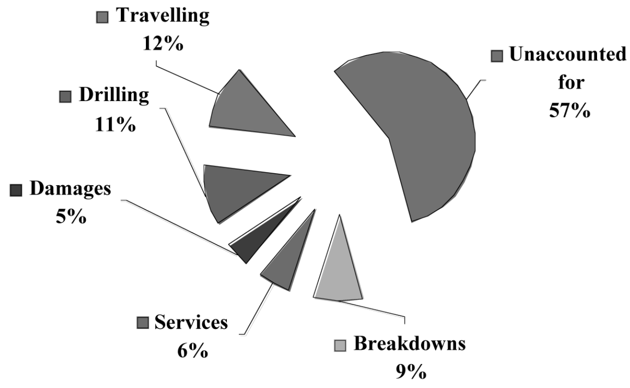

Figure 2. Perceived machine/personnel 'productivity'

contingency measures have to be available to keep all the equipment utilized. This calls for changes in the production cycle, but one still aims to execute all the different processes continuously without jeopardizing safety.

To illustrate this let's take a snapshot of the total cycle. At any one time there should be an end being drilled, another end being loaded, an end being supported, and yet another end being charged so that the planned ends are ready at blasting time. This eliminates a situation where costly machines stand idle because they cannot be operated if the end has not been prepared at the planned time because the interaction between the cycles is so interdependent. Imagine how productivity would be increased if the ends were prepared and the plan is complied with to such an extent that a drill rig will be drilling for longer periods in a shift. This will ensure that the purpose of the drill rig, which is to drill holes, is fulfilled.

The mine activity performance system (MAPS)

The description below will briefly outline the historical background associated with MAPS, together with an explanation of the system in its entirety.

The perceived problem - the missing instrument

Prior to the identification of the distinct need for mine performance measurements, a 'management by excuses' mentality was frequently encountered across a range of mines. Subjective, qualitative opinions were expressed regarding non-optimal performance which may have resulted in antagonistic relationship's, particularly between the mining and engineering departments.

The daily activities of personnel from the respective departments were often overlooked in favour of focus on the primary KPIs of metres developed and tons hoisted. Arguments might have arisen regarding the utilization and availability of the machinery when, in actual fact, the activities underground might have substantially affected these parameters. Without the introduction of clearly - defined measurements, with time attributed to each activity that was performed, it was difficult to determine the root cause of non-optimal mine productivity. This is clearly shown in Figure 2, which illustrates the basic activity measurements with a substantial component of time attributed to 'unaccounted - for time'; that is time that was not assigned to any mine activities.

Clearly little valuable information could be gleaned from the above analysis because the unaccounted - for time could have been assigned to productive activities. This once again resulted in further blame-shifting and non-productive disputes between departments and personnel.

The identified need - finding the missing instrument

The above problems clearly identified the need for a detailed measurement system to holistically measure mine activities, identify potential shortfalls using a quantitative approach, and optimize the given process for the benefit of the entire mining operation. The MAPS was therefore developed to provide integration and understanding of the shift/daily activities, which relate directly to mine productivity KPIs. The system is activity-based and utilizes 'plod sheets' to capture the activities performed by personnel underground. The system in its entirety is intended to provide measurements across a range of functions, including:

- mechanised mining personnel activities
- mechanised machinery activities
- production-cost information
- maintenance activity information.

The primary focus within this paper will be the activity measurements because the majority of mines that have requested the measurement system already have 'stand-alone' maintenance, management, and financial/costing systems.

As mentioned above, the mine activity measurement system utilizes the plod sheets to capture data relating to the functions described in Figure 3.

The end product consists of activity graphs as per the functions described in Figure 3, together with activity ratio analyses, tables for personnel and machine performance, and assessment (using a balanced scorecard approach) on a daily, weekly, and monthly frequency. Personnel and machinery are generally ranked according to their performances with the information being displayed in public for all to see.

Tailoring the product - instrument fine-tuning

No two mines are alike. One hears comments like 'my rock is harder', 'my geology is worse', 'my people are better', but never 'my machines are better'. Measurement systems need to take this into account. MAPS is flexible enough to handle this, although it requires tailoring to enable it to

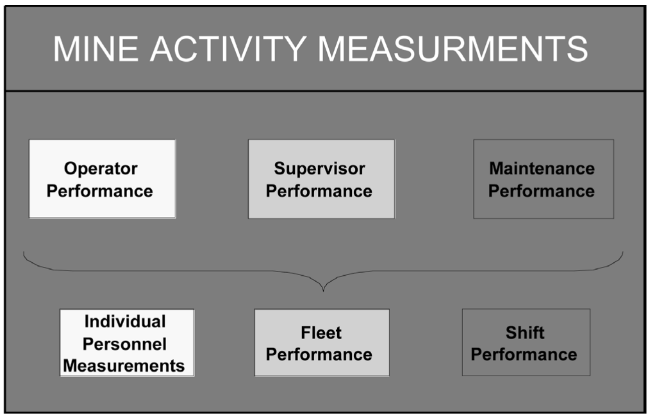

Figure 3. Mine activity performance measurements

become site-specific, depending on the required outputs for the given site. MAPS has been designed in such a manner as to allow for site-specific references (such as personnel names, mine machine numbers, mine locations etc). to be incorporated. The detailed analysis of the information captured using MAPS is then used to create action plans to improve mine productivity and reduce operational waste.

The advantages that have been experienced from the implementation of MAPS on various sites are briefly summarized below:

- the information allows management to assess groups of personnel and individuals to comprehensively evaluate personnel performance and supervision thereof
- the ranking of the personnel in terms of productivity and performance, together with the public display of these results, provides an incentive for personnel to perform more effectively, and public acknowledgement of strong performers has a compounding positive effect
- it provides personnel with the opportunity of 'voicing' their performance; historically the several lower-level operational functions may not have always had the chance to defend their efforts in terms of productivity
- each level within the operational organogram can be measured, which ensures accountability throughout the reporting function
- the results provide valuable insight and understanding, which may not have previously existed prior to the implementation of the MAPS system, into people, process, and system bottlenecks within the mining system
- the system's focused effort on machine and personnel activity, and issues relating to productivity and utilization optimization ensures that all parties are aware of productivity bottleneck incidents. A sustained improvement in productivity can therefore be achieved, as exemplified by a MAPS Jumbo drill rig project carried out on a mine in Eastern Europe as illustrated in Figure 4.

MAPS application - the final rehearsal.

It is hoped that through the implementation of MAPS, the mine will glean additional information into the product-hampering issues, resulting in more efficient and effective mine productivity. Modikwa Mine is one such example being one of the pioneers in driving the collaborative venture across the mining system, and assisting with the development, implementation, and refinement of MAPS, it has seen substantial productivity benefits. By utilizing the MAPS (together with additional comprehensive performance measurements described in further detail below), the mine has found success in identifying bottleneck activities and processes as described in Figure 5.

From the above graphs it is clear that by focusing on non-productive bottlenecks and productivity-improvement initiatives, Modikwa Mine has been able to reduce operational costs and improve productivity, to the benefit of all parties concerned.

The final performance

The manager has finally rehearsed and is happy that all the instruments are playing to his conducting. No sweeter sound exists than quality tons pouring from the mouth of the earth. And herein lies the true test. Mining at Modikwa, for example, is an around the clock operation seven days a week. There is no Friday night concert and, everyone goes to rest. The symphony continues every minute of every day or night. This symphony continues without the conductor even having to be present. Yes, there are still the 2 o'clock in the morning phone calls because of breakdowns or other delays, but the instruments have to continue performing. The orchestra members (shift supervisors, miners, artisans, belt attendants and operators) need to know what to do and when to do it. Again for the shift supervisor on night shift he needs to know at 3 am exactly what all the machines are doing, and be able to ensure that they are on track to fulfil their cycle by 5 am which is the crescendo when the shots are fired. The breakdown foreman needs to know which machines are priorities on his shift. He needs to ensure that

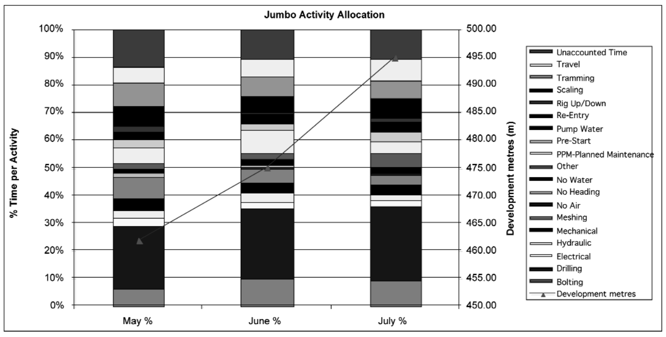

Figure 4. Activity monitoring and comparison to improve productivity

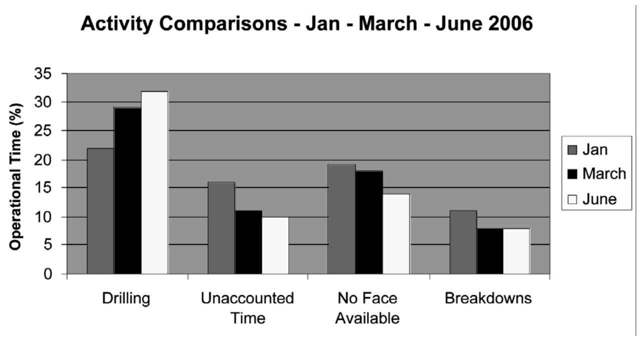

Figure 5. Drill rig monthly activity improvements

breakdowns are repaired as quickly as possible to allow the shift cycle to be completed by 5 am. The service foreman must ensure that he performs his service to a high standard; the machine must be tuned to the extent that it will perform for the longest time possible before breaking down again. Because it is inevitable that machines that have high utilization will break down, it is the whole team's responsibility that this does not happen often, and that the machine's time down is kept to a minimum.

An example of how this all fits together is the increase of productivity shown by the Trackless Mechanised Mining Method (TM3) team in the Hybrid Mining system at Modikwa Platinum Mine. The following case study will illustrate how a manager can conduct a diverse symphony on a platinum mine and add tremendous value.

Case study

Modikwa Platinum mine

The practical application of productivity improvement through managing the measurements

Introduction

When capital and operating expenditure are justified for TM3 equipment, the basis is usually of the manufacturer's stated productivity outputs.

When targets are subsequently not met the failure is blamed on either maintenance and availability, or the claim that the equipment cannot do what the manufacturer said it could. Unit costs to operate the equipment go through the roof, and executives doubt the viability of the mining method.

Although availability and maintenance play a substantial part in TM3, the issue is more about what the equipment is doing when it is available. The biggest risks to TM3 are the misalignment of people and poor design of trackless layouts. If either of these factors is amiss, the system is likely to fail!

As human beings we find it easy and somewhat comforting to externalise reasons for our inadequate performance.

'If I could only have this then I could….'

'If you give me this I will give you….'

'If only this changed, then….'

'One day….'

And the subject of this paper - 'I cannot produce because of breakdowns!'

And that is where we men of the earth, rock breakers, miners, are happy to leave it - because it is removed from us, someone else's fault, external.

If we interrogated the facts more thoroughly and objectively, we would probably (albeit unwillingly) find that apart from the breakdowns, too much time is wasted elsewhere in the cycle, which is in fact losing you more available hours than those breakdowns.

A simple example is thus:

- It takes 3 percussion hours to drill a 5.0 m - 5.0 m development heading with a 3.8 m long round.
- The actual advance on that heading is 3.3 m.
- You have therefore achieved a rate of advance of 1.1 m per percussion hour.
- During the month you have blasted 50 of these rounds for an effective total advance of 165 m.
- Shift time per day is 15 hours, and there are 30 days in a month, providing 450 shift hours per month.
- You have therefore drilled (based on 1.1m per percussion hour) for 150 hours.
- Assuming a very bad shift availability of 70% would imply that the machine was down for 135 hours. This leaves 165 hours unaccounted - for!
- By increasing average advance per blast to 3.5 m (on a 3.8 m round), you increase to 1.17m advanced per percussion hour, and therefore now require the machine for 141 hours for exactly the same output.
- Alternatively you could achieve 176 m with the same hours.

There is still the question of the 165 hours that are unaccounted for. This would obviously include such things as travelling and set-up time. But how much of it is waiting for a face to be marked or pumped, a traffic jam or an operator's power nap? What would you rather your line focus on the breakdowns or the advance per blast and the unaccounted - for time? They would unanimously probably prefer the breakdowns, because that is external. The other two are internal, and require them to carry out specific actions.

Before you get sidelined by the breakdown 'red herring', check the facts!

A need for change

At the end of 2004 the mine was breaking an average of 670 large end metres per month, and tramming with large LHDs and ADTs an average of 191 000 tons per month. Even getting these outputs was a struggle. Maintenance was outsourced to the equipment supplier, and breakdowns were considered to be excessively high. There was an overwhelming 'blame culture' which had all ended up firmly on the maintenance contractor. This was primarily attributable to the management structure at the time, which allowed for externalization of problems. Facts were seldom sought unless the managers had the intention of passing blame to the maintenance function.

Figure 6 indicates this structural problem graphically.

At the start of 2005 this structure was changed to one where the total accountability for trackless mining (production and maintenance) fell under one responsibility (Figure 7). For the first time the interests of both parties were under the same roof. Externalizing at this point would

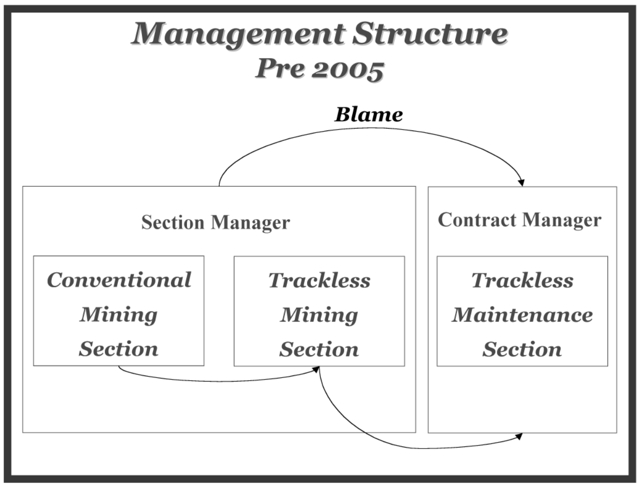

Figure 6.

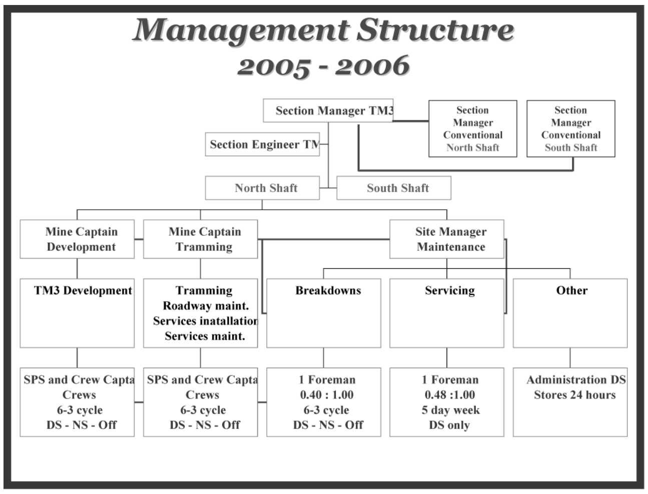

Figure 7.

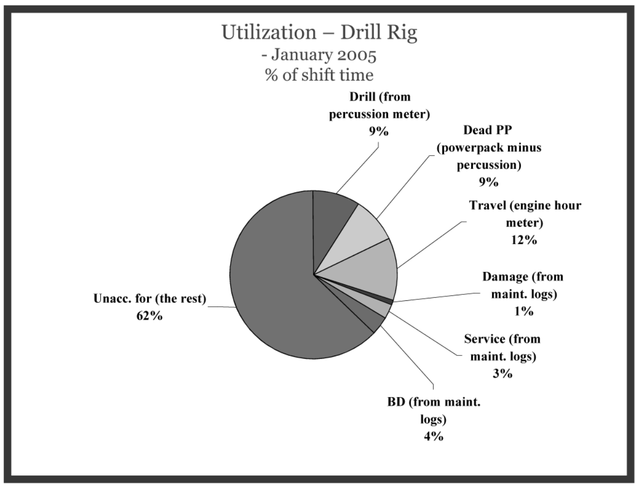

Figure 8.

have been even more counter-productive and would probably have resulted in a dysfunctional split within the section.

The dilemma for the people who had to manage this new organization was what they should do differently. To define this more facts were needed. A process of analysing available information followed.

Fact-finding

All available records were collected and collated, with interesting results.

As an example Figure 8 is a chart showing what was occurring with the drill rigs during available shift time in January 2005.

From the chart:

- total shift time is 15 hours per day
- drilling time is based on the percussion hour meter and implies that the rig was drilling
- dead power pack time is the difference between power pack hours and percussion hours, and implies that the power pack was running but no drilling was taking place
- travelling time is based on the engine hour meter, and implies that the engine was on and that the rig was in the process of travelling
- damage time is the time logged at the control room to repair damage during shift time
- breakdown time is the time logged at the control room to repair breakdowns during shift time
- service time is the time logged that the machine was in for service during shift time.

It can therefore be deduced that:

- the rigs were spending more time travelling than drilling
- the rigs spent only half of the time that the power pack was running actually drilling
- time spent on maintenance was relatively small
- unaccounted - for time (the time spent in traffic jams, waiting for faces to be pumped or marked etc.) was significant!

These charts made it apparent that there were more important things to focus on than breakdowns and maintenance.

Why measure?

In the context of this case study, measurements were made to get the facts and define accountability based on those facts. Now the Mine Captain had something to answer for. What was happening in the unaccounted time, which is almost eight times that of breakdown and maintenance time? (This in no way detracts from the need to manage breakdowns and the maintenance contract, which are essentially also a Mine Captain's functions).

One of the problems with such measurements is the difficulty of getting line managers to accept their implications. Comfort zones are removed! The benefits of sticking with the MAPS process however, are substantial.

Figure 9 shows the ongoing measurement of the same parameters (now shown in a 100% stacked column chart for easier comparison) that were measured in January 2005. (Figure 8). The trends are evident.

From figure 10 it can clearly be seen that time spent travelling was too high relative to drilling time for a while, but has improved. Unaccounted - for time (red) has reduced, and maintenance - related time (the blue shades) has remained fairly constant over the 19 months.

The improvement in utilization has clearly come from the conversion of unaccounted - for time to productive time.

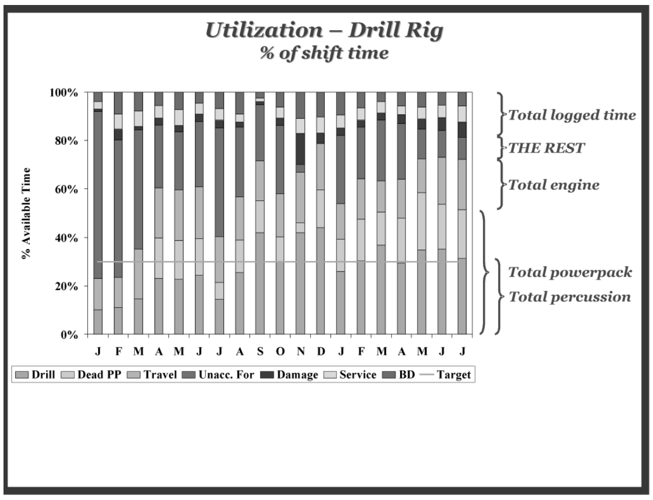

Figure 9.

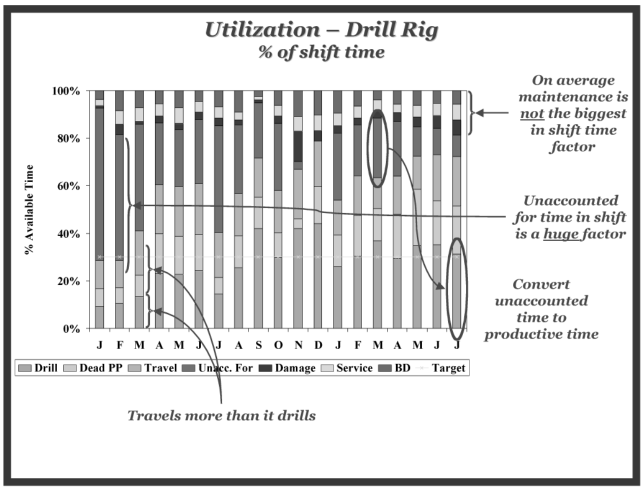

Figure 10.

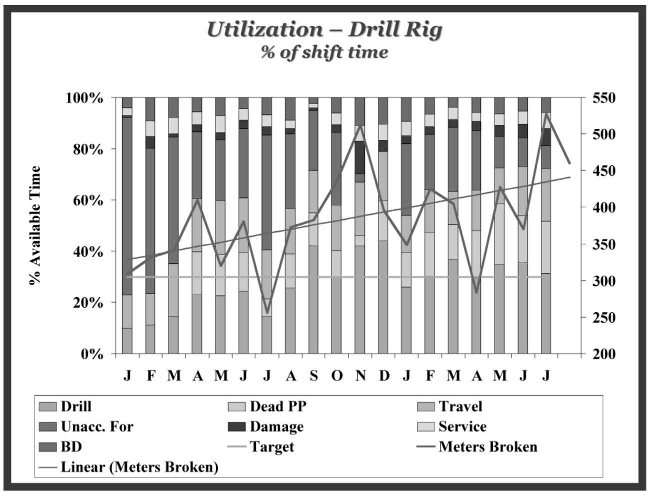

Figure 11.

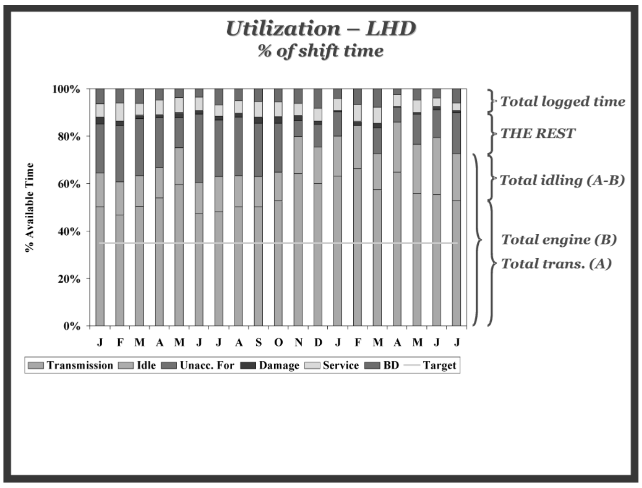

Figure 12.

Plotting meter output on the same graph (Figure 11) indicates that production output improvements are directly related to a reduction in unaccounted - for time and not an improvement in available time.

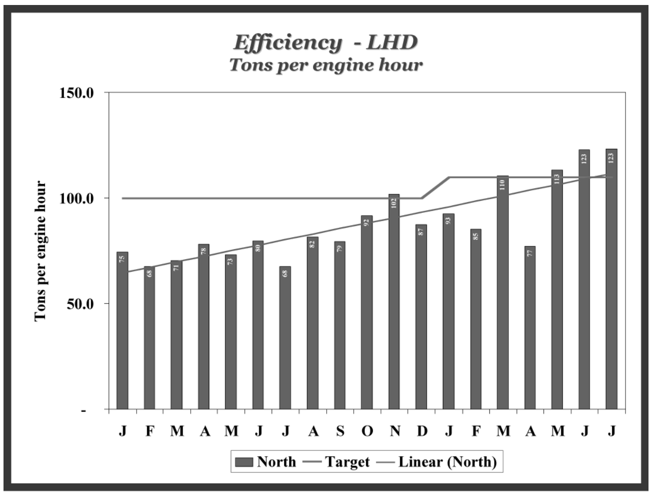

Figure 13.

Using the same principles, charts can be drawn for any type of machine. Figure 12 shows the same type of chart for an LHD.

What should be measured?

When measuring:

- Avoid anything that is not absolute. For example use LHD tons per engine hour rather than LHD tons per shift hour. The latter measures shift effectiveness, but figure 12 already tells you what is happening during the shift. LHDs have engine hour meters, and mines have intricate systems in place to measure tonnage. At a high level total tons produced by a production unit divided by total LHD engine hours for all LHDs in that production unit equals tons loaded per engine hour. Figure 13 is an example.
- Measure to remove fog and background noise that sometimes conceal the truth. Mean Time Before Failure (MTBF) is a measurement often used to show the effectiveness (or ineffectiveness) of maintenance. The problem is that it is usually measured as Shift MTBF. This is clouded by the fact that machines do not necessarily work the whole shift . MTBF measured per operating hour is a far more indicative measure of how

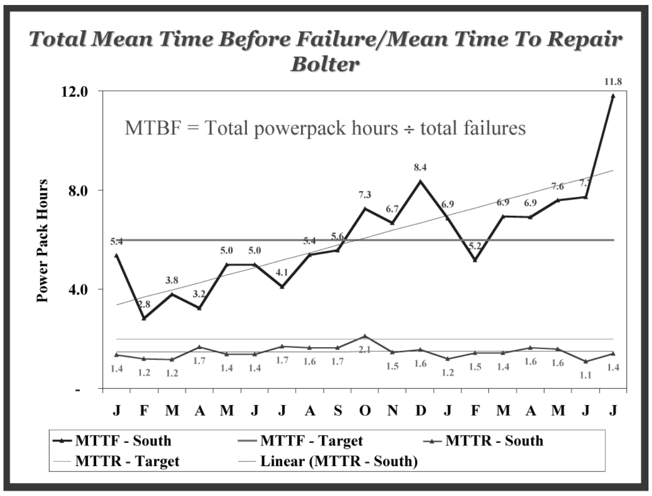

Figure 14.

long a machine is working before it breaks down. Total LHD engine hours worked divided by the number of failures equals how long the machine actually operated between failures. Likewise total percussion hours divided by total failiures equals operating MTBF for drill rigs.

Figure 14 shows an example of Total Operating MTBF for bolters. Note the upward trend.

- Measure to assign accountability to the correct place. For example assigning the entire Operating MTBF (Figure 14) to the maintenance function is not entirely fair, as some failures are the result of damage caused during operation. Ultimately damage is the responsibility of the line function on the maintenance function. To define the accountability for each function with regard to Operating MTBF, two different Operating MTBFs are measured, namely Damages MTBF and Breakdown MTBF. Figures 15 and 16 show these measurements for drill rigs.

Figure 17 represents the two combined and is referred to as Total MTBF. Note all are based on operating percussion hours and not shift hours.

- Measure whatever the drivers are at a high level (e.g. total tons loaded per total LHD hour), at the lowest line level possible. If tons per engine hour are important, then supervisors on the faces need to be measuring them at least at the end of every shift. They therefore need to be reconciling data from shift checklists completed by the operators, at the end of every shift. But this is done per LHD, ADT drill rig etc. on an individual basis. The calculations are fairly simple when laid out in a standard format. If that supervisor does not know at the end of each shift how he has contributed to high-level KPIs then he is probably not doing much, and those KPIs will probably not be met.
- Use trending to indicate progress. At a high level, month-on-month figures may not be relevant, but the trend over longer periods is relevant. Figure 18 shows damage cost over a period of 32 months. The important aspect of the graph is that the trend is downward. You will notice too that seasonality seems to be an issue. It may be related to the fact that in Sekhukuneland it is difficult to sleep in a non air-conditioned room during the day (or night) in the middle of summer. The measurement and subsequent trending indicated that

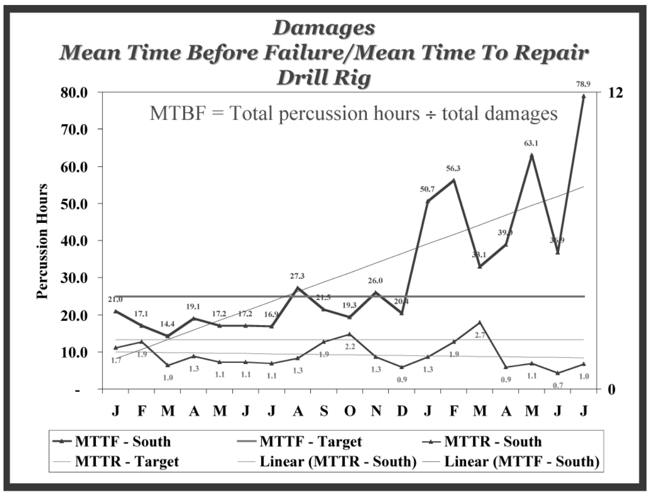

Figure 15.

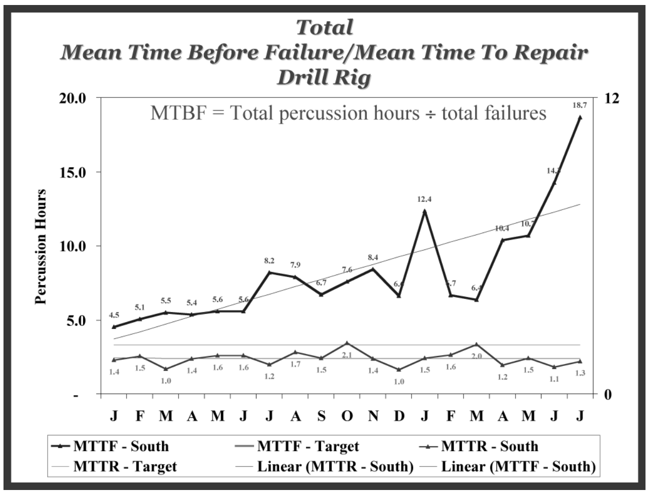

Figure 17.

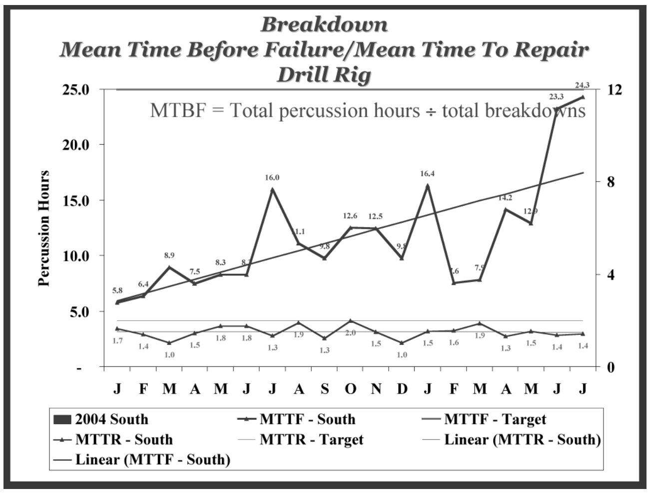

Figure 16.

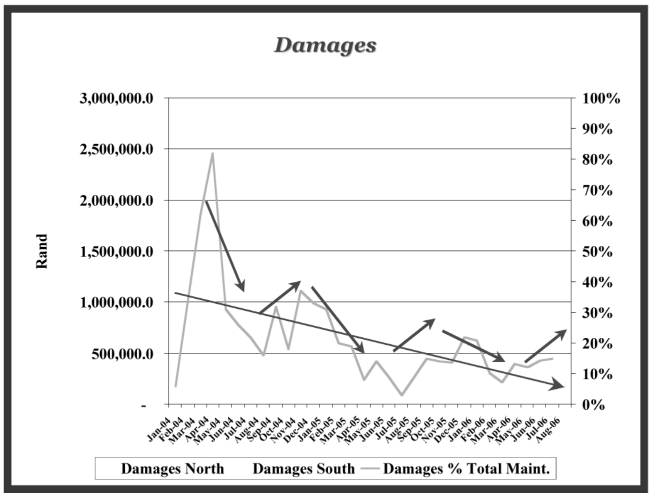

Figure 18.

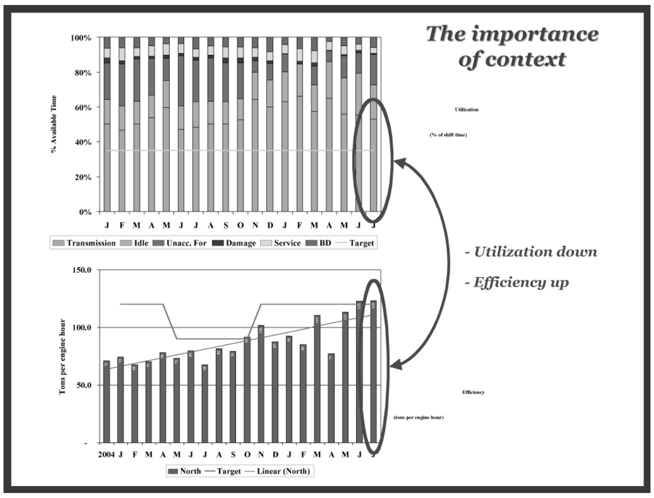

Figure 19.

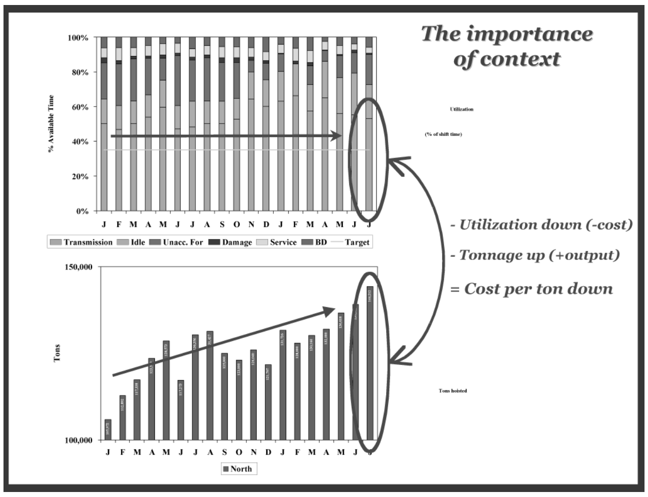

Figure 21.

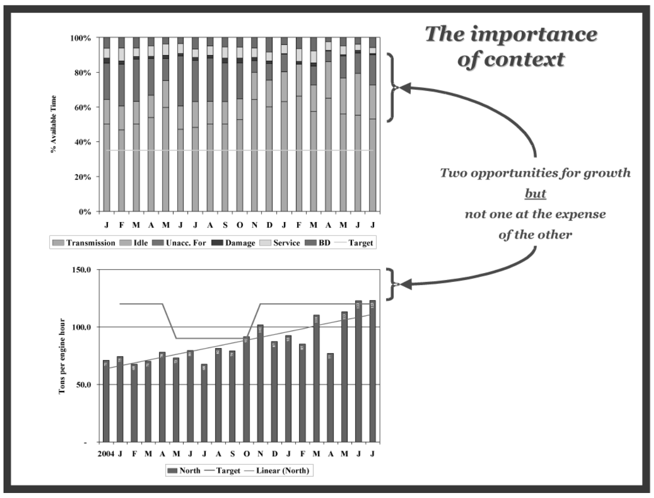

Figure 20.

the seasonal trends point towards a possible need to address fatigue in operators.

The importance of context

Recording so many different measurements can result in confusion, but it is important to look at different measurements within the context of one another. Looking at utilization in the context of efficiency, for example:

- Figure 19 shows both the utilization and the efficiency charts. It is clear that there is an improvement in efficiency, but no real improvement in utilization.
- There is opportunity for growth in both utilization and efficiency (Figure 20), but beware of improving utilization at the expense of efficiency-the unit cost will increase accordingly!
- Replacing the efficiency chart with the chart showing actual tons loaded (Figure 21) shows that despite the flat utilization trend, tonnage output has increased significantly owing to the improvement in efficiency. This result is that the costs of operating that equipment are reduced.

The result

With exactly the same equipment and personnel the mine has achieved an average of 880 m and 269 000 tons per month for 2006. The record in a single month is 1 090 m, (Compared with 822 m in 2004 and 950 m in 2005)! Without the facts gleaned from the numerous measurements the situation would not have improved much. In fact we would probably have recruited loco and rock drill operators by now!

Conclusion

Trackless mining is neither about what it costs to purchase the equipment nor what it costs to operate it. It is about getting what you have purchased to perform at levels that justify its unit cost. The challenge is therefore to put the equipment to work within systems that suit it, and to align the people who operate it with what the fundamental issues are.

That equipment must be allowed to sweat! To do this we need to take a holistic view on what the equipment is doing during every available shift hour, and identify where the accountability for non-performance really lies. By measuring the correct things for the right reasons we can significantly improved productivity.

Reference

PINK, D. A whole new mind