Identification of key performance areas and indicators in the southern African underground coal mining delivery environment

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Abstract

The global resources and commodities market has become highly competitive. While southern Africa’s abundance of minerals resources is still unrivalled, the region has lost its dominance in terms of production. The sustainability of southern Africa’s mining industry is increasingly becoming dependent on its ability to manage the performance of its operations well. A valuable tool for monitoring and managing performance is the use of key performance areas (KPAs) – which are those areas of performance that are reflected explicitly or implicitly in the vision and strategies of an organization and reflect its critical success factors. This paper reviews the KPAs in the southern African mining delivery environment. The KPAs discussed in this paper have been identified by comparing KPAs of several mining houses engaged in mining operations in southern Africa and extracting those that are common to most of them. Although the authors support the view that each organization should develop KPAs to specifically fit its needs, the study reveals that five KPAs – safety and health, costs, product quality, morale and delivery should form a default list that covers the key areas that any organization should consider when choosing KPAs. KPAs exist for performance management. Key Performance Indicators (KPIs) exist for performance measurement.
KPIs are those controllable areas of KPAs that can be measured and here various KPIs require control namely: Cutting Time, Away Time, Downtime of various categories, Travelling Time and others that have been identified internationally.
Keywords: key performance areas, delivery, performance measurement, key performance indicators, safety, morale, leadership, fleet management

Introduction

The sustainability of southern Africa’s mining industry is increasingly becoming dependent on its ability to manage the performance of its operations well. A valuable tool to monitor and manage performance is the use of key performance areas. ‘Key Performance Areas (KPAs) are those areas of performance that are reflected explicitly or implicitly in the vision and strategies of the organization’ (Barker 1997). The terms KPA and KPI (key performance indicator) are often used interchangeably – whether correctly or erroneously is debatable. ‘Key Performance Indicators are quantifiable measurements, agreed to beforehand, that reflect the critical success factors of an organization’ (O’Neill, 2007). Each KPA probably has multiple KPIs associated with it. The state of implementation of that KPI will determine where the organization is measured. Mostly, an aggregation of all the KPIs for a particular KPA determines the final KPA measurement and status.

KPAs exist for performance management. Key Performance Indicators (KPIs) exist for performance measurement. The common focus of mining operations has been on measuring performance in order to control and monitor people. Although this is an important reason for measuring performance, the primary reason – and therefore the focus for any performance measurement system – should be to learn about current performance and inform management on how to improve on it. Another reason for collecting performance measurements is to inform external stakeholders and to comply with external reporting regulations and information requests (Marr, 2014).

Many things in a mining operation can be measured, although this does not make them key to the organization's success. Measurements should be limited to those quantifiable factors that reflect the organizational goals and are essential to the organization reaching its goals. It is also important to keep the number of performance measures low, simply to keep everyone's attention focused on achieving the same goals.

Developing key performance areas

The authors support the view that each organization should develop KPAs that fit its needs. These may be a direct extract from vision statements if these have been recently developed or re-validated. It sometimes helps to agree on a long-term objective for each KPA – a sort of a mini-vision statement. For each KPA, three to five KPIs (specific measures) can then be identified. This is usually done by the senior management team. It typically takes several sessions to settle on a final list. After generating some candidate KPIs for each KPA, the senior team members will typically take these around to their teams and/or convene cross-functional breakout sessions to review the list, add to it, and select the most appropriate set of KPIs. This improves the quality of the resulting measures and also increases buy-in. (Dougall & Mmola, 2014)

Case studies

The KPAs and KPIs discussed in this paper have been selected by comparing KPAs of several mining houses engaged in underground coal mining operations in southern Africa, and then identifying those that are common to most of them.
This researcher has traditionally looked at the process through that which is applied by leading mining houses in South Africa such as Anglo American, BHP Billiton, Kumba and Exxaro.

Coal is no different but here the case studies are derived from nine underground operators and the learnings are reviewed in this paper as sourced originally with the University of the Witwatersrand based research supervised by Prof Huw Phillips “A Review of the Current and Expected Underground Coal Mining Methods and Profiles and an Evaluation of the Best Practices Associated With These”. A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements of the degree of Master of Science in Engineering (Dougall, 2010).

The hypothesis that KPAs and associated KPIs lead to increased optimization of the mining process was tested and the concept experimentally applied through the Morupule Colliery Limited, Botswana case study. This researcher was the Competent Person, Reserves for the Morupule Expansion Project and advisor for mine productivity optimization to the Project team. The KPIs developed in conjunction with nine South African operations have been applied and tested with positive returns at the Botswanan operation.

Most managers and companies identify critical control areas, or key performance areas which enable them when measured to ensure that the performance is achieving objectives (collaborated by research findings from data collected during 2007, 2008, 2009 2010 2014 and 2015). Due to the abstract nature they are referred as soft issues or systems. They may be expressed as standard operating procedures (SOPs) developed to achieve a key performance standard or may take the form of guideline steps or keys to ensure the objective is reached.

Data collection and interpretation for identifying the SOPs and the conceptualisation of the idea they embrace was complemented through personal communication and reports of line managers in the Sasol Mining team namely Jordaan, Scheepers, Steynberg, Leibrandt and Streuders and mine managers, subordinate managers and engineers of collieries benchmarked, namely Khutala, Matla, Douglas, Forzando, Gloria, Goedehoop, Bank, Arnot, Phoenix, Brandspruit, Bossjesspruit, Middelbult, Twistdraai and Syferfontein (Scheepers et al, 2000). This set of data and report Scheepers et al (2000) was made available to this researcher by a General Manager of Sasol Mining, Secunda Collieries, (Mr Pierre Jordaan, and was complemented by interview and personal communication.)

As has been mentioned, a mine in Botswana was used as a case study by this researcher for many of the concepts discussed in this research. But this is still a growing or learning organisation and some of the concepts are not perfected in application by them at the time of this research. They were however used as a target subject, by this researcher, to implement ideas and over time monitor results. This is done by Competent Persons review and Technical Reports. The latest input was the study and review to deliver the document Competent Person’s Advisory Report – Production Optimization (Dougall, January 2015) in which certain KPIs implementation has been fine tuned.

KPAs: QCDSM

A system identified by a world class achiever, in the sample population, Sasol Mining, controls Quality, Cost, Delivery, Safety and Morale (QCDSM) as measuring instruments for performance (Scheepers et al, 2000) These are deemed by this author to be KPAs and not KPIs. KPIs can be derived for each KPA. These aspects (QCDSM) were used as guidelines to evaluate the performance of the identified mines. The mines studied were selected because of their acknowledged achievements and status in the coal industry in South Africa. These mines were considered by their peers as being top performers.

The mines focus on getting things done right and on doing the right things. Most have accepted a culture of ensuring that it gets done right the first time (Quality Management). This requires that objectives are clearly set by both, the supplier and the user, of the service or product developed. They need to establish by consensus what needs to be done by whom and by when. It may involve a complicated and sophisticated formal planning process in certain instances such as the 7 steps of planning and annual planning cycles for the development of budgets and 12 month plans including medium term or 5 year plans often for the life of mine. Mines need to ensure they meet market demand at the correct product specification which normally includes not only volumes or masses to be delivered but also includes limiting or quality criteria. In coal the proximates and the ultimate elements or constituents of the coal rock (which is a fuel mineral, made up of lithotypes for example vitrain and macerals for example vitrainite) is placed under the spot light. This often requires declaring a reserve from a resource. This may not be achieved without laying a detailed capital and operating plan to that resource and determining or budgeting what the potential income statement and balance sheet for a business cycle implies.

Volumes are often seen as the prime deliverable to customers and quality will involve the type of coal, the rank of coal and often its grade or purity (Ash Content) or potential chemical energy value (Calorific Value). Its application or use is critical and the dilution (such as moisture content) or problematic qualities (abrasiveness) need to be controlled. Another such a problem creator is fine coal for example.

The following KPIs, reduction of fine coal volumes and horizon control impact on the KPAs Quality, Costs and Delivery.

KPI: Reduction of fine coal volumes

One of the key performance indicators that some mines focus on, is the reduction of ***Fine Coal Volumes***. Fines are generated in the cutting and transportation process and often the amount of fines because of the contamination threat is strictly controlled, even if the final user grinds the delivery to fine grading for injection into boilers” Scheepers et al (2000). It is in fines were greater moisture dilution has potential to reside including impurities that contribute to abrasiveness and increases beneficiation costs when effort is made to bring the fines to specification. It is therefore essential to control fines, for certain operations to be a success.

Some mines controlled it indirectly by evaluating pick spacing’s, this was done by Gloria (Scheepers et al, 2000). It is understood that one of the factors that contribute to fine coal is related to cutter pick efficiencies. Blunt picks or inefficient picks will require more grinding of the cutter head on the face to remove a required amount of coal and in the process would generate more fines. Eskom the South African power utility generally is adverse to fines owing to higher than expected contamination levels (of abrasive constituents and moisture) and are also more expensive to beneficiate to a suitable quality.

“Phoenix Colliery also focused on the fine fraction. According to the mine manager, the Duiker group has done a lot of work to ensure the sizing of their product for the various markets. It was found that conventional (blasting) methods resulted in higher fines percentages but delivered a better spread over the various product sizes (Scheepers et al, 2000)”. In the experience of this researcher the more mechanised the process the more likely the propensity to generate fines. When doing blasting the calculation of a suitable powder factor input to create a suitable muckpile is essential and may require some modelling and blast design to enable this. “Sweeping is an important activity in the control of fines as coal lying on the roadways is prone to trampling and accordingly crushed fine and received in this state when eventually swept and delivered. A number of sections had dedicated LHDs Scheepers et al (2000). The LHDs should be deployed in the cleaning of loose coal in roadways thus preventing the trampling potential when the coal is left to lie around as batch haulage units and the LHD itself will have an impact on fines generation).

The measures implemented to reduce fines included investigations into: pick spacing and lacing; drum design; cutting operations; chute and bunker design; conveyor design (speeds and transfer mechanisms); rehandling or double handling of coal; trampling on coal; and section housekeeping. Often these investigations provide some solution but generally the problem perpetuates and coal will or did produce fines. The need to reduce the formation of fines is essential and may be seen as a size specification and therefore impacts on quality of the product if outside the tolerance level. Many users will accept a fines concentration of up to 15% by mass but will penalise the supplier if this level is exceeded. The astute producer, however, will blend in fines which normally stockpiles when screened out to ensure the level of dispatch to the customer is at 15%. The fines stockpiles in total, in South Africa alone, are many millions of tonnes in mass.

KPI: Horizon control

The quality is pre-empted through prospect drilling of cored boreholes and sampling the core for laboratory analysis. A preferred horizon is determined if the whole seam is not taken this is referred to as a selective horizon. The controls apart from effective sampling of boreholes are orientated around the horizon control techniques applied by the operator. This was addressed by most of the collieries investigated.

Goedehoop Mines selectively mine up to 4.5m high, leaving the poorer quality roof and floor coal. This is a similar approach at Morupule Colliery in Botswana. Floor strata may be too weak to carry the heavy CM and the coal strength provides better resistance. Morupule (MCL) leaves 1m of coal in the floor to even out undulations and hence avoid contamination from low strength floor lithotypes (rock layers). The CM will cut a 4.2m channel to attain a selective quality extraction that is optimum for the 8m seam height. The 2 to 3m poorer quality coal is left as roof, isolating the mudstones found outside the coal channel in the roof, which displays poor strength and quick weathering characteristics. At Sigma Colliery in the Number 3 seam this was essential as the roof strata was composed of carbonaceous shale and needed to be sealed by a layer of at least 0.5m of coal to enable support integrity to be maintained. Only resin grouting could be used on the rebar rockbolt as an expanding or mechanical shell would allow weathering of the shale, the quick deterioration of roof conditions and the consequent roof falls that resulted.

Drilling by means of hand drills into the roof until the shale or sandstone is exposed and similarly, into the floor helps the operator determine at what horizon he is instantaneously positioned in the coal seam. The operator can determine how far he is from the coal roof limit by measuring the depth of the drill hole. He should be able to determine the limit by the change of duff or drillings colour when the rock changes from coal to other sediment or type of rock.

“At Douglas a plan in section was used profiling the coal seam. This gives a clear picture of the thickness of coal that is to be left in the roof for quality control. The thickness of the roof coal is controlled by drilling holes in the intersections to allow the measuring of and determining horizon position. Gloria controlled contamination by examination of the floor cut. The section ganger measured the floor cut of the previous shift and recorded it.

Quality may be controlled during data modelling in the scheduling phase allowing the determination of the optimum selective horizon within thicker seams.” (Scheepers et al, 2000).

On some mines use of the electronic assistance equipment such as the Joy’s JNA (Joy Network Analyser) were not applied to control horizon. Where this is available it should be effectively utilized.

“In general, the mines who were mining selectively managed to control the Quality by staying within the range by either following markers, by drilling and determining roof coal thickness or by reduced cutting distances to allow better control by the operator” Scheepers et al (2000).

Quality influences the price attained for the delivery. Generally a broad spectrum of proximate parameters are controlled, generally on an air-dry (ad uc) (air-dry uncontaminated) basis as opposed to as received. Penalties may be incorporated if specifications are not met to specific tolerances having cost implications for the supplier. The supplier’s reputation is also at stake.

“Middelburg Mines use a system on their Surface Mining Operation known as CAVITY focused around product specification on qualities and the relative acceptance or rejection by the customer (Calorific value; Ash; Volatile matter; Index of abrasivity; Total moisture; and Yield). They also use the A to G Principle to ensure they mine the correct quality and do not contaminate it afterwards (Area; Barrels; Contaminating triangles; Distance; Edge; Flow; and Geological factors). Both ‘CAVITY’ and the ‘A to G’ are “aid to memory” acronyms to help reduce abrasiveness and contamination, hence control quality”. (Dougall & Mmola, 2014)

KPI: Pit Head Costs

It is important to appreciate that which makes up the pithead cost and may be viewed as having a cash cost component for which there is cash flow required, to non cash cost component which are recorded against asset depletion such as amortisation for example (non cash costs).

Mining costs may be the costs of the mining department only and on activity based costing (ABC) structures the cost of exploiting the coal and delivering it to the point where another department such as the Engineering & Maintenance Department may take over. Until they once again transfer it to the Inventory or Stores Department if on a neutral stockpile or blending yard the subsequent transfer to Metallurgical or Coal Preparation Department. Each of the departments will have their own cost which must be accounted for in the determination of the value added to the coal as it moves down the line. Costs are often seen as variable or fixed and may be direct or overhead (indirect).

Cash costs are costs of purchasing equipment and operating materials including labour but exclude non cash costs such as depreciation. Mine mouth costs are cash costs for RoM delivery and exclude beneficiation and selling costs.

“Certain mines benefit from softer coal. This reduces machine maintenance and increases overhaul periods. Sasol maintain an interval of 2 years or 2Mt however Morupule plan to stretch this to 4 years or 4Mt. The differences lie in the relative hardness of the seams” In the Morupule case study it is evident that the softer coal or the absence of abrasive lenses (sandstone lenses), greatly enhances the pick life and overhaul intervals of equipment. This reduces mining consumable costs and hence benefits the production of cheaper coal. Often the maintenance costs are also reduced as there is less fatigue on the CM or coal winning machine. (Dougall, 2009)

KPI: Maintenance Cost

Maintenance costs are a major contributor to mining costs. Costs will by their very nature be the target and focus of managerial control. The maintenance on the section equipment was also only done once a month in mines with softer coal compared to bi-monthly maintenance on those with relatively hard coal. It was evident that the softer coal contributed positively to the cost of maintenance, especially in the case of continuous miners.

Certain operators use the OEM (original equipment manufacturer) to do maintenance. Matla do machine overhauls at the central workshops on the mine. It has been perfected to the stage that some of the other mines actually consider a machine overhaul with Matla instead of the OEM” (Scheepers et al, 2000).

KPI: Labour cost

Many mines opt for different organisational structures the trend is to become flatter and leaner. The drive is to ensure maximum output for minimum input. Khutala and Matla are most probably the leaders regarding labour productivity. Both mines produce some 14Mtpa. Khutala employ 1,441 employees, and Matla 1,640. “At Khutala a mine manager, for each seam, manages the two seams. The typical structure for a seam will be a mine manager with two mine overseers and an engineer reporting to him. Some 700,000tpm is produced from a seam. This means that a mine overseer is responsible for producing some 350,000tpm. The mine overseer is also responsible for infrastructure in his area of responsibility which includes road building, conveyors, water pumping. Six shift overseers, two of which are responsible for the outbye area, are allocated. A shift overseer is responsible for three production sections on his shift. On the engineering side, five foremen manage the seam, four being responsible for the production sections and work shifts. There are also a further three chief foremen. To be able to look after such a wide area with such a small team, delegation down to miner and artisan level is vital.

At Matla the system is more or less similar. The mine is divided into three mines, operated individually by a mine manager each. A general manager overlooks the operations. A mine manager, production manager and engineer manage each mine. Section superintendents look after two sections each, with two foremen and shift overseers. The Engineer has a superintendent reporting to him, together with five foremen, and they look after all the services and the boiler shop, transport, mechanical and electrical departments. Inbye the section the crew consist of the miner, electrician, fitter, aid, two CM operators, three shuttle car operators, two roofbolt operators, four multi skilled operators and 0.5 scoop drivers” (Scheepers et al, 2000). The Scheepers team reported that “Most collieries have in-section structures of more or less similar composition. The mines, not only had lean in section structures, but also lean management structures. Use of a small number of people on the services and infrastructure was notable on the better performers. None of the mines had a manager with an engineer looking after the services. In almost all cases the manager responsible for the production in an area, would be responsible for the services of that area. This was achieved by delegating this duty to the mine overseer responsible for the production in that area, or to another mine overseer reporting to the responsible manager. Geographic area would be a major variable in this comparison. The mines that mined multiple seams had an even greater advantage in this instance. Some mines were geographically extensive (Scheepers et al, 2000).

Many mines made use of contractors for the building of walls and moving of stonedust barriers. In some cases contractors were also used to do belt extensions.

A major opportunity exists for certain operators to reduce cost dramatically if they restructure and increase productivity levels to levels observed at Matla, Khutala and Syferfontein (underground). The need is to reduce large number of service labour to essentials and increase multi-skilling productivities. Scheepers et al (2000) states, “Multi skilling becomes essential as section labour numbers are reduced as the people could perform any function trained for in the absence of a colleague. Without such a system it becomes necessary to build in excess to cater for unforeseen circumstances” (Scheepers et al, 2000).

KPI: Operational cost

Operational costs will be the major determinant of the profitability of the mine in the long run. “Picks and roof support make up the major portion of operational cost. Although operational cost contributes to the total cost to a lesser extent, it must not be overlooked. Douglas, Khutala, Matla, Goedehoop, and Forzando are all mines that get some 90t per pick on a 30mm shank pick. Arnot gets around 20 while Bank and Gloria get 24 and 45t per pick respectively. The higher tonnes per pick for the collieries that are in the 90 range and result in much lower expenditure on this item and increased production time. It was also evident that these collieries had to do less maintenance on their continuous miners and was able to get a higher tonnage from machines before overhauls. Sasol Coal on average achieved much less tonnage per pick. Bossjesspruit, Twistdraai and the export mines all process higher pick costs” Scheepers et al (2000). Scheepers et al (2000) concludes, “In general most of the mines visited have good roof conditions requiring normal support density. The support installed under normal conditions was in the range, four bolts per row spaced at 1.5m. A number of the mines used mechanical anchoring bolts and in many cases 16mm bolts were used” (Dougall, 2010).

KPI: Tonnes per shift

Delivery is the ability to meet the required production from the section. It is the volumes or tonnages that need to be produced to contribute to the demand satisfaction. None of the mines visited are doing any pillar extraction. Arnot and Matla each had a shortwall operation. Goedehoop is investigating the start of stooping operations.

At Khutala the production is around 1,806t/shift (tonnes per shift) for an ABM30 with Stamler battery haulers. The best sections produce some 80,000tpm (tonnes per month) on average. The shuttle car section produced 1,400t/shift. This was for the No.4 Seam operations” (Scheepers et al, 2000). The No.2 Seam operations resulted is a substantial drop in production and increased costs as a result of tougher mining conditions. Shift cycles and duration as is the number of shifts per week influence deliveries. It is desirable to effectively utilise capital equipment and a 24 hour, 7 day per week objective is ideal but people are involved and need consideration. Maintenance is required and sections require relocations or belt extensions and need to be stone dusted. Equipment needs to be stopped to ensure maintenance. This leads to the debate to the optimum shift cycle and duration. It should be noted that best practice performance is often attained by the two shift and utilised “off shift” cycle as opposed to the three shift cycle. It is important to note that a 5 day week, two-shift operation is used at Khutala. No overtime is worked. Maintenance is done on the day shift.

At Matla, two sections produce 1.1Mtpa each and one more than 1.2Mtpa. The monthly record production for a shuttle car section is some 141,000tpm. Average production per section is in the region of 80,000tpm. Maintenance is done on the night shift. Strict overtime control is followed. The ‘coal recovery system’ whereby money is paid into pool for tonnes mined during the weekend is used, and people that produce that coal, share equally. No money is paid if no production takes place. Gloria worked a five day, two shift operation. Production average is in the region of 66,000tpm per section. Some sections produced up to 80,000tpm but others only 35,000tpm. The seam is high, but a lot of dykes make mining difficult, much like Syferfontein underground operations.

The target for a continuous miner section at Douglas, was 55,000tpm, and that of the ABM30 was 70,000tpm. A five day, two-shift operation is worked. This resulted in an average of 1,300t/shift. Production at Bank was in the region of 50,000tpm per section. The ABM30 on average produced 72,000tpm, with a record of about 90,000tpm. A three shift system was worked.

At Goedehoop the average production is 65,000tpm per CM. A three-shift system was used and the mining height is 4.5m” (Scheepers et al, 2000). Forzando produces at around 80,000tpm from the 2.2m seam with a HM 31 and a continuous haulage. Their best is 100,000t over a 21-day period. A 5-day, 2 shift operation was worked (Scheepers et al, 2000).

“Production at Arnot is lower. The coal is regarded as being hard and this may be a significant contributor to lower productivity. Production is of the order of 900t/shift from the three shift operation” (Scheepers et al, 2000).

“The mines were all shallow compared to the Secunda operations. This meant smaller pillar centres” (Scheepers et al, 2000).

KPA: Safety

Safety and the avoidance of harm is important to us all. The study finds that “Safety is extremely important to the Billiton group. It was communicated that the general manager and mine manager must personally fly to London to explain to the Directors when a fatal accident occurs as they are held accountable. In this case the entire group's mine and general managers do the investigation into the accident, on the mine where it occurred, within two days after the accident. An attitude of stewardship by the whole group is enforced” as noted by Scheepers et al (2000).

There is a strong cultural drive in many groups as noticed by this researcher to adopt a system of zero harm and is often coupled with a system of extreme risk assessment which is admirable. The most common goal in southern Africa on safety is ‘Zero Harm’. This goal reflects an eventual target that the industry has set and taken a stepwise approach to achieving. This is reflected in the current targets which despite the implied target of “Zero” are in fact not zero.

The most common measures of safety in the southern African mining environment are the Lost Time Frequency Rate (LTFR) and the Fatality Frequency Rate (FFR).

MOSH initiatives have brought respiratory diseases to the fore and there is a strong focus on their prevention. It is further recorded that “Most of the collieries achieved dust levels of below 5mg/m3, a standard set by the Department of Mineral Resources (DMR) guidelines. Machines were all fitted with the latest spray systems and scrubbers. Some mines used a colour coding system for the scrubber filters, each team equipped with its own screen. It must however be stated that the coal in most mines visited generated little dust and this may be a function of relative coal hardness. Generally the softer the coal the more dust is released” (Dougall & Mmola, 2014).

There is also a parallel priority with the reduction of NIHL (noise induced hearing loss).

KPA: Morale

The project team reports that “Probably the most difficult aspect to measure and define is morale. It was not the intention to measure the morale on the mines visited, but rather to identify practices as used by the various mines to keep the employees content. Khutala claimed to have had a production increase when the work week was reduced to a five day, two shift operation. The shift hours were also changed in consultation with employees to accommodate their needs. Their employees travel about 50km to work from Witbank. Another improvement is the fact that most workers are settled in Witbank with their families – and the mine claims this creates stability. They have only seven migrant workers on the mine. The bonus system caters for payment into a pool from which all those who contribute share equally - the miner and artisans get the same amount as the operators. The "coal recovery system" at Matla is regarded as a contributor to employee morale. This system allows for production over weekends with the mine contributing on a rand per tonne basis. The people that produce the coal share equally in the money that is paid into the pool.

At Goedehoop the section crew is given a shopping voucher of R150 when they produce 50m per shift twice per week. They are also rewarded when they produce more than 70,000tpm. This is also the case when they achieve their monthly target.

At Gloria containers were changed into "waiting places" on surface where the team gathers daily to discuss topical issues. The mine overseer and shift overseer is then also close by to assist to resolve problems that may arise. In some cases there is not even a notice board underground to keep employees informed on the progress against their target etc.

To summarise, very little is done to really keep the employees content, over and above the aspects mentioned, though no discontent was observed or mentioned. If one looks at the performance of the mines and take into consideration that they were some of the best performers in industry, the morale must have been satisfactory. This is not necessarily true” (Dougall, 2009).

As people we need to feel that we contribute, that we make a difference, and that we are of value to those we are involved with or to our companies. We need to find dignity and worth in our endeavours. If we do, this will motivate us and boost our morale making us feel good about our purpose and ourselves. Management needs to tap and nurture this emotion in people to the benefit of the people and the company.

Critical KPIs

As we move from managing the areas defined by QCDSM we need to consider the importance of measuring the following areas (thirteen KPIs) to assist control:

- How quickly the team gets to the working place (Travelling Time)
- How effectively and how quickly inspections are done (making safe initialisation)
- In what condition the section is left at the end of the shift
- How to reduce cable handling time
- Minimise tramming and manoeuvring (relocation time)
- Maintaining a fast cutting cycle
- Time taken to change picks effectively
- Reduction of shuttle car cable damages
- Decrease shuttle car change out times (away time)
- Quality and effectiveness of roof support to ensure safety
- Extending infrastructure every two pillars
- Do as much as possible during the off shift
- Benchmarking and understanding Group Best Practice (GBP) and Industry Best Practice (IBP) in Tonnes per month, Tonnes per week, Tonnes per unit shift, Tonnes per paid production hour, Machine available hours per week, Tonnes per machine available hour, Cutting Rate, Away time, Relocation time average, Tram to wait ratio, Downtime (various categories), Total travel time per shift

Production is mostly influenced by:
1) Plunge depth (maximum allowed cut out depth from the last through road owing to ventilation requirements Stringent controls may lead to force exhaust ventilation systems being imposed, this will in turn influence production.
2) Seam conditions, No.4 Seam vs. No.2 or No.5 Seam in South Africa. Mining conditions are more difficult in No.2 Seam and much more difficult in No.5 seam. The No.2 Seam coal is generally harder and impacts on pick efficiencies and therefore CM performance. The No.5 seam has lower seam height and poor floor and roof conditions and will put pressure on production rates. This may however be off-set by increasing yield for maintenance of saleable tonnes. Conditions in the No.4 Seam are more favourable for production in general.

KPI: Machine available hours

“Unproductive time could include time spent on:

- Planned maintenance.
- Infrastructure extensions.
- Stone dusting.
- Downtime due to breakdowns.
- Travel (total travel in and out time).”

Dividing the tonnes produced per week by the number of machine available hours per week produces a KPI, tonnes per machine available hour (tpmah) to determine how effectively the section is using the time they have. It is displayed in Figure 2 and varies from 413.5 to 252.3tpmah (MCS Report, 2006).

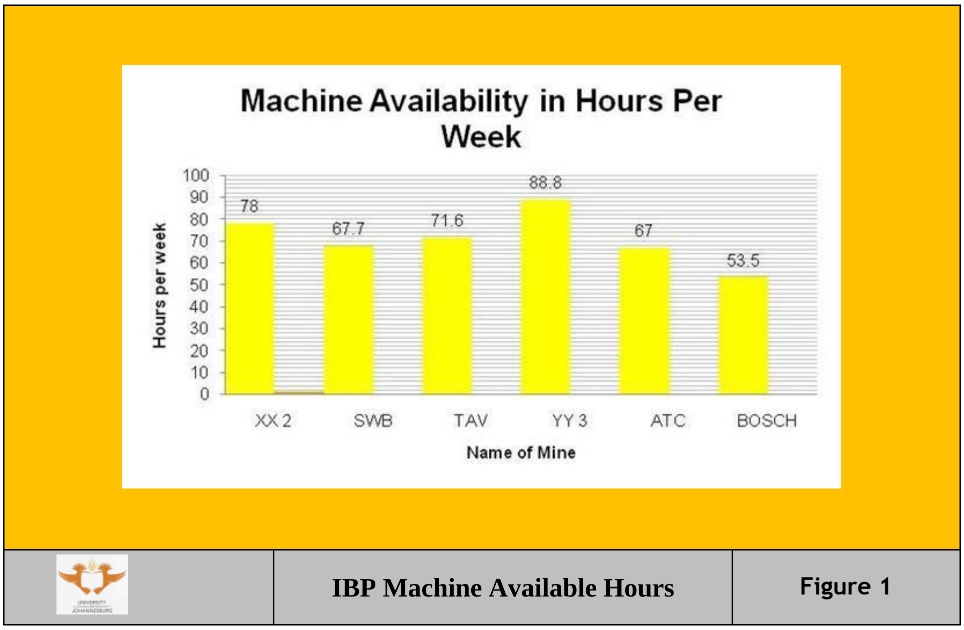

Figure 1 IBP for machine available hours (data from Hoffman & MCS)

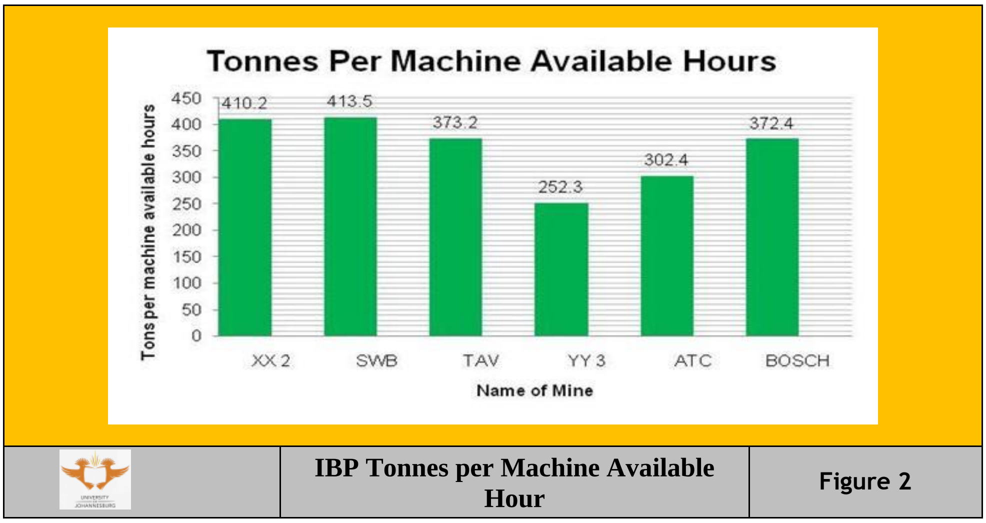

Figure 2 IBP for tonnes per machine available hour (data from Hoffman & MCS)

Section 1 at South Witbank is IBP in this category at 413.5tpmah (tonnes per machine available hour). Figure gives the weekly availability.

KPI: Cutting rate

A machine is deemed to be cutting when it is actively producing coal by sumping in, shearing down and trimming the roof and floor. The rate at which the coal is liberated is called the cutting rate and is measured through an electronic monitoring system. The cutting rate can be deduced by physical measurements.

The best cutting rate of 785 tonnes per cutting hour was achieved by ATC section Inyathi. Inyathi has a Joy 12HM31 JNA1 CM. Poor cutting rates may be attributable to machine setup according to the OEM. Cutting rate is shown in Figure 3 varying from 825 to 650 tonnes per cutting hour. IBP is 825 tonnes per cutting hour (MCS Report, 2006).

Figure 3 IBP for cutting rate (data from Hoffman & MCS)

KPI: Away times

The time it takes for shuttle cars or battery haulers to change out behind the CM or ABM is the away time and the aim should be to use the unproductive time when the CM is trimming the floor and tramming forward as part of the change out time. The CM's spade can hold approximately eight tonnes of broken coal, which means the machine can sump in and shear down approximately 50cm (0.5m) without the conveyor chain having to run. The combined time for these activities is 44 to 60seconds as calculated in Table 1.

Table 1 Away time (from MCS)

Activity	Best	Average
Trim Floor	5seconds	8seconds
Raise head while Tramming forward	13seconds	15seconds
Sump in	18seconds	24seconds
Shear down	8seconds	13seconds
Total	**44seconds**	**60seconds**

If the away time exceeds 60seconds the CM is waiting unnecessarily on the shuttle cars. If the away time is less than 44seconds the CM is probably not making optimal use of the cutting cycle. Figure 4 ranks the Xstrata 'away times' and vary from 24seconds to 81seconds.with the external mines.

"Highest away times can be attributed to:

- Not following optimal routes.
- Not having change out points in correct positions.
- Constraints at feeder breaker.
- Floor conditions and sweeping" (MCS Report, 2006).

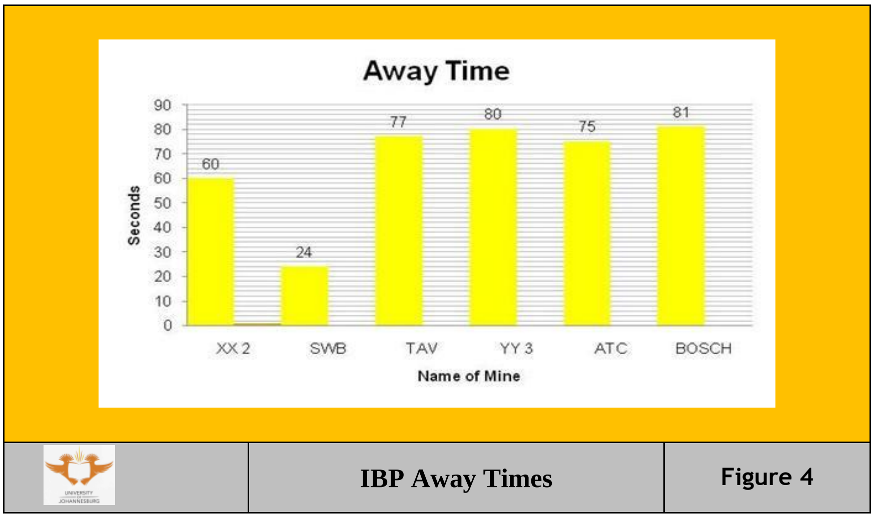

Figure 4 IBP Away Time (data from Hoffman & MCS)

The target range should be within 44 – 60 seconds and Section XX-2 meets this benchmark.

KPI: Relocation time

This is the average time spent per relocation that is the time it takes to move the CM from one cutting position to the next. Figure gives the relocation benchmark and values vary from 19 minutes to 23 minutes. This consists of actual tramming time as well as time spent on activities such as cable work, face preparation and pick changes (waiting time). The IBP is shown in Figure 5 and has a value of 14 but it should be noted that factors such as pillar centres or linear layouts can significantly influence this.

The ratio between the two (tram to wait ratio) should be equal to or greater than 0.5. Tram to wait ratios are depicted in Figure 6 and ranges from 0.78 to 0.30. Note 0.5 means for every one minute spent on tramming two are spent on cable suspension, cable moving or changes and pick changes. 'Wait' in this context is to stop and not weight (mass x gravitational acceleration). (MCS Report, 2006). Data also validated by Hoffmann, Personal communication (2008).

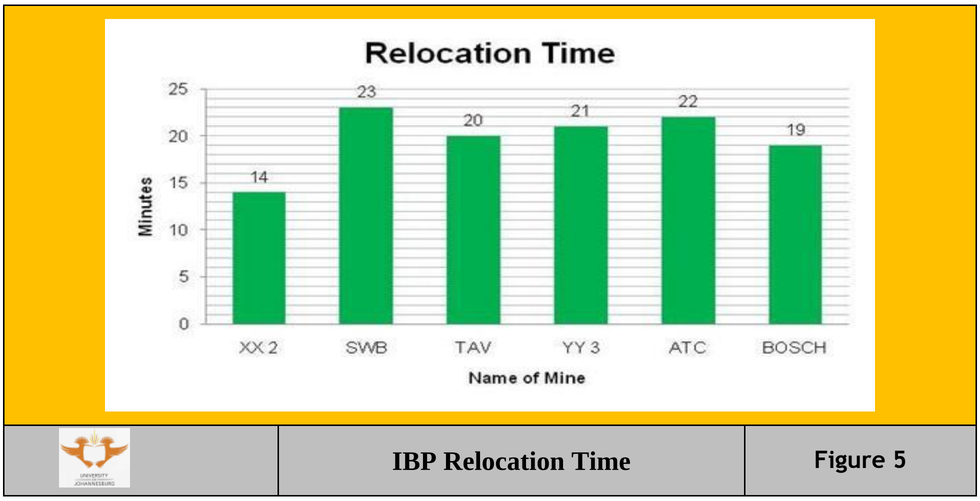

Figure 5 IBP for average time per relocation (data from Hoffman & MCS)

Relocation efficiency is an extremely important productivity optimisation area since the number of relocations is directly proportional to the metres cut per shift. A better tram to weight ratio implies less waiting time. The CM should be moving (tramming) or cutting. IBP for relocation efficiency is depicted in Figure 6 at 0.3.

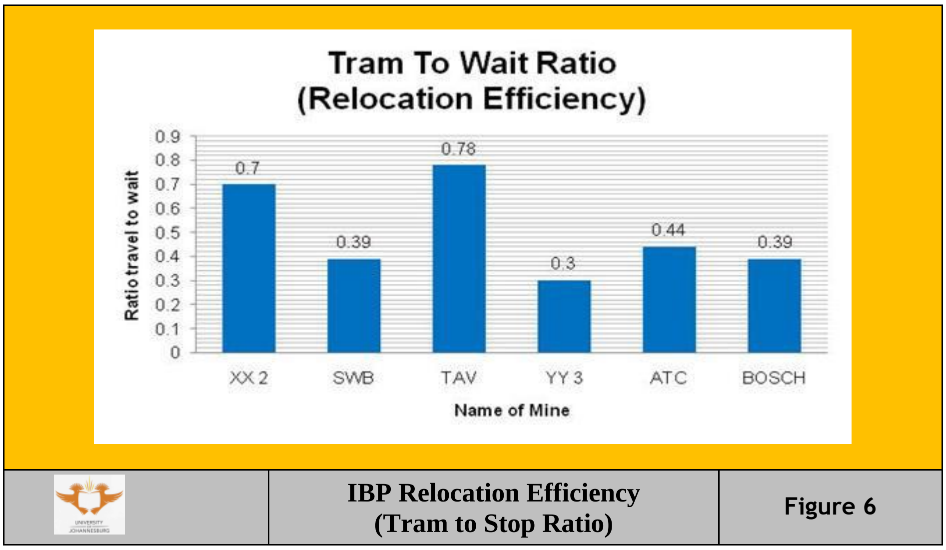

Figure 6 IBP for Relocation Efficiency (Tram to wait ratio) (from MCS)

KPI: Equipment availability

Based on data provided by the Xstrata group, planned maintenance database, an analysis was carried out. Average downtime of the CM is shown in Figure 7 and varies from 3.2% to 10.6%. Figure 8 gives hauler downtime and the conveyor downtime.

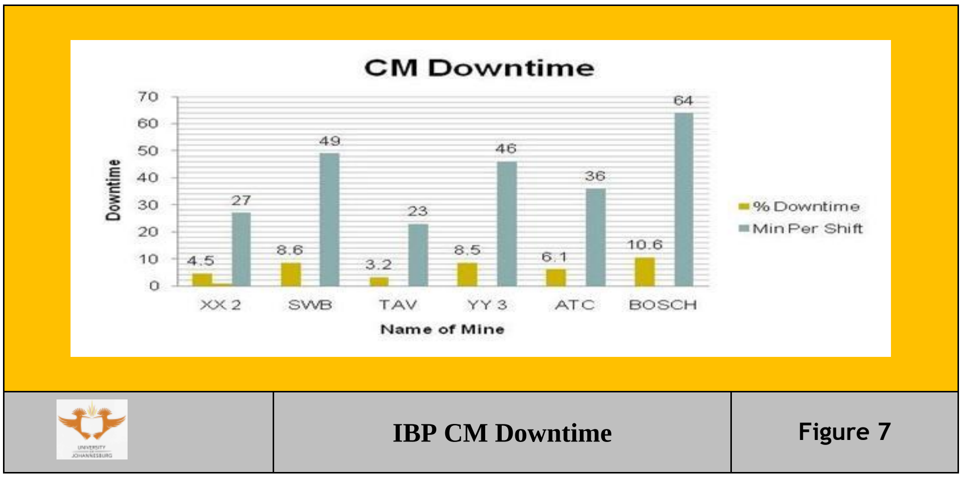

Figure 7 IBP for CM Downtime as percentage of shift (data from Hoffman & MCS)

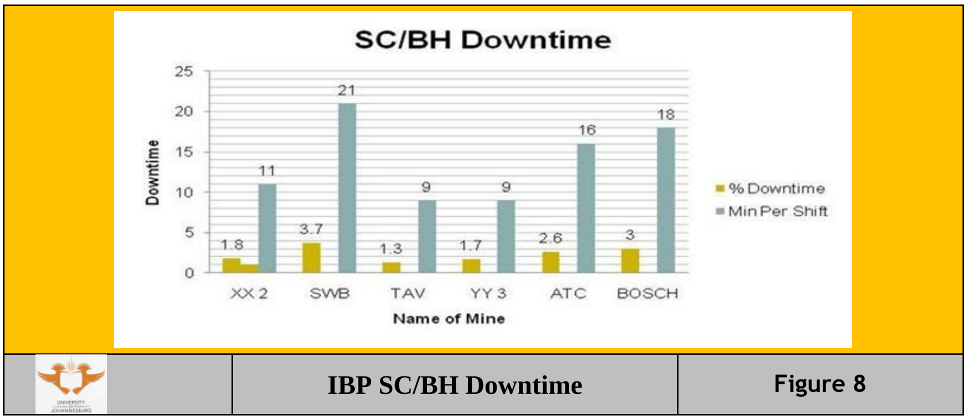

Figure 8 IBP for Hauler downtime as percentage of shift (data from Hoffman & MCS)

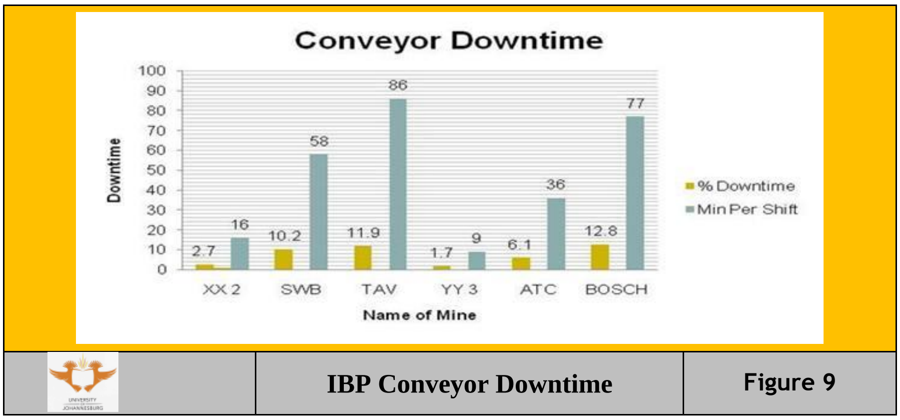

Figure 9 IBP Conveyor Downtime (percentage of shift) (data from Hoffman & MCS)

Minutes of CM downtime vary from 23 to 64 as shown in Figure 7. Note 23 minutes per shift is the IBP recorded at Tavistock by Section 3. This section uses an ABM30”. (MCS Report, 2006). Data validated by Hoffmann, Personal communication (2008). The IBP for shuttle cars and battery haulers is 9 minutes per shift. Section YY on a 3 shift cycle has set the benchmark at 9 minutes per shift or 1.7% of shift time.

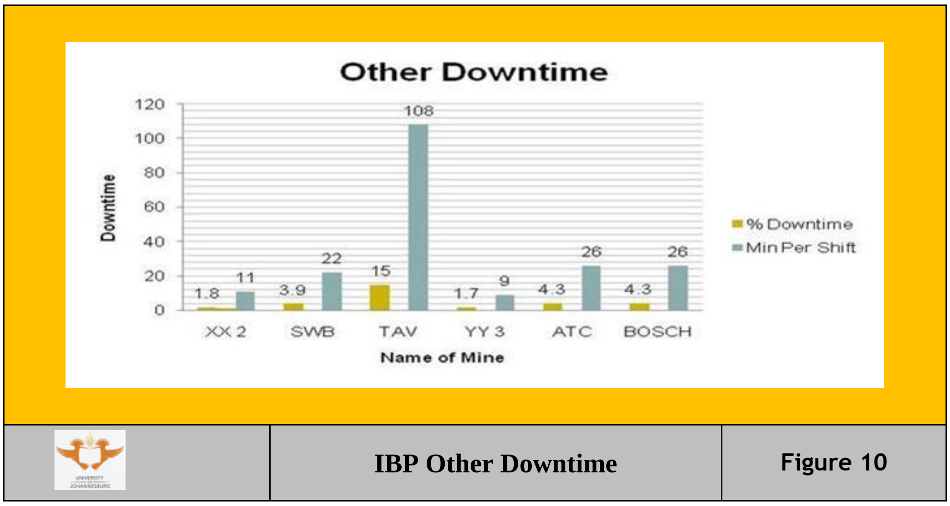

Figure 10 Other Downtime (percentage of shift time) (data from Hoffman & MCS)

"Remaining downtime grouped together as other downtime (Figure 10) fall into:

- Plant.
- Electrical power and water distribution.
- Blasting.
- Operational – wait for support or ventilation" (MCS Report, 2006).

KPI: Travelling time

Total travel time combines travel in and travel out time and the results are shown in Figure 11. The target is to minimise total travelling time, so that it is equal to or less than the overlap time between the shifts. The IBP value is at 60 minutes. When the hour total travel time is exceeded it becomes a trade off between labour cost including lost production to the cost of a closer access. (MCS Report, 2006). Data validated by Hoffmann, Personal communication (2008).

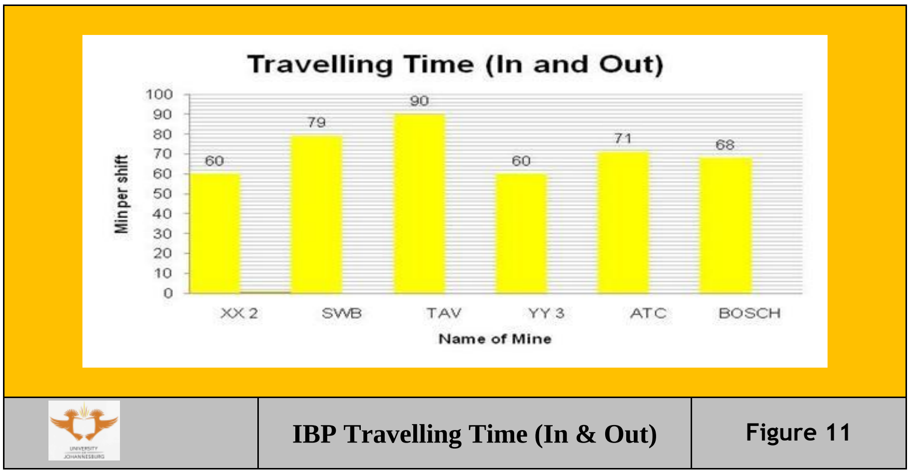

Figure 11 IBP for Total Travel Time (data from Hoffman & MCS)

KPI: Cutting time

The targets of 260 minutes per shift need to be maintained in perspective (MCS Report, 2006). The best achieved is at Boschmans' Indlovo section which was 180 minutes and second best Ingala section 175 minutes. This author believes that 180minps is a reasonable target. At a cutting rate of 825tph or 13.75tpmin at 180minps cutting will yield (13.75 x 180) = 2,475tpshift = (2,475tpshift x 2shiftspd x 22dpm) = 108,900tpm potential. You need 83,000tpmonth to produce 1Mtpa.

Summary of underground coal mining CM section KPIs

The following KPIs summarized in Table 2 are what mines focus on in the South African mechanized environment.

Table 2 Coal Mining CM KPIs

KPI	IBP
Monthly Production (Tonnes per month)(tpm)	129,000
Weekly Production (Tonnes per week)(tpw)	32,000
Shift Production (Tonnes per shift)(tpshift)	3,000
Production per hour (Tonnes per paid production hour)(tppph)	320
Machine available hours per week (mahpw)	89
Tonnes per machine available hour (tpmah)	413
Cutting rate (tph)	825
Away time (seconds)	45
Average relocation time (minutes)	14
Tram to wait ratio (minutes)	0.7
CM downtime min per shift (minutes)	27
CM downtime % of shift (%)	4.5
Hauler (SC/BH) downtime min per shift (minutes)	9
Hauler (SC/BH) downtime % of shift (%)	1.7
Conveyor downtime min per shift (minutes)	9
Conveyor downtime % of shift (%)	1.7
Other downtime min per shift (minutes)	9
Other downtime % of shift (%)	1.7
Travel time per shift (minutes)	60

European Union's mining operations use ICT to measure KPIs

"In the demonstration project OPTI-MINE funded by the European Union`s RFCS pro-gram five underground coal mines have applied newest Information and Communication Technologies (ICT) to improve efficiency, mine safety, occupational health and environmental impacts. The improvements set by these technologies have been assessed with Key Performance Indicators. Some of the KPIs cover the transport performance, the increase of the level of information, the decrease of mean time to repair, the average decrease of time to call a person and cost savings. The preliminary results give clear evidence that the new enhanced ICT will positively impact mine productivity and mine safety". (Dauber & Bendrat, 2014).

Mining strategies and tactics

All mines will find the necessity to measure availability and utilisation of mining plant and systems. These controls will require the accounting of minutes in the production process. Targeting cutting times of 280 or 350 minutes per shift in the 8 hour or 9 hour shift time available is essential if productivities are to approach the 2Mtpa target. It is apparent that the 1Mtpa level is still very elusive. It is apparent to this researcher that industry best practice (IBP) for cutting time is only of the order of 220 minutes per shift and 180 minutes per shift for different shift durations.

The best performing longwall face recorded is situated in NSW Australia delivering in excess of 5.5Mtpa and averages 460,000tpm it delivered 7.5Mt in the 2007 production year. This is Beltana Colliery which operates a highwall entry mine. The defining parameters are powerful equipment applied in wide faces (300, and 400 to 500m) of optimal panel length (3,000m). The lean and mobile or portable format of this operation is very effective. The manpower complement is also kept very lean.

Fewer mines are currently applying pillar extraction techniques and where wall mining conditions are suitable; wall mining is the preferred method although it remains capital intensive. Depth to floor and required high extraction rates remain the main drivers.

Pillar extraction methods have followed from the previously widely applied Rib-pillar (RPE) or Wongawilli methods. Productivity levels do not show significant improvement on partial extraction methods. Rib-pillar has lost favour in South Africa but the derivative (Wongawilli) is preferred in Australia when secondary pillar extraction occurs.

The better performers found in South Africa involve the NEVID method of pillar extraction (it is in reality a partial pillar extraction process) as this provides a means of managing horizontal stress found in the mining environment and allows pillar extraction above 3.5m mining height with 4.5m actually performed in South Africa. Horizontal stress is however not fully understood in collieries and further research is needed in this area. Modifications arise were smaller and older pillars need to be extracted. The methods do not fully recover all coal and partial pillar extraction has become the trend.

Gerike has proposed a sequence for extracting small pillars (Gerike, 2003) and is similar to the pillar extraction method at Arthur Taylor colliery which was published in Lind (2004).

Pillar extraction methods have evolved to derivatives of pocket and fender mining with the leaving of snooks (small remnants of reduced fenders) as common practice. Continuous miners are the preferred tool in this exercise.

Partial extraction or bord and pillar mining is still favoured as it is believed to offer less risk. It offers competitive productivity levels, with reduced subsidence, if any. Wall mines will still apply this method in remnants that cannot accommodate suitable wall panels or where blocks are significantly disturbed. Partial extraction or bord and pillar mining is further necessary in primary and secondary developments. Continuous miners are preferred with conventional (blasting and mechanical loading) systems few and far between.

Linear panel layouts are finding increased favour as demonstrated in Magatar methods. The advantage accrues by placing narrow roadways in close proximity and parallel to each other, with no use of support in the roadways, the splits are generally cut forming diagonal pillars in certain layouts (Venter, Personal communication, 2009).

The coal moving system behind the continuous miner is open to much debate. Continuous haulages offer the greatest productivity levels but their application is less flexible. The best recorded performance is 160,000tpm at Syferfontein but it is noted that this is a long standing statistic. The average is of the region of 80,000tpm. Sandvick, the Voest Alpine agent in South Africa, maintain that the ABM30 now delivers 110,000 to 130,000tpm regularly. They maintain a control room in Delmas, were production reports are centralised via LAN (Sandvick, 2009).

Pillar Design Evolution

Salamon has tradionally be used in his slender and squat pillar formulae derivatives for the design of coal pillars in South Africa. Latest development by Prof N van der Merwe has resulted in the acceptance that squat pillar design does not present the exponential strengthening at width to height ratio of less than 10. The tendency then is eliminate squat design with the formula developed by Dr B Madden.

Van der Merwe has altered the K to factor (7.2MPa to altered values based on one of two approaches) and α (0.46 to 0.8) and β (-0.66 to -0.8) values in the strength formula and requires that the probability of survival and the life index of the pillars be considered in the design process (Van der Merwe & Mathey, 2013, a & b) and (Van der Merwe, 2003).

Conclusion

1) A system identified by a world class achiever, controls: Quality; Cost; Delivery; Safety; and Morale, as measuring instruments for performance. These are really KPAs.
2) QCDSM is not the forté of one company or organisation but a continuous improvement strategy that has specific key performance indicators all very important to the success of the coal production and product operation.
3) All mines will find the necessity to measure availability and utilisation of mining plant and systems. These controls will require the accounting of minutes in the production process e.g., targeting cutting times of 280 or 350 minutes per shift in the 8 hour or 9 hour shift time available. This will not be achieved if the ‘soft issues’ of Systems Thinking are not implemented.
4) SOPs dealing with QCDSM, quality, costs, delivery, safety and morale are paramount in ensuring objectives are met.
5) Morale and behavioral factors in safety and health is referred to as soft systems in systems thinking as the concepts are not always tangible and are implemented cognitively.
6) The use of KPAs is necessary to manage performance. In order to manage effectively we need to measure KPIs. This will ensure the effective optimization of our processes.

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