

**Determining the Suitability of the Current Functional Production KPIs at
Greenside Colliery in Managing Production Section Downtime and To Identify
Critical Areas of Lost Time**

Critical Areas, Recording, Analyses and Reporting

By:

Sandile Mzi Khumalo

25219252

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Sandile T. Khumalo

B (Eng) Industrial Final Year

25219252

sandilek@ezomoya.co.za

Cell: 0733252348



Short Project Title

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Abstract

Over recent years Anglo Coal Underground CM mines have consistently been able to increase production output by improving their production process efficiency. However, in the very same time, the utilization of available production time has declined.

This report will explore the architecture the current Performance Management System (PMS) for frontline production section in Greenside Colliery, with specials impetus given to the measurement front line time utilization.

Guided by existing literature and case studies on Performance Measurement Systems and equipment time losses one was then able to conduct work studies in the erratic underground coal mining sections. This was done with the view of building a factual basis for process flows and root cause identification.

Informed by the above the report will give recommendations, on the short comings and suitability of the current PMS, a concise definition of what “production downtime” and illuminate critical areas of lost production.

From the study of best practices the PMS was found to be suited generally for frontline coal management. However more needs to be done in improving the accuracy of the data recorded and its communication.

A definition was fabricated for “Lost Production Time” based on the existence of a critical value chain. Based on this definition the critical areas of lost production time were identified and summarized in diagrammatic form that will be used in the data capturing of the new PMS.

The study found that Continuous Miner operational stoppages and Feeder Breaker breakdowns present the best opportunities of improvement and recommends that work studies be done to improve the operational stoppages and equipment redesign consideration be made to reduce shearing pin and torque shaft damage.

The report culminates by giving further recommendations based on findings on other aspects that are not contained within the project scope but however do have a bearing on the efficiency of the total PMS.

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List of Abbreviations

BH:	Battery Hauler
CI:	Continuous Improvement
CM:	Continuous Miner/Mining
CMIG:	Continuous Mining Improvement Group
DT:	Downtime
FB:	Feeder Breaker
IDEF:	Integrated Definition Methods
KPA:	Key Performance Area
KPD:	Key Performance Driver
KPI:	Key Performance Indicator
KPO:	Key Performance Outcome
MCS:	Mining Consultancy Services (PTY)
PMS:	Performance Measurement System
RB:	Roof Bolter
SB:	Section Belt
SC:	Shuttle Car
SOP:	Standard Operating Procedure
TB:	Trunk Belt

Key Terms

Board and Pillar, Torque Shaft, Trimming, Pick, Pick Replacement, Shuttle car, Battery Hauler, Mining Sequence, Roof Bolter, Benchmarking, Process Based Management, Best Practice, Target Setting, Change Management, Process, Six Sigma, Process Variation, Process mapping, Key Performance Indicator, Strategy, Process Control, Balanced Scorecard, Performance Measurement, Operational Downtime, Engineering Downtime, Breakdown, Action plan, Continuous Improvement, Metrics, Productivity Metrics, Utilisation Metrics, Downtime Metrics, Value Chain, Utilization, Efficiency, Availability.

Glossary of Terms

Continuous Miner	Primary machine with rotating cutting tool bits used for dislodging coal from the face, <i>Appendix A</i>
Face Boss	First line manager, responsible for managing a production crew at a section often referred to as the Miner, <i>Appendix B</i>
Heading	The position the CM is mining
Metrics	The arithmetic construct of a measurement tool. i.e. production rate = tons/minute
Mining Sequence	A predetermined production maneuvering chronological order guided by safety, tramming distance and cable handling, <i>Appendix C</i>
Production Rate	Measure of efficiency in the use of the availability of production time
Production Section	Smallest production unit of a mine, where coal is essentially mined
Production Time	Shift Time less non value adding process times. Utilization measure
Relocation	Moving from a complete face to new face, <i>Appendix C</i>
Shear	Secondary cutting motion, when the cutter head is moving down removing coal until parallel with floor
Shift Boss	Second Line Manager, responsible for sections
Sump	Primary cutting motion of moving cutter head of CM into the coal face
Tramming	Process undergone by CM when moving and not cutting. Usually when moving between faces, <i>Appendix C</i>

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Bertus Prinsloo , Pieter Steyn, Andile Ndiweni, Markus Denkhaus, Matthew Eardley, Clement Mufamadi, Rambani Raphulu

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“When you can measure what you are speaking about, and express it in numbers, you will know something about it [otherwise] your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science”

Lord Kelvin

Introduction

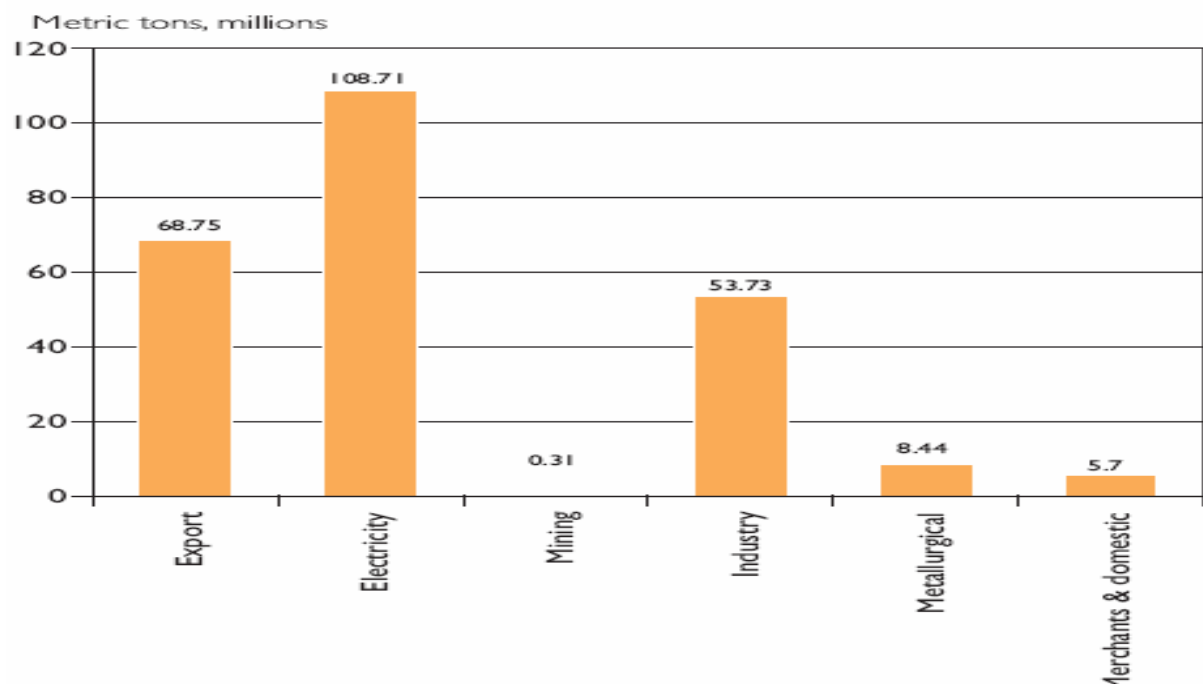
Coal Mining in South Africa

South Africa's coal mining industry is the second biggest mining sector after gold, with sales contributing 16% of export revenue in 2003 and 4% of GDP (Mbedi,2005). Total revenue earned by the industry in 2005 was R37.7-billion of which R21.5-billion was revenue from export earnings. The coal sector accounted for 1.2% of GDP directly, 4.8% of merchandise exports, employed 57 777 workers and paid R7.2-billion in wages in 2006(DME,2006).

Coal provides about 70% of South Africa's primary energy needs, with 93% of electricity and 37% of local liquid fuels production sourced from coal, primarily via the coal to liquid technology deployed by Sasol. It provides the basis for a world-class electricity sector, one of the cheapest electricity sources in the world, which has come under direct threat in recent time as a result of erratic coal supply. South Africa has the world's fifth largest coal reserves estimated at 49 billion tons or 10.2% of the world total. The country was ranked as the fifth largest producer with 244.8 million saleable tons in 2006 representing about 4.5% of global supply (Figure 1).

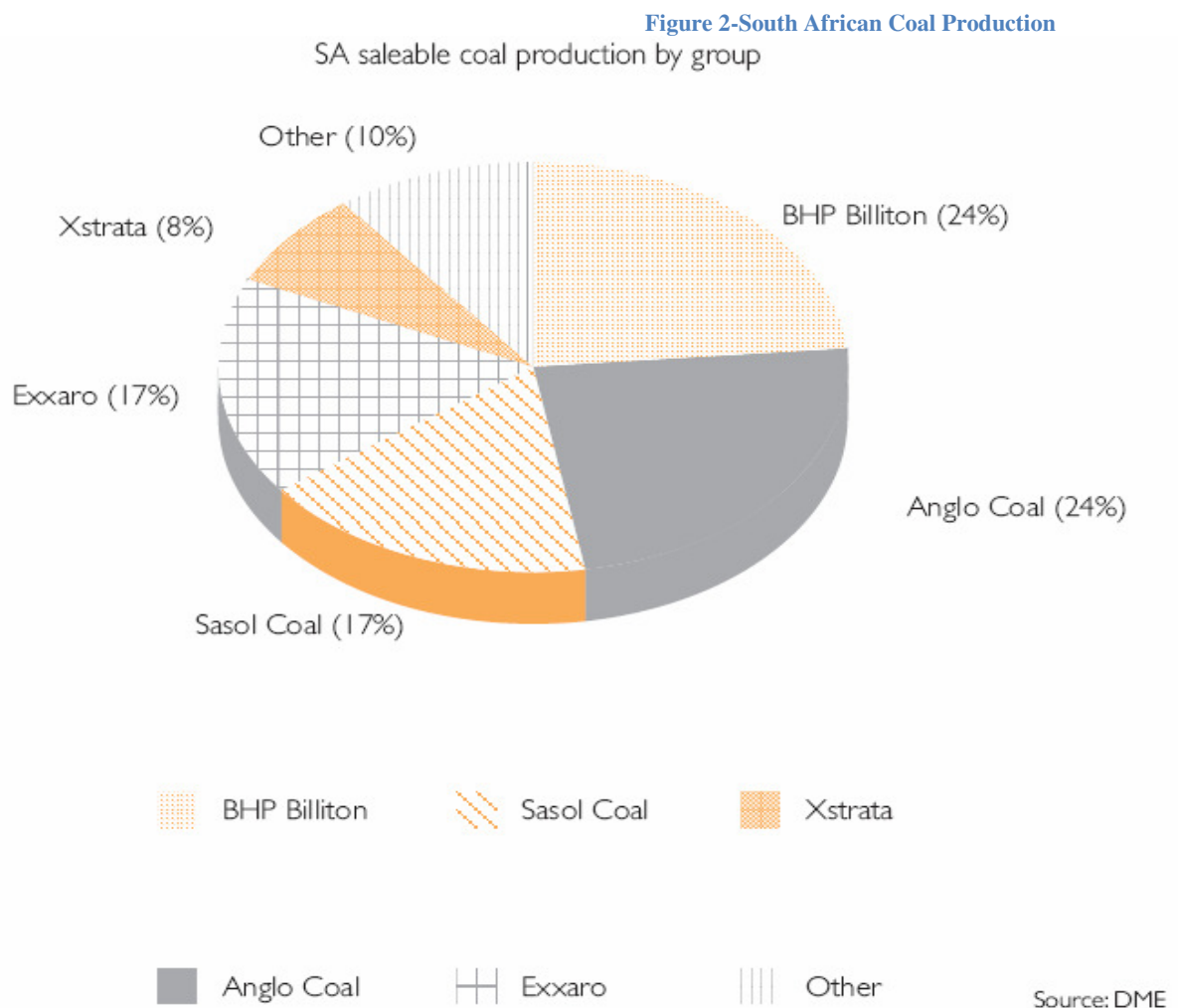
These figures give credence to the importance of the coal mining industry to the South African economy as a contributor to GDP, a major source of FDI, a strategic resource to satisfy domestic energy needs and one of South Africa's biggest employers.

Figure 1-South African Coal Consumption (DME, 2007)
Sectors of South African coal market in 2006



Anglo Coal

Anglo Coal is a wholly owned subsidiary of Anglo American and is one of South Africa's largest coal producers, being the largest producer of saleable coal in 2007, with its 24% contribution of local production, figure 2 (DME, 2007). Operations are based in South Africa, Columbia and Australia. The mines in South African mines are located in the Highveld; within the area know as the South African Coal Estate (SACE). The 6 opencast and underground mines are Goedehoop, (18) Greenside, (4) Isibonelo, Kleinkopje, (21) Kreil, Landau and (25) New Denmark, (Figure 3) produced an estimated 56.9 million tons in 2007, (Barrads, 2007).

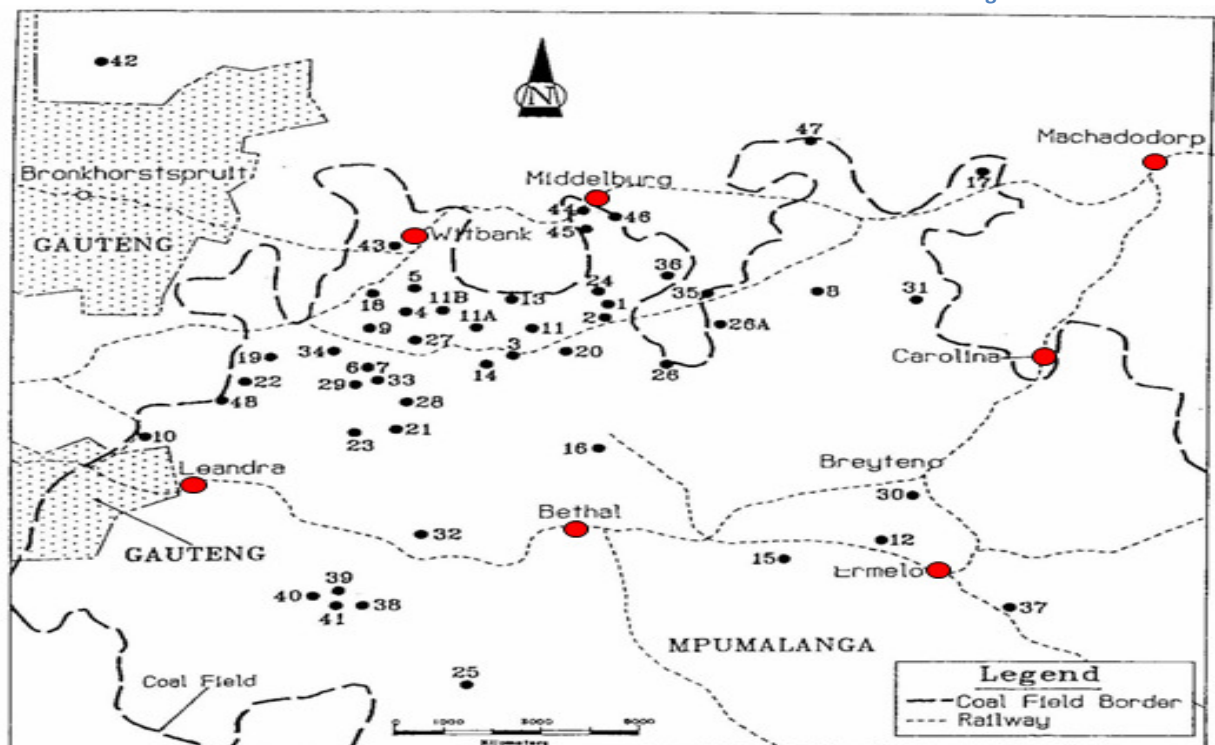


In order for the company to reach it's the target of 80-85 million tons/year and still improve on its realised profit R414 million in 2007 (Anglo America, 2007) the company should continuously search for methods to reduce its operating expenses. Organisations that are able to continuously improve their processes by seeking better ways of doing things will inevitably become the market leaders, (Welch, 1999) hence, CMIG has committed to improving production by 15% in 5 years (Barrads, 2007).

Greenside Collieries

Greenside Colliery (4) (Figure 3) to which the study is dedicated to, is located 20km south-west of Witbank, Mpumalanga and forms part of the greater South African Coal Estates (SACE) complex. Production officially started in 1947 and up until 1998 Greenside was owned by the diversified mining group Goldfields before being acquired by Anglo Coal. Its four underground 4 seam sections, Thandeka, Vumagara, George and Thusanang (MCS, 2008) produce a combination of pulverised coal injection and thermal coal for the domestic and international market.

Figure 3-SACE



Greenside makes use of the board and pillar mining method. In this method, the ore-body is excavated completely as far as possible, leaving parts of the ore body to support the hanging wall (Phil Crous, 2007). Board and Pillar is ideally suited for coal seams that are at a shallow to medium depth. Greenside makes use of a two-production shift system plus one maintenance shift, unlike the other Anglo Coal mines that produce continuously using a rolling three-shift system intermitted with maintenance activities. This translates to 16 production hours plus 8 maintenance hours, daily. There is no production over the weekend. Each of the underground four seam sections has one Continuous Miner (CM), three haulers, one roof bolter and one feeder breaker which connects to a network of conveyor belts.

Project Background

CMIG has commissioned this study, to investigate the suitability of the current functional Key Performance Indicators (KPIs) for frontline production. This study is born out of two previous studies done by other Industrial Engineering students and internally by MCS (PTY) in defining what exactly are the main KPIs and the related metrics, these two works articulate around:

- *“Defining the standard Anglo Coal front line performance measurements for Underground CM sections”*:2006 Bertus Prinsloo , Pieter Steyn, Andile Ndiweni
- *“Review of the Current Approach to Measurement and Reporting of Continuous Miner Relocation Time as a Key Performance Indicator”* 2007 Markus Denkhaus, Matthew Eardley, Clement Mufamadi, Rambani Raphulu

The latter sought to define what were the current frontline Performance Measures (PM) at the time in 2006 with the objective of creating a standard across the organization. While the former focused mainly at establishing the acceptable metric that can be used to measure the effectiveness of relocation and what metrics can best be used to communicate the production sections ability to relocate effectively and efficiently. These standardized KPIs and their metrics, informed by the were cut down to a total of six, and coined the “the Pick Six”. These being **First Sump Late** , **Last Sump Early**, **Relocation Time**, **Loading Time**, **Away Time** and **Lost Time**.

These KPIs have been recorded in the past. However, the exercise of recording and reporting has proven rather invaluable as the data is not converted to accurate or useful information. The reasons for such incongruence is multi-fold, but its effect in assisting the management of operations proves rather detrimental as the data recorded remains just that “data” and not information that can be used to improve the production process.

Greenside has subsequently embarked on an ambitious project to improve production by 3% during 2007, 8% during 2008 and a further 4% in the first half of 2009. This projection has materialised itself with Greenside posting a 4.3% improvement on the 2007 baseline, which was 1.3% higher than the set target. The interim results as of June 2008 production are projected up 0.6% (AOS, 2007). The Continuous Mining Improvement Group (CMIG) was the department established and mandated with the responsibility of ensuring that these objectives are realised.

The table below defines the “the pick six”:

Table 1-Pick Six

KPI	Definition
First Sump Late	Time lost if the first sump occurs after the designated time for the first sump. The ingoing shift is allowed 45 minutes for traveling, safety meeting, production planning and pre-shift section and equipment inspections. If, for example, the morning shift goes underground at 06h00 then we would expect the first sump to be at 06h45. If the team misses this time then we have a "first sump late" by however many minutes they miss it by. The metric is measured in minutes.
Last Sump Early	This is the time lost when the crew leaves the section early for some reason and the last sump for the shift is earlier than specified on the shaft program. The production team in Greenside is expected to spend at 8 hours from in the section from the expected first sump time. Last sump early, will be the number of minutes that production stops before the allotted 480 minutes have lapsed. The metric is measured in minutes.
Loading Time	Time taken for the continuous miner to fill one shuttle car or battery hauler. Usually expressed as an average across the shift. Via the onboard PLC system, current fluctuations can be used detect when the flight chain moving and dumping coal onto the shuttle car. The total loading time during the shift is summed over the entire shift and divided by the number loads completed. The metric then becomes, seconds per load.
Away Time	This is the time that the continuous miner stands waiting for the next shuttle car or battery hauler to pull in behind it for filling. We usually express this as an average across the shift. This is not all non productive time as the CM trims the floor, raises its boom and sumps in (to pre-load the spade) during this waiting time.
Tramming Time	This is the total time that the continuous miner has spent traveling around the section for some reason. This may be for relocating, going out for maintenance, going back to cut floor. This KPI is given further effect by the metric tram time per meter cut. Which sums the total tramming time, read of the onboard PLC divided over the number of meters cut during the shift.
Lost Time	Is defined as all time not accounted for as production time nor tramming time. This may be in or out of the section but it implies tat the continuous miner could not /did not produce coal or move around the section during that time

Project Aim

The narrowly outlined project title speaks to determining the suitability of the current functional production KPIs at Greenside Colliery in managing production section downtime and to further identify critical areas of lost time in the section. This needed to be translated into concise aims and tangible deliverable.

The report will go about studying the current PMS KPIs to determine if they are indeed suitable for measuring frontline production section performance. Such a study will have to clearly define what us “Production Lost Time”. From this time, illuminate on sub-processes than still present prospects for improvement in reducing total lost time. Based on these findings, the report should recommend how best, to go about recording, analysing and reporting this lost production time.

The project aim can be summarized into four deliverables:

1. Definition of Lost Time – Page 27
2. Findings on the suitability of Frontline Production KPIs in measuring production process – Page 30
3. Presentation of areas of Lost Time and Key Performance Areas (KPAs) which still present areas of opportunity for improving KPIs - Page 40
4. Recommendations of how best lost time can best be Recorded, Analysed and Reported – Page 51

Understanding, the nature of the report, the only deliverables would be a report on the findings, recommendations and a poster on the schematic representation of the critical lost time to be used to as a basis to communicate this change in the organisation.

Methodology

Guided by the project aims of determining if indeed the current set of frontline production KPIs are “suitable” for frontline production management and also to find out the critical areas of downtime presented two unique challenges one went about developing a methodical, qualitative and quantitative investigation.

Any study to determine “suitability” can prove itself incredibly self-defeating if based on subjective preconceived understanding and there are no factual baseline criteria on which this “suitability” based on. This is further relevant as I have fair amount of experience in underground sections in different coal mines.

To counter that, case studies were examined and extensive literature examined that speaks to the best practices that PMSs must subscribe to in different industries. This was done to allow for best practice benchmarking. The aforementioned literature is contained in the literature review. The objective of this exercise was to consciously debrief oneself and consider as many possible solutions as possible.

Second that was the objective of presenting critical areas of “lost production” time. This could only be solved by clearly defining the process from start to finish. This encompasses the production process and its appendages.

Having prior knowledge and experience of underground coal mining methods, one went about clarify some aspects of general mining process variability like the shift system, production crew composition and equipment specification.

One then went about building a hypothesis on the critical lost production time based on the previous shift reports. While these shift reports were largely inaccurate, they did provide a factual base from which work studies were conducted. This statistical study would form the quantitative evidence needed to support the qualitative hypothesis.

Approximately 110 hours were spent alternating the four underground sections doing work studies. The findings of the work studies would corroborate or dispute the findings of the quantitative, statistical findings. Further more, these work studies, gave an insightful account of how frontline management actually accounts and interprets these KPIs for front line production.

Based on the above sequence of steps one was able to determine the suitability of the frontline production KPIs generally, the correct definition of “lost production time” in coal mining specifically and the “critical lost production time” in Greenside Colliery specifically.

Literature Review

Introduction

There exists a great deal of literature on strategic organizational management and the tools and techniques managers can use to improve their organizations. This literature study seeks to summarize this large body of knowledge on performance measurement into information that will be guiding in concluding, ascertaining findings and pass credible recommendations as required in the project objectives.

This study seeks to discuss the development of performance measurement and the various methods and frameworks that have been successfully implemented. The studied formed the back drop from which the definition of Lost Time was defined and further assisted and find best practices for Performance Measurement Systems, downtime recording, analyses and reporting.

Business Process Management

Business process management is a recent field of study (Harrington, 1991) but performance measurement goes back a long way. Remembering “if you can’t measure it you can’t control it, and if you can’t control it, you can’t manage it”. Companies prefer to use the term performance indicators instead of performance measures. Planners usually prepare a suite of key performance indicators (KPIs) to measure progress towards corporate objective, as is the case with Anglo Coal. These corporate indicators normally include measures of quality, flexibility, competitiveness, environmental impacts, innovation and learning, all designed to complement resource utilization and financial measurement.

Organizations will typically identify an area where performance is to be measured (e.g. quality) and then brainstorm a list of indicators (e.g. customer satisfaction, errors, scrap). It will then classify indicators into lead and lag depending on whether they represent cause or effect, and begin reporting them. Fitzgerald et al. (1993, p. 7) use the classification determinants versus results, while Greif (1991, p. 175) prefers the terms process indicators and results indicators. Refer to Table 2.

Performance Management System (PMS)

A performance measurement system may be used for top management control or continuous coal production section level improvement. It may be compared against internal targets or external benchmarks. No matter what the objective of the system or use of the performance information, a complete OMP measurement system needs to be comprehensive and cover the most critical performance dimensions of the organisation.

When designing performance measurement systems it is necessary to decide first, what to measure, and second, how to measure. The dimensions “strategy”, “flow orientation”, “internal efficiency” and “external effectiveness” of the present framework mostly describe the “what to” question. It is not enough to identify what dimensions to measure; the measures also need to be designed so that the performance information can be successfully used. The way may differ between systems with different objectives. However, the characteristics “improvement drivers” and “simple and dynamic” describe the “how to” question.

According to Tangen (2002) a PM should:

- Support strategic objectives. It should be derived from the company’s strategic objectives. Otherwise, the PMS may support actions that have the opposite effect of those implied in the strategy. Since strategies usually change over time and when a strategy does change, some performance measures must change too. Therefore PMSs must be flexible and at all times coherent with the objectives of the company.
- Have an appropriate balance. A PMS should consist of various types of performance measures covering all important aspects agreed as representing the success of the company. There must in turn be a balance between the various performance measures in the PMS. A PMS should be appropriately focused on short- and long-term results, different types of performances (e.g. cost, quality, delivery, flexibility and dependability), various perspectives (e.g. the customer, the shareholder, the competitor, the internal and the innovativeness perspective), and various organizational levels (e.g. global and local performance).
- Guard against sub-optimization. An improper set of measurements for employees can lead to dysfunctional or unanticipated behavior (Fry, 1995).

Sometimes employees seeking to improve the measure of their performance often make decisions that are contrary to the desires of management. Occasionally, an improvement in one area leads to deterioration in another, even resulting in a decline in overall performance. Skinner (1986) termed this phenomenon the “productivity paradox”, where dysfunctional behavior results from poor performance measures. A PMS must guard against sub-optimization, possibly by establishing a clear link from the top of the company all the way to the bottom, to ensure that employee behavior is consistent with corporate goals.

- Have a limited number of performance measures. More measurement demands more analysis time. It is a waste to collect data if they are ignored. Attention must be paid to limiting the data requirements to both the necessary detail and frequency and to consider whether the data is needed for a specific useful purpose, and whether the cost of producing it is not higher than its expected benefit (Bernolak, 1997). A large number of performance measures also increases the risk of information overload. This is also a good reason to remove “old” performance measures that are no longer of interest from the PMS.
- Be easily accessible. A PMS’s main goal is to give important information, at the right time, to the right person. An important point to remember is that the PMS must be designed in such a way that information is easily retrieved, usefully presented and easily understood by those whose performance is being evaluated.
- Consist of performance measures that have comprehensible specifications. A performance measure should have a clear purpose and be defined in an unambiguous way along with details of who will use the measure (e.g. collect the data, with what frequency, and how to act on the measure). Furthermore, it is also necessary to specify a target for each performance measure and a timeframe within which that target should be reached.

Walsh (2006) further recommends that a PM:

- Traceable to key business processes. Each key business process should have at least one KPI. A change in the KPI (a change in the average or variability) should be traceable to a change in the operation of the key process.
- Avoidance of ‘turf protection’. If departmental or business unit performance is made competitive, there will be a temptation for managers to maximize their own

performance at the expense of others. A win-lose situation can result when processes transgress functional boundaries. Such 'turf protection' can be avoided by encouraging cross-functional management and aligning performance indicators with processes, not the functional units which contribute to processes.

- Relevant to all people. Senior and middle managers use performance indicators for strategic and tactical decision-making, while first-line supervisors and the general workforce are concerned with operational decision-making. Performance measurement must therefore reflect the needs of people at different levels of the organization.

What is needed at corporate level may not be relevant at the coal face. Therefore people at all levels must be encouraged to contribute ideas towards what should be measured. Walsh (1999) suggest that Performance Measures (KPIs) can be classified as two types: key performance outcomes (KPOs) and key performance drivers (KPDs). KPOs being those measures which indicate progress towards corporate objectives; they are what is expected from the business. KPDs are those measures which have a direct influence on the outcomes; they are the drivers of outcomes.

Performance Management Models

According to Toni and Tonchia (2001), the main models of PMSs can be classified in one of five typologies:

- (1) PMSs that are strictly hierarchical (or strictly vertical), characterized by cost and non-cost performance on different levels of aggregation, until they ultimately become economic financial.
 - a. Activity Based Costing
- (2) PMSs that are balanced scorecard, where several separate performance measures which correspond to diverse perspectives (financial, customer, etc.), are considered independently.
 - a. Balanced Scorecard
 - b. Sink and Turtle Model
- (3) PMSs that can be called frustum, where there is a synthesis of low-level measures into more aggregated indicators, but without the scope of translating non-cost performance into financial performance.
 - a. Performance Pyramid
- (4) PMSs that distinguish between internal/external performances.

- a. Medori and Steeple's framework
- (5) PMSs that are related to the value chain
- a. Theory of Constraints

Introduction to Productivity Measures

The term productivity is defined as the relation of output (i.e. produced goods) to input (i.e. used resources) in the manufacturing transformation process. Two traditional types of index productivity measures are distinguished (Tagen, 2004):

- (1) Partial productivity measures, ratios of output to one source of input, such as labour, capital, material or energy.
- (2) Total productivity measures, ratios of total output to the sum of all input factors.

Partial Productivity Measures

The most common partial productivity measure is labour productivity (Tagen, 2004), e.g. output per working hour or output per employee. Criticism aimed at this way of calculating productivity argues that terms like labour productivity are becoming useless measures in modern manufacturing operations, since the total direct labour cost is becoming a smaller fraction of the total manufacturing cost (Suh,1990).

It has been the convention to have the efficiency of a CM measured against total tonnage production per shift. This approach is rather too simplistic as that output can be achieved at the expense of other resource areas, such as materials. For example, improving CM productivity can actually hurt the overall profitability by increasing costs in supplies (electricity, water) and materials (CM picks).

Labour productivity can be an appropriate measure if the workforce is a dominating production factor. This is not the case in mining, as it is largely mechanised, and thus productivity measures should be based on the output of the machinery. Coal mining is semi-automatic and would require more multifaceted metrics that will measure the competency of the operator t using the machinery. It is questionable as to whether just measuring the productivity of the labour per shift would contribute to main derivable of increasing production per section.

One can conclude that partial measures do not have the ability to explain overall cost increases, and can be very misleading if they are used alone (Sumanth, 1994) and hence may not be suitable for mining.

Total Productivity Measurement (TPM)

Total productivity measures provide an overall productivity of a process or a company. A major advantage of total productivity measures is that they take account of capital-labour substitution. The disadvantages are that they are more difficult to understand and to measure (Grossman,1993). Due to the difficulties in calculating such measures in practice, they are not always accurate. Total productivity measures are based on a number of more or less carefully supported assumptions, and can produce different results because of the many different ways of weighting the production factors.

It is also more difficult to track activities that improve productivity with total productivity measures. Another weakness lies in that the data needed to calculate the measure becomes more difficult to retrieve.

These shortcomings should not however deter on from vigilantly developing ratios that measure both productivity of machinery (CM, Shuttle Car) and labour (Production, Services). The challenge would be to create a reporting system that would ease the interpretation of ratio. This is made significant by the low literacy levels of front line mining operators.

Time-based Productivity Measures

One possible problem to overcome when measuring productivity is the definition of output and input. At company level, output can, for example, be a single product, but it is also possible that output of a factory is varying models of a single product, or even varying models of a number of individual products. This problem is usually solved by the use of monetary values; however, such a solution results in the measures being influenced by the price recovery factor.

Arnold (1991) suggests that the unit time can be used in the case of several products being produced: Where a variety of products are made, it may be that a common unit does not exist. In this case the unit common to all products is time. The work content of a product is expressed as the time required making the product using a given method of manufacture. Using time study techniques, the standard time for a job can be determined.

Coal produced in coal mining is homogenous and continuously produced. One can however be able to create productivity measures on based the solitary unit of time, the shift which is 10 hours long. The input, outputs and processes can be calculated over the 10 hour or predetermined available time after unpreventable losses have been deducted. The time approach can also be applied to inputs; this has been done by, Jackson and Petersson (1999). Whereby time can be seen as a resource and a completely time-based productivity measure, defined as a ratio between value-adding time and total time can be created. Time productivity measures are applicable to mining, as there is linear relationship between overall coal output and the utilization of time in production section.

Jackson and Peterson, (1999) recommend the use of time-based measures because:

- It is easy to measure;
- It is easy for everyone to understand;
- It facilitates benchmarking between production sections (independent of cost structure).
- It facilitates comparisons between mines in countries (independent of currencies); there is approximately a linear relationship between time and cost. It is questionable if a completely time-based measure can be classified as a real productivity measure, since total time does not provide information about the consumed resources in the production process.

The short coming of the above classification is that it does not say much about the performance measures themselves, i.e. about their "intrinsic dimensions", which do not depend on where and by whom the performance measures are used. A new classification of performance measures involving three intrinsic dimensions is therefore introduced (Flapper et al., 1996).

Process View to Performance Measurement

IBM (Harrington, 1991 p. 45) Unisys, Ford, British Telecom (Jones, 1994) and Sydney Electricity (Walsh, 1995) has adopted a process view of how they conduct business. A process view requires describing the organization in terms of business processes, assigning ownership of these processes and undertaking a strategic improvement plan based on key processes. It requires separating the organizations processes into those which address the needs of customers (e.g. production, outbound logistics) and those which address the needs of the organization (e.g. maintenance, supply management).

Heard (1993) uses the terms delivery and support processes but more common terms are customer and administrative processes. With respect to coal mining, Heard's (1993) expressions of; delivery and support would be appropriate. "Delivery" refers to all internal process inputs directly leading to coal production and consequently the other departments being the "support" processes. All processes must be assigned process owners.

The process view has major implications for the establishment of organization performance measurement systems. It implies that key business processes should be identified before performance indicators are developed and the indicators so developed should be aligned with what is expected from these processes. It suggests that performance indicators are essentially a process issue and the principal purpose of performance measurement is to improve business processes.

The process view further suggests that performance indicators should be aligned primarily with processes and then, if appropriate, with functions. For example, consider the continuous mining process. Downtime during a shift could be as a result non performance or ill performance, of the artisan, CM operator, shuttle car operator, and technician, millwright or supplies departments.

This nonperformance could be individually monitored and the departmental heads held accountable for minimizing departmental downtime times. This might lead to competition between departments as they try to minimize their downtimes at the expense of one another. The important indicator for the organization is not the departmental downtimes but the downtime of the entire production process. If departments work cooperatively towards this goal where the performance indicator is

attached to the entire process and not to the processes of contributing departments, there will be less likelihood of win-lose situations developing among departments.

Overall Equipment Effectiveness

OEE is a simple but yet comprehensive measure of internal efficiency; its revision in my literature study will guide me to finding definitions and metrics for Engineering and Operational Downtime. OEE can work as an important indicator of the continuous improvement process (Jonsson and Lesshammar, 1999). OEE is also an effective way of analysing the efficiency of a single machine or an integrated machinery system (Ljungberg, 1998).

A large proportion of the production losses can be attributed to time losses and other indirect and “hidden” costs. Overall equipment effectiveness (OEE) attempts to reveal these hidden costs (Nakajima, 1988) and when the measure is applied by autonomous small groups on the shop-floor together with quality control tools it is an important complement to the traditional top-down oriented performance measurement systems. The use of OEE emanates within the concept of total productive maintenance (TPM) (Nakajima, 1988). TPM has been widely accepted as a methodology for improving tool operating efficiency. The main goal is to increase equipment efficiency so that each piece of equipment can be operated to its full potential and maintained at that level (Chand and Shirvani, 2000). This goal is measured by using the OEE-ratio. The measure is based on three aspects of performance (Slack.2001):

- The time that it is available to operate;
- The speed, or throughput rate, of the equipment; and
- The quality of the product. Not relevant to scope of the project

The best application area of OEE is limited to semi-automatic and automatic manufacturing processes. Coal mining can be considered to be a semi-automatic manufacturing, as the skill of the operator does have a bearing on the equipment productivity. OEE is not suitable for manual manufacturing processes, since it does not consider the number of workers working in a process and anticipates that there is a fixed ideal cycle time of each machine that controls the maximum processing rate (Nord and Johansson, 1997).

The definition of OEE includes downtime and other production losses that reduce throughput. Three dimensions of effectiveness are recognised in OEE:

- (1) Availability;
- (2) Performance rate;
- (3) Quality rate, not relevant to scope of the project

Limitations of OEE

The definition of OEE does not take into account all factors that reduce the capacity utilisation, e.g. planned downtime, lack of material input, lack of labour etc. (see further, Nakajima (1989)). OEE measurement, alone, does not provide a tool to support improvement programs. The power of OEE is in the linkage of the OEE data to the identification of major equipment losses (Pomorski, 1997). There are also several aspects that OEE does not consider, such as planned downtime and disturbances from incoming material.

Jonsson and Lesshammar (1999) found in a case study of three companies that OEE systems did not measure strategy, flow orientation or external effectiveness to any great extent (Jonsson and Lesshammar, 1999). The most important objective of OEE is not to get an optimum measure, but to get a simple measure that tells the production personnel where to spend their improvement resources.

Measure of OEE

To be able to record key figures and investigate how manufacturing contributes to the overall performance it is of vital importance to measure and understand how to conduct measurements of disturbances in the manufacturing process.

Disturbances can, according to Ljungberg (1997), Nord et al. (1997) and Tajiri and Gotoh (1992), roughly be divided into the two categories, chronic and sporadic, depending on how often they occur. Chronic disturbances are usually small, hidden and complicated because they are the result of several concurrent causes. Sporadic disturbances are more obvious since they occur quickly and as large deviations from the normal state. They occur irregularly and their dramatic effects are often considered to lead to serious problems, but instead there are chronic disturbances that result in the low utilisation of equipment and large costs because they occur repeatedly (Nord et al., 1997).

Availability

The availability measures the total time that the system is not operating because of breakdown, set-up and adjustment, and other stoppages. It indicates the ratio of actual operating time to the planned time available. Planned production time (or loading time) is separated from theoretical production time and measures unplanned downtime in the equipment, i.e. by this definition unavailability would not include time for preventive maintenance. This definition gives rise to planning of preventive activities, such as preventive maintenance, but it might lead to too much maintenance of the equipment and too long set-up times. If planned downtime is included in the production time, the availability would be significantly lower, but the true availability would be shown. That would create motives for decreasing the planned downtime, e.g. through more efficient tools for set-up and more efficient planned maintenance.

The performance rate measures the ratio of actual operating speed of the equipment (i.e. the ideal speed minus speed losses, minor stoppages and idling) and the ideal speed (based on the equipment capacity as initially designed). Nakajima (1988) measures a fixed amount of output, and in his definition (P) indicates the actual deviation in time from ideal cycle time. De Groote (1995), on the other hand, focuses on a fixed time and calculates the deviation in production from planned. Both definitions measure the actual amount of production, but in somewhat different ways.

Downtime Definition

Many enterprises do measure downtime in one way or another. The downtime is often recorded as repair-time. Minor stoppages are usually not considered. Neither are speed losses. This study seeks to answer; what losses should be measured and how should the losses be classified?

Bennett and Jenney (1979) have emphasized the production losses from fixed assets. They have divided failures into types i.e. hydraulic, mechanical, electrical and electronic. Wiendahl and Winkelhake (1988) analysed automated assembly plants focusing on “standstills” in production line and divided those into technical and organisational causes. Ericsson and Dahlén (1993) have divided the downtime in two groups, planned stop and unplanned stop. Further, the downtime was divided into labour, maintenance, set-up and other.

Downtime Data Recording

Most companies have some system for collecting data on machinery disturbance data. Often administrative maintenance systems record the repair time, which is not the same as stoppage time. Further, there exist log books where the operators record major stoppages (Ljungberg, 1998). Anglo Coal uses the latter system of a log book. Neither of those two data collection systems gives, in most cases, an appropriate and comprehensive picture of the losses and their reasons.

To succeed with data collection, it is necessary to find a method that is less time consuming that while also being precise. The method of collecting data for a machine analysis can differ. It can be an automatic data collection, like the onboard PLC system on the CMs or a manual data collection, like the log book filled by the miner. Continuous automatic data collection is a powerful method to increase the equipment's utilisation according to Wiendahl and Winkelhake (1988). Automatic data collection systems tend to be expensive and complex and must be fully integrated in management systems to justify the investment. Manual data collection systems can be very detailed and allow for failures can be carefully examined, (Ljungberg, 1998) if designed properly.

Data Collection

Collection of data about the losses is an important phase of continuous improvement and performance measurement. What has not been measured can not be improved. Critical parameters of the six big losses can be identified by using the existing competence in each process. The data collection should be at such detailed level that it fulfils its objectives without being unnecessarily demanding of resources. A too detailed data collection may result in unmotivated personnel and reaction against the measurement.

Often the forms are designed by someone who does not understand the complexity of production losses, and second, the procedure of filling in is in most cases not easy enough for the operator. A lot of data has to be recorded on a regular basis and calculations have to be made. This task is possible to carry out by the operator in most cases. In the case when operators fill in the form the system is not always working accurately.

Furthermore, in many cases the data is not compiled and analysed at all. When the operator does become aware of this, the motivation of filling in the form decreases considerably.

In some enterprises we have observed a resistance to data collection of losses from operators and foremen. One solution to this problem which has been tested is a two-step model.

When a recurring stoppage occurs, the other operators have to take some action in order to start the machine again. Then the operator does not have time to report the stoppage. To assess the time length of the stoppage the operator should need to have a stop-watch, which is never the case. It is of course not uncommon that the operator forgets to report the stoppages. It is these stoppages that often lead to unaccounted for time. It is impractical and unfair to expect the operators report even short stoppages. Ljungberg (1998) recommends that downtimes be classified according to length in classes e.g. less than 1 min., 1-2 min., 2 -5 min. etc.

Sometimes the process in itself is so complex that it is impossible to avoid a detailed data collection. The data collection can then be facilitated by measuring the actual time of each downtime and speed loss, instead of measuring the frequency of these losses. Measuring the actual time of the losses gives more correct data, but measuring the frequency is often enough. The reason for this is that the most important objective is not to get an optimum measure, but to get a simple measure that tells the production personnel where to spend their improvement resources. Variations that are built into the organisation, such as different shifts and weekdays, have to be considered. There are also variations in the market, such as seasonal demand.

The period for a data collection should be adapted so that these variations are equally considered; this would need to be – per 10 hour shift. The data collection should be carried out by personnel that can affect the measured parameters, the miner, CM operator or section artisan. Nearness is an important aspect in continuous improvement and therefore the result of data collection should not only be summarised to a key figure as a part of the measurement system, it should also be used as input in small group activities (Tangen, 2004).

Downtime Measurement

The reason for enterprises to measure losses is to find reasons for major losses and use this information as a basis for remedies to improve related processes and increase output metrics. Ericsson and Dahlén (1993) state that over 80 per cent of measured disruption were a result of machine downtime; this would typically vary from value chain to value chain but is consistent with mining. Suehiro (1992), supports the argument by saying, idling and minor stoppages stands for 20-30 per cent of downtime in most automated lines. The speed losses are much larger in equipment such as automated machinery, automated assemblers and automated packers (Nakajima, 1989).

Forms for collecting data on disturbance should be developed in co-operation with operators, foremen and production technicians. And if possible verified computerised control systems should be to provide the length of stoppages, as is the case for Anglo Coal.

Computerised systems for collecting data can be very precise, but they cannot always assess the underlying reasons for failures. Further, the computerised systems can be expensive and sometimes difficult to use by engineers, foremen as well as operators. It is, however, often beneficial to put the system in operation as it can give both exact magnitude of the frequency and length of different stoppages. With a computerised system it is possible to force the operator to indicate a code/reason for stoppage before the machine can be started again. If the operator has to select a reason for stoppages before starting the machine again, the number of codes/reasons has to be limited. If not, the operator will tend to press just any code (Ljungberg, 1998).

Ljungberg (1998) further advises that the data collection and the analysis have been performed by specially skilled engineers without involvement of operators. This method is, of course, expensive but it has shown good results, especially when the production equipment is highly complex.

A more cost-effective way is to conduct frequency studies. This can be beneficial if one seeks to achieve a quick overview of the production losses (Ljungberg, 1998). The system used at Anglo Coal combining both automatic and manual data collection has advantages. Another version of the system exists where the operator indicates the number and type of failures while the computerised system indicates the length of

stoppages and the actual cycle time. This provides a system which is not too time-consuming and very precise.

Ljungberg (1998) advises one to design the operator data collection form together with the operator responsible for filling in the form. The forms should be tailor-made to suit the pattern of losses at each machine. Further, the design of the form together with the operator is a good way to commit the operator to fill in the form. The forms should be compiled regularly by the operator, supported by the foreman or engineer. This seems to provide a good basis for success. How losses should be collected and calculated seems easy in theory. However, we have experienced how skilled engineers fail to go from data collection to reliable calculated values of losses.

Initially the procedure of filling in the form and calculating the losses takes some time for the operator. When the operator is used to the system the time for filling in the form and calculating the losses should not be more than 15 minutes a day (Ljungberg, 1998), This time is also a loss to be registered if the calculation is not done during time when the machine is operating.

Theory Productivity Management

The TPM theory has, however, in the last years developed the view of losses from the six major losses to the 16 major losses. Here, losses related to equipment have been divided into eight major losses, see Figure 8. Moreover: losses related to manpower, energy and materials are formulated.

The way of classifying losses have been developed in relation to break down losses, but this classification can also be used when it comes to other losses. The classification can be done in relation to cause, measure, and technology area or time dependence.

Loading Time:

All machinery systems basically have 8,760 hours per year to produce.

Max. Output = 8,760 hours/cycle time per unit of production

This view is in reality rare in manufacturing industries. In the capital goods industry it is indicated that production equipment will be run at a certain number of shifts and this is the base for determining available operation time. When the losses are high or when the demand peaks, it is always possible to increase working hours from two

shifts to three shifts, or to work extensive overtime. Anglo Coal, Greenside makes use of two 10 hour production sections. This then equates to; 20 available hours with 6 day/night shifts per week.

8,760h/years will be referred to as available production time. This time can be reduced by the following losses:

- (1) No operation for legal reasons, i.e. public holidays, public inspections etc.
- (2) No operation for economic reasons, night shifts can be too expensive.
- (3) No operation for reasons as low demand, lack of input factors such as raw material, electricity or other external reasons.

Time losses such as meetings, education and planned maintenance should be omitted from loading time unless these activities are conducted during time periods when production is not desired due to reasons mentioned above under (1)-(3). But if those activities are carried out during normal production hours, which are often the case, they should be regarded as losses equal to other losses (Ljungberg, 1998).

If for example: the planned downtime is 5 per cent of manned hours on average. When the losses of 5 per cent on average have been specified, we will end up with loading or time. Once the loading time is defined, one can then to follow the division of “six major losses” according to Nakajima (1989) or 10 Losses (SEMI).

Loading Time = 8760 hours/year – Unavoidable Losses – Planned Downtime

Or

Loading Time = 24 hours/day – Unavoidable Losses – Planned Downtime

(Ljungberg, 1998) (Operating time = Working hours – planned downtime – downtime losses – set-up time (3))

In many cases, major time losses are not considered as losses, e.g. set-up and adjustments are not regarded as losses (Ljungberg, 1998).

In manufacturing much like coal mining, there are marking out between maintenance and production, where maintenance is responsible for the machines and the unavailability, while the production department is responsible for using equipment.

The maintenance department should use the availability as a measure of how efficient the maintenance department is operating.

Many companies are not aware of and do not focus on performance losses. Performance losses consist of both cycle time losses and minor stoppages. To be able to divide those losses, it is necessary to measure the cycle time or production speed on a regular basis. It could also be beneficial to distinguish between start-up quality losses and process capability losses. This separation is, however, not done in most cases (Ljungberg, 1998).

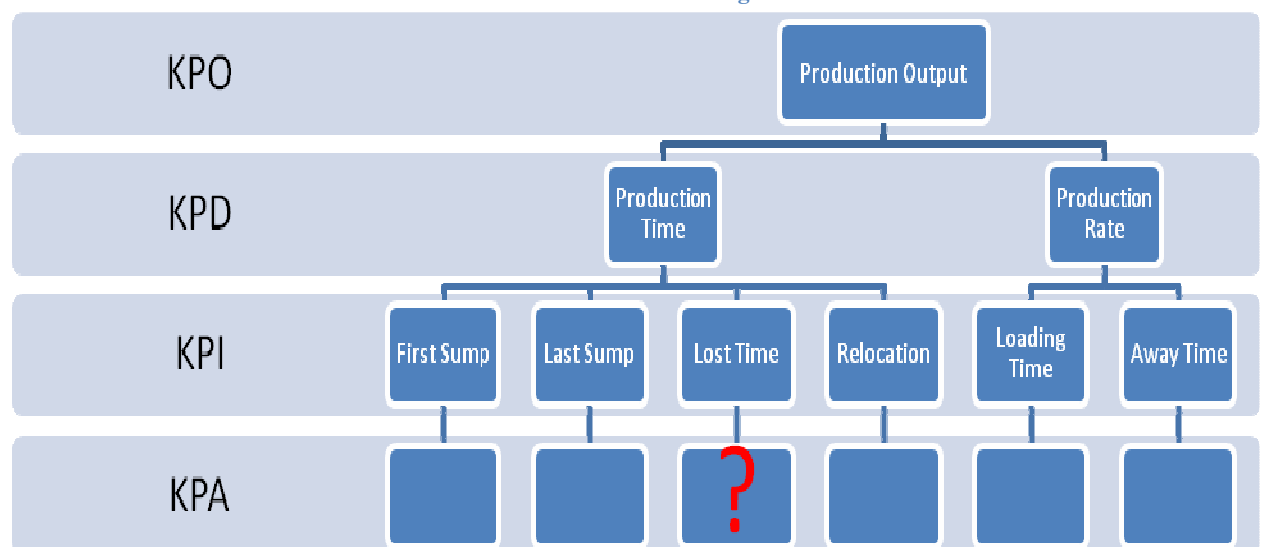
Project Context

The objective of this section is to define, the problem according to the context outline in the literature. The problem statement needs to be contextualised in accordance to terms and language that have been used in solving similar problems.

According to Walsh (1999), organisational Performance Measures (PM) can be classified under two types: key performance outcomes (KPOs) and key performance drivers (KPDs). KPOs being those measures which indicate progress towards corporate objectives; they are what is expected from the business. While KPDs are those measures which have a direct influence on the outcomes; they are the drivers of outcomes.

Chase (2005) argues that in order for management to identify production bottlenecks and untapped value, in the organisation and inter alia, the areas of improvements, a factual base on metrics of KPIs is needed. He further defines a KPI as *a set of measures that help managers evaluate the company's economic performance and spot the need for changes in operations*. These KPIs highlight areas or operational facets within the organisation that must and should be monitored. The monitoring and the communication of the results should allow management to make and validate decisions taken from a well defined factual base. All KPIs should be aligned and also enhance the strategic objective of the organisation. This can be summarised as “IF THERE IS NO MEASUREMENT, THERE IS NO CONTROL.” (Vuuren, 2005) and “what we can't control we can't improve”.

Figure 4 - KPO vs KPD vs KPI vs KPA



The underground production sections have strategically selected the 6 Key Performance Indicators (KPIs) that are linked to two Key Performance Drivers (KPDs) production time and production rate as indicated in Figure 4. The Pick Six is recognized as the six strategic production KPIs that must be monitored and controlled with the intention of improving by means of process reengineering in order to increase production time and production rate, the KPDs. An improvement in the production section's KPDs will invariably lead to an improvement in the mines Key Performance Outcome (KPO), overall coal production. The KPO is measured by the metric (tonnes/unit time).

The two KPDs, Production Time and Production Rate were identified with intent as the main value adding drivers, and that more or others could have been selected. It is prudent for every manger, line and support, in the mine to only focus on improving **Production Time** and **Production Rate** within his/her department with the conviction that these KPDs are indeed leading indicators for the lagging KPO, Production Output. Within that context, the pick six KPIs were developed to compile a fact base through which Production Rate and Production Time can be monitored to ascertain operations performance standards and gaps and allow for benchmarking within sections and progress towards KPD and KPO targets.

Informed by the above, and the project aim, operational sub-processes that have an expressive impact on the Pick Six should be illuminated (*refer to figure 5*). While it is possible to measure and report, on these sub-processes, their measurement and control should always be guided by the context of them arising from the already existing KPIs. This project will search for such aforementioned processes that contribute to the pick six, KPIs, and special impetus on those impacting on **Lost Time**. These sub-processes will henceforth be referred to as Key Performance Areas (KPAs).

The table below summarises the terms, KPO, KPD, KPI and the term defined as KPA

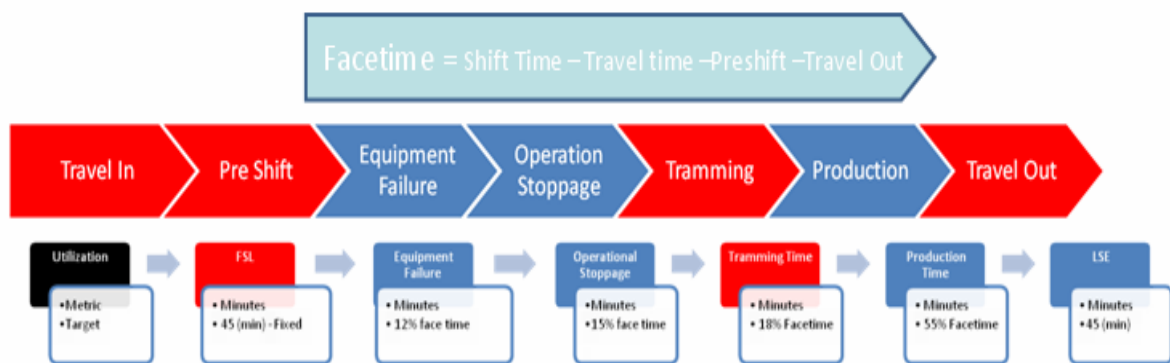
Table 2 - KPO, KPD, KPI, KPA

	Definition	Lagging/ Leading	Management Control	Example
KPO	Outcome measures that are results of past actions and aligned to organizational strategy	Lagging Measures for KPD	Strategic: Every person in the organization can directly effect KPO	Production Output
KPD	Measures of drivers of future dated performance, that aligned to strategy that will directly affect organizational performance outcome	Leading Measures for KPO and Lagging Measure for KPI	Strategic: Every Department, line and support must strategically identify KPIs that will affect the chosen KPDs	Production Time/ Production Rate
KPI	Set of metrics used to measure organizational performance at a tactical level. Every Departments' KPIs must be aligned with the overalls KPD and should derived from a function or process	Leading Measures for KPD and Lagging Measure for KPA	Tactical: Performance from department to department that changes from shift to shift that can be influenced by the department's workers.	Operations: First Sump, Lost Time, Relocation, Loading Time, Away Time. Engineering: MTBF, MTTB, Availability, Fault Finding Time Support: Lead Time of Delivery, No supplies in section
KPA	Tactical sub-operations, that contribute to action or process measured by KPIs. KPA cannot always be measured, but must be monitored and controlled if KPIs are to improve	Leading Measures for KPI and	Tactical: Process operations and occurrences that do influence metrics of pre-selected KPIs of department	First Sump: Leave surface time, traveling distance, distances of from bus stop. Away time: Ground Condition, Distance from feeder breaker Lost Time: Belt extension, Pick Changes, Cleaning Scrubber Fan.

Fact Base: As-Is

One of the main project deliverables is to identify critical areas of lost time. These being all stoppages that arise from the time of first sump and till last sump in shift time. The process that needs to be understood was the **production process**, special consideration being paid the process flow and functional relationships that exists with the front end production section. Further, to understand the casual causes and effects of the lost production, the process that seeks to capture this process must also be mapped out (*refer to figure 5*).

Figure 5 - Process vs KPI



1. Section Layout - Appendix A
2. Section Equipment - Appendix B
3. Section Personnel – Appendix C

The appendix contains detailed fact files of each of the components the production value chain.

In the months prior to and during the time the study was conducted all sections were consistently been able to reach and exceed production targets. These production targets are derived from the forecasted budget cost of operating a production section. This target is then divided by the forecasted market price of the coal needed to be mined, divided by the number of expected shifts in the financial year.

Table 3-Production Rate vs. Time

Section	Prod time/Shift (min)		Prod rate tons/hour	
	Target	(June 2007-2008)	Target	(June 2007-2008)
Thandeka	274	216	456	589
Vumagara	262	219	450	514
George	265	195	456	519
Thusanang	223	206	450	577

As indicated in table 3, which averages the production time and rate for the four sections from June 2007-June 2008, all sections have reached their targets by only increasing the production rates. This was achieved through value adding process reengineering and subsequent training on improving the loading and away times in the sections. However, the question still remains, “why are the sections not reaching the production time target?”

From qualitative studies and knowledge, it becomes apparent that sections were not reaching production time targets as result of poor downtime management. This hypothesis was further supported by the quantitative study (*Table 4*), reaffirms that indeed the section are consistently unable to reach the production time targets as a results of time lost in non value adding actions.

Table 4-lost time/shift per section

	Target	Historical	Feb	Mar	Apr	May	Trend
Thandeka	105	135	123	84	119	126	117
Vumagra	105	172	183	176	150	125	161
George	105	172	169	214	155	150	172
Thusanang	105	114	108	161	84	166	172

The table illustrates the latest trends for downtimes in the latest 4 consecutive months. The table communicates the consistence inability of the Greenside production sections in reaching the allocated target of 105 lost minutes. The relationship between doentime stoppages and production stoppages is depicted schematically in figure 5.

Problem One: Definition of Lost Time

Introduction

While there was generally understood definition of Lost Time in the organization, which encompassed only in shift engineering stoppages and operations, there is need a formal and standard definition across the organization. This definition shall form the basis in which, one can be able to determine the suitability of the KPIs and the critical lost time areas.

Literature Synopsis

Downtime or outage refers to a period of time or a percentage of a time span that a system is unavailable or offline. This is as a result of the system failing to function because of an unplanned event, or because of routine maintenance. The term is commonly applied to networks and servers. The common reasons for unplanned outages are system failures (such as a crash) or communications failures (commonly known as network outage). (IEEE)

In organizational management, mean down time (MDT) is the average time that a system is non-operational. This includes all time associated with repair, corrective and preventive maintenance, self imposed downtime, and any logistics or administrative delays. The difference between MDT and MTTR (mean time to repair) is that MDT includes any and all delays involved; MTTR looks solely at repair time.

Nakajima (1988) however suggest that lost time can be defined as “Chronic and sporadic disturbances in the manufacturing process result in different kinds of waste or losses”. Further definition these activities as being “activities which absorb resources, but create no value”. These being classified under six big loss classes:

Downtime losses

- (1) Breakdown losses categorised as time losses when productivity is reduced, and quantity losses caused by defective equipment.
- (2) Set-up and adjustment losses result from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item.

Speed losses

- (3) Idling and minor stoppage losses occur when production is interrupted by a temporary malfunction or when a machine is idling.
- (4) Reduced speed losses refer to the difference between equipment design speed and actual operating speed.

Quality losses

(5) Quality defects and rework are losses in quality caused by malfunctioning production equipment.

(6) Start-up losses are yield losses that occur during the early stages of production, from machine start-up to stabilisation.

Nakajima (1988) Further suggests that in the study of losses distinctions should be made between: Causation, Measure of the downtime, and technology area that caused the downtime and time dependence of that particular downtime.

Figure 6- Nakajima's (1988) Downtime Classification

Cause	Measure	Technology area	Time dependency
Operator	Maintenance mechanic	Mechanical	Time dependent
Hardware	Maintenance electric	Electronic	Non-time dependent
Software	Production	Electrical	Irregular stop
Adjustment	External	Hydraulic	Process failure
Design		Pneumatic	

The Semiconductor Equipment and Materials International (SEMI E 10-92 1992) has chosen to classify time losses under:

1. **Non Scheduled Time:** Time duration for which equipment for which equipment is not scheduled to operate. i.e holidays, weekends
2. **Scheduled Maintenance Time:** Time spent on preventative maintenance on equipment. i.e. maintenance time.
3. **Unscheduled maintenance time:** Time spent on breakdown. i.e Broken torque shat, damaged cable.
4. **R n D:** Time spent for purpose of research and development. i.e equipment on standby due to tests.
5. **Engineering Usage Time:** Time spent during operation for routine check ups on equipment state. i.e In shift inspection of CM and SC.
6. **Setup and adjustment:** Time spent preparing equipment and making necessary adjustments prior or during shifts. i.e tramming, cable handling, pick changes

7. **WIP starvation time:** Time when equipment is in operation but there is no WIP to process. i.e dykes in face.
8. **Idle time with no operator:** Time for which, WIP is ready but there is no operator ready. i.e absent or late CM, SC or RB operator.
9. **Speed Loss:** Time lost due to equipment operating under standard speed.
10. **Quality loss:** Time for which equipment is operating for unqualified products. i.e cutting into hard coal.

Barrow (2003) further infers that analyses of lost time should be based on root causes analyses which have the following origins.

- **Man:** We stop producing because manpower is not available Absenteeism, Injury or artisan or electrician is not available
- **Machine:** Stop Production because there is no machinery available to produce, breakdown
- **Utilities:** Stop because the utilities needed to produce are not available
- **Raw Material:** Stop when there isn't enough coal in proper condition to be mined.
- **Environmental:** We are forced to stop because environment does not allow for production to carry on, either legislation or policy.

Downtime can be summarised as being: a period of time or a percentage of a time span that a machine or system is offline or not functioning.

Findings

Within Anglo Coal, the terms "Downtime" and "Lost Time" are used interchangeably to consign all production time "lost" as a result to "engineering" or "operational" stoppages. This definition is based on the premise that any downtime is caused by malpractice by other the engineering or operations crew in the section. "Engineering breakdowns will not occur if the engineering team does their job" like wise and conversely the same could apply to operations.

Downtime is further recorded and reported in the frontline, in the miner's report and faceboss report respectively. The "bucket allocation" for the respective downtimes is under the following heading:

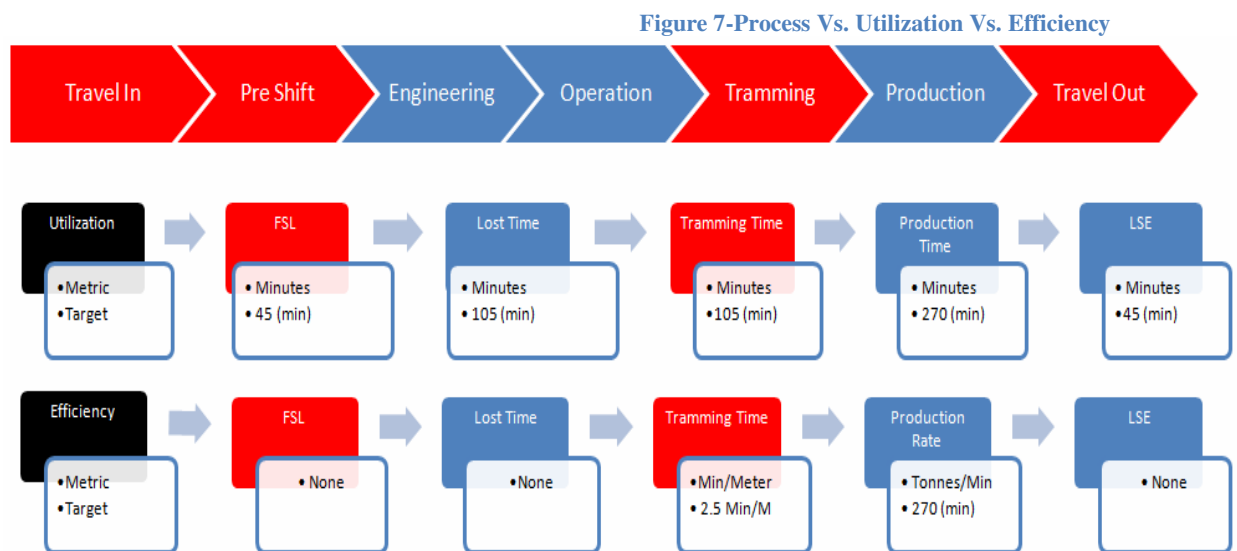
1. Engineering Downtime: All stoppages of moving frontline machinery as a result of unforeseeable and unforced breakdowns. The machines include, are the CM, SC, RB and FB.
2. Operational Downtime: All stoppages of frontline equipment exclusive to engineering stoppages. This includes breakdowns of machinery as a result of operator "negligence", operator commissions and omissions and process based stoppages. The machines included CM, SC, RB and FB.
3. Section belt Downtime: Any and all stoppages that result in the section belt stopping for more than 2 min
4. Trunk Conveyor Downtime: Any and all stoppages that result in the section belt stopping for more than 2 min
5. Outside Downtime: Any and all stoppages arising from an event or failure of equipment outside of the geographical confines of the sections.

This assertion is indeed flawed on a number of grounds.

1. This leads to turf protection and sub-optimisation when downtimes keep moving from either engineering, operations or late/early start of shift.
2. Occasionally it becomes difficult to determine the exact trigger of the breakdown.
3. Breakdowns of the RB and SC do not necessarily result in the stoppage in production, as Nakajima's (1988) definition suggests. If either the RB and SC breakdown, the production rate is affected but not the production time. The previous definition did not seek to distinguish stoppages of non value chain machinery, and their impact on production. Hence reports are abundant that, erroneously recorded breakdowns of roof bolters as being downtime. The breakdown of shuttle cars are erroneously recorded as downtimes, this application is indeed flawed and misleading as the breakdown of one or two shuttle cars do not in any way affect production time, but rather production rate.

Emphasis should not be who exactly caused by the breakdown, but who and how quickly it takes to rectify a breakdown.

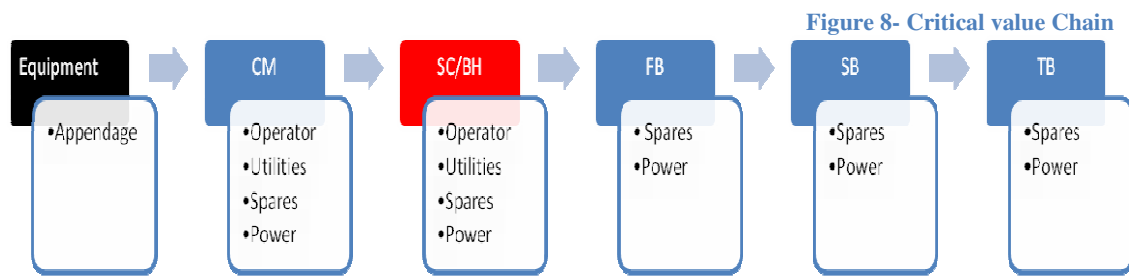
The current buck allocation allows for double booking or penalisation. If a section has a first sump late, it is most likely all the Performance Indices will also be negative; this is fundamentally flawed as it doesn't give a true reflection on sections performance relative to its available Facetime.



The table above summarises the current definition of time allocation is the section and the respective targets. Lost time, as by definition includes only engineering and operational downtime and a target of 105 is assigned for both stoppages.

Within the context, one can therefore understand the inherent system capacity as being a product of value chain throughput bottle neck capacity rate and the production time available. This bottleneck capacity is know in underground mining to be the lie between the CM and shuttle car. The metric used is tons per minute. This capacity is a function of the CMs loading rate on the shuttle car and size of the size of the shuttle.

If indeed time is a resource that should be exploited, and KPIs are put in place to measure that utilisation, it is important that such KPIs do indeed measure the specific process, only from start to finish. KPIs should not overlap, leading to double penalisation. An example is the fact that while, there is KPIs to pre-shift time utilisation, in the first sump and its target, it does to make any sense at all to improvements in either utilisation or efficiency measures present considerable benefits.



Understanding, that downtime is best defined relative to the production process, of which production only occurs when all components of the system are operational. One there can conclude that the uptime and downtime of the critical components of the system is exact to that to that of the system.

If either, the CN, FB, SB or TB and the critical appendages as indicated in figure 6 are down, there entire section cannot produce.

Understanding that, these four machines and there appendages will hence be referred to as the critical value chain (CVC).

Recommendations

Production Downtime definition:

Any and all event of commission or omission, by man, machine or material that results in cessation in the primary function of the primary machine in the critical value chain during a time allocated for production.

Meaning

Any and all events, that result the Continuous Miner to stop cutting or loading in the shuttle cars.

Rules for down classification:

Distinction should be made between equipment downtime and value chain downtime.

- Only value chain downtime should be reported in the Faceboss Report, meaning the duration of time to which the primary machine and/or the CVC as indicated in figure constitutes downtime.
- Downtime should be classified as either: *Detail Provided in findings*
 1. Equipment Breakdown: Unplanned and unforeseen stoppages resulting from damage of CVC. The time lapse from the initial damage of equipment to time when machine is available for operation. Time for fault finding, waiting for spares, repairing and testing should be recorded separately. *Appendix D*

2. Operational Process Stoppages: Planned and reasonably foreseeable stoppages in production to accommodate routine check ups or equipment setups and process adjustments in the section.
 3. Other non process stoppages: Unplanned and unforeseen stoppages resulting from events or actions outside of section management influence.
- Specific Equipment Downtime must be recorded but must be reported against the specific machine in a separate engineering report or shiftboss report.
 - Stoppages of roofbotlers should under no circumstances be classified as downtime, unless the breakdown of such leads to the cessation of CM primary function (cutting or loading).
 - Stoppages of one or two Shuttle cars should under no circumstances be classified as production (value chain) downtime.
 1. The stoppages can only be classified as downtime, if such results in the obstruction of path or some other reason such breakdown leads to the stoppage in the CM primary activity.
 2. In the event that production stops because all three shuttle cars are on stop, and consequently leading the stoppage in production. Such a stop will be referred to as CM downtime.

Problem Two: Suitability of Current Functional Key Performance Indicators

Background:

The first objective was to ascertain, whether indeed, the current set of production KPIs is suitable in measuring and communication shift activities. To determine such, the KPIs were compared against industry best practices and assessed against such benchmark adapted from Tangen (2002).

1. **KPIs should support a strategic objective.** *It should be derived from the company's strategic objectives. Otherwise, the PMS may support actions that have the opposite effect of those implied in the strategy. Since strategies usually change over time and when a strategy does change, some performance measures must change too. Therefore PMSs must be flexible and at all times coherent with the objectives of the company.*

The KPIs do not at face value seem to support the organizational strategy, as the overall organizational strategy is based on increasing operating profit. An argument can therefore be made, that KPIs should in fact contain financial metrics that include cost of mining and real income generated per production section. However after reflection on the context of the operating environment, as well as following the balanced scorecard framework that seeks to assign four performance areas namely;

1. Financial View, Overall company financial performance
2. Customer View, how do we look to our customers
3. Internal Process View, how well do we do our business
4. Learning and growth, how well do we improve

One can conversely argue that **frontline production** KPIs do indeed support the overall company's objectives, as front line production sections are in fact primary internal process drivers in the organization. Anglo Coal as a business unit set itself a target of increasing profits from its realised profit of R414 million in 2007 (Anglo America, 2007) by increasing its process output by 80-85 million tons/year. CMIG, hence made a commitment to improving underground continuous mining production by 15% in 5 years (Barrads, 2007), this inline with the strategic objective of the organisation at an operational level.

Greenside further went on an embarked on an ambitious project that sought to improve production by 3% during 2007, 8% during 2008 and a further 4% in the first half of 2009. This was realized when Greenside showed a 4.3% improvement on the 2007 baseline, which was 1.3% higher than the set target. As of June 2008 production was projected up 0.6%. This can largely be attributed to the constant monitoring of loading time and loading and innovation and training involved which has paid dividend. Through this analysis, one can conclude that, the internal process performance KPIs do indeed support organizational strategy.

2. **KPIs should an appropriate balance.** *A PMS should consist of various types of performance measures covering all important aspects agreed as representing the success of the company. There must in turn be a balance between the various performance measures in the PMS. A PMS should be appropriately focused on short- and long-term results, different types of performances (e.g. cost, quality, delivery, flexibility and dependability), various perspectives (e.g. the customer, the shareholder, the competitor, the internal and the innovativeness perspective), and various organizational levels (e.g. global and local performance).*

3. **A good PMS should have KPIs traceable to key business processes.** *Each key business process should have at least one KPI. A change in the KPI (a change in the average or variability) should be traceable to a change in the operation of the key process*

The balance of the front line KPIs can best be critiqued against the KPIs ability to measure the performance of frontline production CVC. The measurement and the communication of these are treated as completely mutually exclusive exercises. This is important, as while the measurement at process performance mat be important performance, its communication may however not prove to be worth while to communicate to the entire frontline production crew.

1. **Cost is a measure of the process to perform at the right cost,** is measured, as the cost of producing a metric Tonne of coal per unit of production. While this information is important for manage, its communication to frontline production my prove rather redundant and confusing at the worst. I

recommend that cost metrics be communicated from shift boss level. The malaise that espouses the belief that “production at all costs” is fundamentally flawed. Shareholders are not interested in the coal produced, but rather in the money made.

2. **Quality is a measure of the process to deliver the right “form”**, the quality of coal produced is measured relative to the ability to meet customers, ash, sulphur, and energy content per gram. Again, while this may be important for overall organisational PM, it is not a direct internal process measurement the production section can control. I would however recommend that a contamination of coal produced be monitored and reported from shift boss level. Contamination can result of pick or other debris mixing with coal in its journey in the supply chain.
3. **Delivery** is the measure the ability of the process to deliver the right quantity at the right time. This is adequately measured and correctly reported to the front line production crew in the form of the Face boss. The leading delivery KPIs is a measure of production/shift. This is supplemented by, lagging indicators. These are divided into those related to time usage measures (non value adding process efficiency) and value adding process efficiency measures. Time usage measures include (start of shift), end of shift, tramming time and downtime. Efficiency measures include, loading time, away time.
4. **Flexibility is a measure of ability of process to adapt to changes to a variation to inputs and environment.** There are no measures that speak specifically with process flexibility. This is largely due to the belief that frontline production is erratic. This erratic nature of coal mining does indeed prove to be the Achilles heel of any PMS in coal mining. By any standard, the results of a performance measurement exercise allows one to compare performance production units, crews within production units and the same production units over time. This exercise however cannot be as easily extrapolated from the manufacturing realm and implanted in mining due to erratic nature. The change in mining sequences, ground condition, crew experience, machine age, stage in mining sequence, type of coal, seam height are all but some of the reasons, that disproves any exercise that seeks to do any

comparative study. Arguments can then arise that seek to question the relevance and value of measuring process performance.

5. Dependability is the system to consistently deliver on the process outcomes. The current PMS has a measure on the dependability of the sections equipment. Engineering services are measures against the machines MTTF, availability and reliability. While this is standard and progressive. The entire value frontlines' dependability can be measures against, the consistent ability of production unit to meet and exceed levels of performance. It has often been remarked that coal mining is not necessarily a trade, but a team sport. A team's mental state and morale has huge impact on overall performance. Crews fall in and out off form, on a good day can cut nothing and on a god sent day can break records. The mark of a good team however is not its ability to mash production records over a shift, but rather its ability to consistently perform above average and keep form. It therefore becomes import for the PMS to be reflective of this mantra.

A. A detailed Data Envelope Analyses study be done that will seek to scientifically weight in the effect of each reason that causes variability. This study, can conducted over two phases. Over a year, an industrial engineer or team, do an coloration study to determine the correlations between any changes in the variables and its effects on the pick six, production rate, production time and culminating in the overall production. This can be followed up, by the by and the building of a mathematical computer model that will automatically factor in changes in one the variables.

B. A process based Performance Management System be developed. This recording and reporting system will record performance relative to process activities and not necessarily against shift activities. The pick six will be communicated relative to the stage of mining sequence. E.g Trammig and number of stoppages can be better analyses relative to the stage of mining sequence. This report should not necessarily replace the shift report but must supplement it. It should form the bases of discussion between the shiftboss and miner, after the mining sequence has been completed.

C. Retain the current recording and reporting system in structure and form. However, efforts must be put in place to ensure that the information contained in the faceboss and other KPI reports is as precise and accurate as far possible. Precise but inaccurate data is as misleading as inaccurate but precise data. An elegant solution effective downtime to narrow the scope of measurement to the area of greatest influence. This is extremely valuable in downtime management. The rest of the document will speak at length with regard to this recommendation.

4. **PMS should guard against sub-optimisation.** *An improper set of measurements for employees can lead to dysfunctional or unanticipated behaviour (Fry, 1995). Sometimes employees seeking to improve the measure of their performance often make decisions that are contrary to the desires of management. Occasionally, an improvement in one area leads to deterioration in another, even resulting in a decline in overall performance. Skinner (1986) termed this phenomenon the “productivity paradox”, where dysfunctional behavior results from poor performance measures. A PMS must guard against sub-optimisation, possibly by establishing a clear link from the top of the company all the way to the bottom, to ensure that employee behavior is consistent with corporate goals.*

5. **A good PMS guards against of `turf protection`.** *If departmental or business unit performance is made competitive, there will be a temptation for managers to maximize their own performance at the expense of others. A win- lose situation can result when processes transgress functional boundaries. Such `turf protection` can be avoided by encouraging cross-functional management and aligning performance indicators with processes, not the functional units which contribute to processes.*

Frontline production teams consist of 11 or 12 crew members as described in item, refer to appendix A. The frontline production crew can however be divided into engineering and mining operations. This allocation of responsibilities is also reflected in the retrospective allocation of downtime minutes to either or the other. The current

Lost Classification system, assigns Lost Time as either being caused by engineering or operational downtime. This definition is indeed very narrow and exposes the section to sub-optimisation. Through such narrow definitions, downtime can easily be shifted from one team to another. Lost time should not be based on the person's direct casualty, but rather to process performance or supply chain. To say 40% of our lost times, is caused by Engineering Downtime, is less informative than saying 40% of our stoppages of equipment failure.

Noting the above, one recommends, that Lost time names and allocation be changed to:

1. Operational Stoppages: All process related stoppages that are inherent with the mining process. The stoppages are stoppages that are reasonably anticipated or planned.
2. Equipment Failure: All stoppages resulting from unplanned or unforeseen stoppages.

A short list of downtime codes that fall within each category is available further in the report.

6. **PMS should have a limited number of performance measures.**
More measurement demands more analysis time. It is a waste to collect data if they are ignored. Attention must be paid to limiting the data requirements to both the necessary detail and frequency and to consider whether the data is needed for a specific useful purpose, and whether the cost of producing it is not higher than its expected benefit (Bernolak, 1997). A large number of performance measures also increases the risk of information overload. This is also a good reason to remove "old" performance measures that are no longer of interest from the PMS.

The data needed for the Faceboss report is collected from three sources:

1. Miners shift report, which is filled in manually. This report records, the start of shift, end of shift, and shift stoppages. The stoppages, must give account to the description of the stoppage, the start, end and duration. The miners report also

requires the miner to fill in, pick and bolt usage, mining plan layout during shift more.

2. The miner also has to call, the control room on an hourly basis to give a status report. It is during this time that the miner can give account to the start of shift, stoppages that occurred.
3. The onboard PLC JNA 2 systems have the capability to record the first sump time and last sump time. The PLC system can also record, loading time and away time.

The total quantum of data that is required to be communicated in the three systems is rather cumbersome. There is duplication, in that some KPIs are recorded twice, but only one version is recorded officially.

One can resolve and recommend:

1. The miners reports be redesigned, repetitive elements be removed
2. The system of recording and reporting Lost Time causes should be streamlined, by only recording the most prevalent causes of stoppages both accurately and precisely. The, prevalence of stoppages will be reported further on in the report.
3. The CM operator, be capacitate with a “notebook” downtime recorder to record any stoppages in the critical value chain.
4. An on board PLC system with restart mechanism which requires a downtime reason before resume of operation. This can be mounted on the CM screen.
7. **KPIs should be easily accessible:** *A PMS’s main goal is to give important information, at the right time, to the right person. An important point to remember is that the PMS must be designed in such a way that information is easily retrieved, usefully presented and easily understood by those whose performance is being evaluated.*

The reporting of KPIs in frontline sections is through three media.

1. Faceboss report (Appendix A), of which the faceboss is expected to collect from the control room and communicate to the crew in the safety meeting as indicated in the information flowchart (Appendix B). Instances are prevalent where these Faceboss reports are not collected and hence communicated in the safety meeting.
2. The Faceboss report is sometimes read out and the meters cut, loading time, away time, production time are written on the section notice boards (Appendix C). These whiteboard notice boards are not always updated.
3. Downtimes graphs are pinned up in the section waiting area. These communicate a section or mines performance on any of the companies KPIs. This include safety, environmental, overall production, new SOPs.

One can resolve and recommend:

1. All Faceboss reports must be emailed to the incoming shift boss, prior to the miner setting foot underground. The discussion of the faceboss boss report **must** form part of the agenda between the faceboss and shiftboss prior to the start of shift. By doing such, one can assure that all Faceboss reports are printed by the faceboss and that the face boss does in fact understand the contents.
2. The notice board layout allocation in the waiting area must redesign. A notice boards must be divided for; Safety, Environment, Operations, Engineering. These should have, each should have CI reports, Memos and SOPs.
3. All CI reports, SOPs and Memos should be printed and distributed on Anglo Coal Greenside templates. This template should be made available to all line managers. The authorisation to use the notice board should be sought from the Mining Planning Manger. Under no circumstance will any communication that does not meet these requirements be sent under ground.

8. **PMS should consist of performance measures that have comprehensible specifications.** *A performance measure should have a clear purpose and be defined in an unambiguous way along with details of who will use the measure (e.g. collect the data, with what frequency, and how to act on the measure). Furthermore, it is also necessary to specify a target for each performance measure and a timeframe within which that target should be reached*

9. **The KPIs should be relevant to all people.** *Senior and middle managers use performance indicators for strategic and tactical decision-making, while first-line supervisors and the general workforce are concerned with operational decision-making. Performance measurement must therefore reflect the needs of people at different levels of the organization.*

The current set of Frontline KPIs are indeed relevant. The metrics are also quite comprehensible. The efforts made to educate crews via the MCS course do indeed prove valuable as they increase both the comprehension of the metrics and their use. This is made evident by the fact that section production rates have consistently increase since that training started. However, the metrics used to measure tramming efficiency, Average Tram time Per 12m cut, is perhaps questionable. Empirical evidence, suggests that it not understood or perhaps irrelevant for the frontline production crew. The electrical trips metrics contained in the faceboss report do not, according my findings have any relevance to the production.

One can resolve and recommend

Electrical metrics be removed from the faceboss report together with the tramming per 12m cut. If need be the electrical reports can be included in a **foreman's report** which can be discussed prior to shift by the foreman, electrician and fitter. The foreman's report should contain a detailed report of equipment failures, a reconciled audit of section spares and tools.

10. **A PMS should have appropriate balance between data accuracy and precision.** Accuracy is the measure of the absolute correctness of data recorded, relative to the true account. While preciseness is detail to which data is recorded to.

Further Noting:

If a section stopped the CM for 1:10:23 hours. That being 1 hour, 10 minutes, and 23 seconds but the miner records it as being 1h10 one can be relatively satisfied with the accuracy of the recording. Conversely, another recording could be made of the very same stoppage, but recording as 1:23:14. While the second recording may be more precise, in that the seconds are recorded and hence more information, it far less

accurate and conversely less useful than the less precise but accurate recording of 1:10. Conversely, it does not suffice if 10 pick changes that in actual fact range from 35m to 1h10, are all rounded off to 1 hour as is the case. This unfortunately doesn't give a proper indication of the real process performance.

At this stage empirical evidence suggests that the margin of error could be between 15% -50%. There is a converse relationship between the length of stoppage and size of error. The smaller the stoppage; the percentage larger the error. The larger the stoppage, the smaller percentage the error.

One can resolve and recommend:

A threshold value of accuracy 10% margin of error to be created as an acceptable level. Once the process indicates more accuracy, this target can be lower, to a more acceptable level.

1. To improve the accuracy, only stoppages that account for 80% of the stoppages be recorded to acceptable level of preciseness. The preciseness should be to the closest minute. The list of the top Pareto stoppages is presented further in the report.
2. Stoppages which do not fall within the bracket of stoppages should be recorded in a check box system with 10 minutes increments. An example is provided in appendix D.

Problem Three: Determine Critical Areas of Lost Time

A study of the lost time, suggests that the scope of improvement is far-reaching. The most generic sources that consume into the lost time are known generally, but not specifically. It is this mysterious lost time that must be properly recorded with the intent of resolving. The scope of the report is limited only to identifying these and not necessarily remedying the downtime.

That Anglo Coal already has classified stoppages under the following classes:

Engineering Stoppages:

- **Boiler:** Mechanical damage to body panel of equipment
- **Electrical:** Damage of or severance of equipment from power source
- **Hydraulic:** Damage of hydraulic manoeuvred pondage in equipment
- **Mechanical:** Physical damage to equipment mobile parts
- **Instruments:** Damage related to computerised PLC systems
- **Maintenance:** Planned stoppages to do routine or major maintenance

Operational Downtime:

- Stoppages related to equipment failure due to operator negligence
- Stoppages related to process stoppages
- Holidays, Sundays, Industrial Action

These stoppages which were developed over extensive work studies have been able to great extent cover all possible reasons for production downtime. This is given credence by the fact that over 90+ codes have been developed to cover all possible reasons that may cause a stoppage (*Appendix F*). A need has arisen to perhaps question whether “which of these codes should be recorded, analysed and recorded?” The benefits of the controlling these KPAs must outweigh the cost. It is for these on KPAs must be identified and elegantly controlled with the intent making a impact in reducing total lost time.

Noting that downtime has been defined as being:

Any and all event of commission or omission, by man, machine or material that results in cessation in the primary function of the primary machine in the critical value chain during a time allocated for production.

By definition, stoppages as a result of holidays, Sundays, maintenance and industrial action were not monitored as they by the broad definition do not qualify as Production Downtime. Further more, equipment standby during testing was excluded, as it does not reduce production time.

In the analyses, emphasis was put on measuring downtime durations instead of occurrences. This is based on the general understanding of the positive coloration that exists between downtime durations and occurrences. Furthermore; guided by the project aim, the intention is to reduce downtime durations with the intent of increasing net production time.

The methodology followed was to first examine if indeed there existed Pareto distributions with reference to downtimes in the sections. This was based on a qualitative understanding that there are critical downtime areas that contribute the most of the downtimes and it is these that must be monitored and investigated at a later stage for opportunities of improvement.

Twelve successive shifts were spent, amounting 52 hours underground doing work studies around the various sections in Greenside. In this time period, interviews were done with frontline management to answer the question. Informed by both the work study and statistical data the following study was done.

Section Comparison

Studies conducted in the four different sections. Downtimes recorded from June 2007 – June 2008 were perused with the objective to determine the most prevalent downtime occurrence in each of the four production sections. Each section was studied independently so as to allow for benchmarking of findings.

Stoppages related to maintenance and holidays were not considered. From a list of possible 50+ possible reasons Pareto tables we constructed which yielded the following results:

Table 5-Vumagara of Downtime

Vumagara Downtime Patterns						
Code	Description	Function	Duration	Contribution	Cumulative	
1	OCRE	Cable Handling	Operation	304.19	15.15%	15.15%
2	OCDO	Trailing Cable Damage	Breakdown	198.00	9.86%	25.01%
3	ECON	Electric Control Damage	Breakdown	181.96	9.06%	34.07%
4	DOEM	Tramming	Operation	170.03	8.47%	42.54%
5	DOGT	Pick Replacement	Operation	127.44	6.35%	48.89%
6	DOAC	Operator Damage	Breakdown	122.39	6.10%	54.98%
7	DONO	No Operator	Other	88.33	4.40%	59.38%
8	DOCV	Conveyor Damage	Breakdown	74.55	3.71%	63.09%
9	EM01	Electric Motor Damage	Breakdown	73.86	3.68%	66.77%
10	DSTK	Stuck	Breakdown	60.10	2.99%	69.77%
11	MCHN	Mechanical	Breakdown	50.48	2.51%	72.28%
12	DOPS	Water System	Breakdown	50.00	2.49%	74.77%
13	HHOS	Hydraulic System	Breakdown	41.94	2.09%	76.86%
14	OSWE	Sweeping	Operation	38.91	1.94%	78.80%
15	DODP	Water System	Breakdown	36.62	1.82%	80.62%

Figure 9-Thandeka Downtime

Thandeka Downtime Patterns						
Code	Description	Function	Duration	Contribution	Cumulative	
1	OCDO	Cable Damage	Breakdown	163.17	10.15%	10.15%
2	DOAC	Operator Damage	Breakdown	153.33	9.54%	19.70%
3	DOEM	Tramming	Operation	144.40	8.99%	28.68%
4	ECON	Electronic Control	Breakdown	141.69	8.82%	37.50%
5	OCRE	Cable Handling	Operation	124.65	7.76%	45.25%
6	DOGT	Pick Replacement	Operation	93.99	5.85%	51.10%
7	MCHN	Mechanical	Breakdown	124.00	7.72%	58.82%
8	DOCV	Conveyor Damage	Breakdown	68.39	4.26%	63.07%
9	DSTK	Equipment Stuck	Breakdown	62.44	3.89%	66.96%
10	MWU1	When Unit	Breakdown	53.33	3.32%	70.28%
11	HHOS	Hydraulic Hose	Breakdown	43.91	2.73%	73.01%
12	DONO	No Operator	Other	39.75	2.47%	75.48%
13	EM01	Electronic Motor	Breakdown	35.41	2.20%	77.69%
14	HCYL	Hydraulic Cylinder	Breakdown	34.42	2.14%	79.83%

Firstly, the tables above reaffirms the hypothesis that there is indeed an 80/20 pattern regarding causes to production lost time. The quantitative evidence points to the fact that most of the downtime in the section is related to cable damage and handling. This indeed not surprising as these sections make use of shuttle cars instead of battery haulers, (Appendix B).

What is interesting however is the fact that Vumagara spent 304.19 hours compared to the 124.65 hours used by Thandeka to handle cables over the same period further more, Vumugara has spent more time tramming than Thandeka?

The Pareto study for Vumagara reveals that 80.65% of downtimes are a result of 18.75% codes. This is a classis Pareto pattern. The first two codes, OCDO and OCRE, are downtime codes related to cable handling and cable damages respectively. DOIA, related to lost hours, because of industrial action. While this may be lost production, this downtime will not be considered as lost time as it doe fall within the scope of the project. Tramming, DOEM, is the most time consuming and prevalent operational action, seconded only by DOGT, which is denotation for Pick Changes. ECON, refers to stoppages related to electronic controls that may trip or overload.

Cable handling is a done prior or after a crew trams from one section to another. Noting that then, this quantitative evidence points to the fact that cable handling still remains are challenge in Vumagara. The work study conducted in the section was not conclusive in determining indeed cable handling is being done differently in this section. Further more, Vumagara shows more instances of times with a machine operator in section.

Table 6 – Thusanang Downtimes

Thusanang Downtime Patterns						
Code	Description	Function	Duration	Contribution	Cumulative	
1	DOLY	Battery Change	Operation	281.86	20.34%	20.34%
2	ECON	Electronic Control	Breakdown	214.21	15.46%	35.79%
3	DOAC	Operator Damage	Breakdown	117.74	8.50%	44.29%
4	DOGT	Pick Replacement	Operation	93.98	6.78%	51.07%
5	DOEM	Tramming	Operation	93.49	6.75%	57.81%
6	DOCV	Belt Damage	Breakdown	68.93	4.97%	62.79%
7	DONO	No Operator	Other	53.41	3.85%	66.64%
8	DSTK	Stuck	Breakdown	51.61	3.72%	70.37%
9	HHOS	Hydraulic Hose	Breakdown	42.36	3.06%	73.42%
10	DODP	Water System Damage	Breakdown	37.17	2.68%	76.10%
11	OCDO	Trailing Cable Damage	Breakdown	34.12	2.46%	78.57%
79						

Table 7 - George Downtimes

George Downtime Patterns						
Code	Description	Function	Duration	Contribution	Cumulative	
1	DOLY	Battery Change	Operation	456	22.60%	22.60%
2	DOAC	Operator Damage	Breakdown	277.91	13.77%	36.37%
3	ECON	Electric Control	Breakdown	262.62	13.02%	49.39%
4	EM01	Electric Motors	Breakdown	94.99	4.71%	54.10%
5	DOGT	Pick Replacement	Operation	90.90	4.50%	58.60%
6	DSTK	Stuck	Breakdown	81.16	4.02%	62.62%
7	HHOS	Hydraulic Hose	Breakdown	78.57	3.89%	66.52%
8	DOEM	Tramming	Operation	64.14	3.18%	69.69%
9	DOCV	Conveyor Damage	Breakdown	57.67	2.86%	72.55%
10	DONO	No Operator	Other	55.06	2.73%	75.28%
11	HYDR	Hydraulic	Breakdown	51.13	2.53%	77.82%
12	MECH	Mechanics	Breakdown	37.67	1.87%	79.68%
79						

The table's exhibit 80/20 patterns. The table above supports the hypotheses, which most of the downtimes in BH sections will arise from battery changes. At this point in times, to attempt to conclude whether indeed Battery Haulers are have less downtime would be impossible, as the downtime is not allocated to a specific machine. Further

more, it is apparent more stoppages in BH sections arise because of operational stoppages instead of breakdowns i.e (battery change, tramming and pick change).

Operational processes as KPAs as they are easy opportunities to be exploited by process reengineering and not necessary equipment in the case of equipment breakdowns remedies.

Resolution and conclusion

From the study of the above codes, it can be concluded that, there is indeed a Pareto pattern in the downtime. 80% of production stoppages arise because of 18.5%, 18.5%, 15% and 17.5% in Vumagara, Thandeka, Thusanang and George respectively.

This analysis seeks to further support the hypothesis, built on lost time definition that indeed all production downtime KPAs, can indeed be classified under three major classes equipment breakdowns, operational stoppages or other.

Further noting that lost production time can only be lost only if the CVC is down, one can infer that indeed KPAs will be located within from each of the components of the CVC.

Equipment Downtimes

Noting:

Table 8 - Equipment Downtime

Greenside Equipment Downtime Patterns: Jan 2007- June 2008		
Equipment	Quantum	Contribution
Continuous Miner (3)	2725.84	30%
Shuttle Car (6)	2996.90	34%
Battery Hauler (6)	1527.77	17%
Feeder Breaker (3)	317.31	4%
Conveyor Belt	1059.54	12%

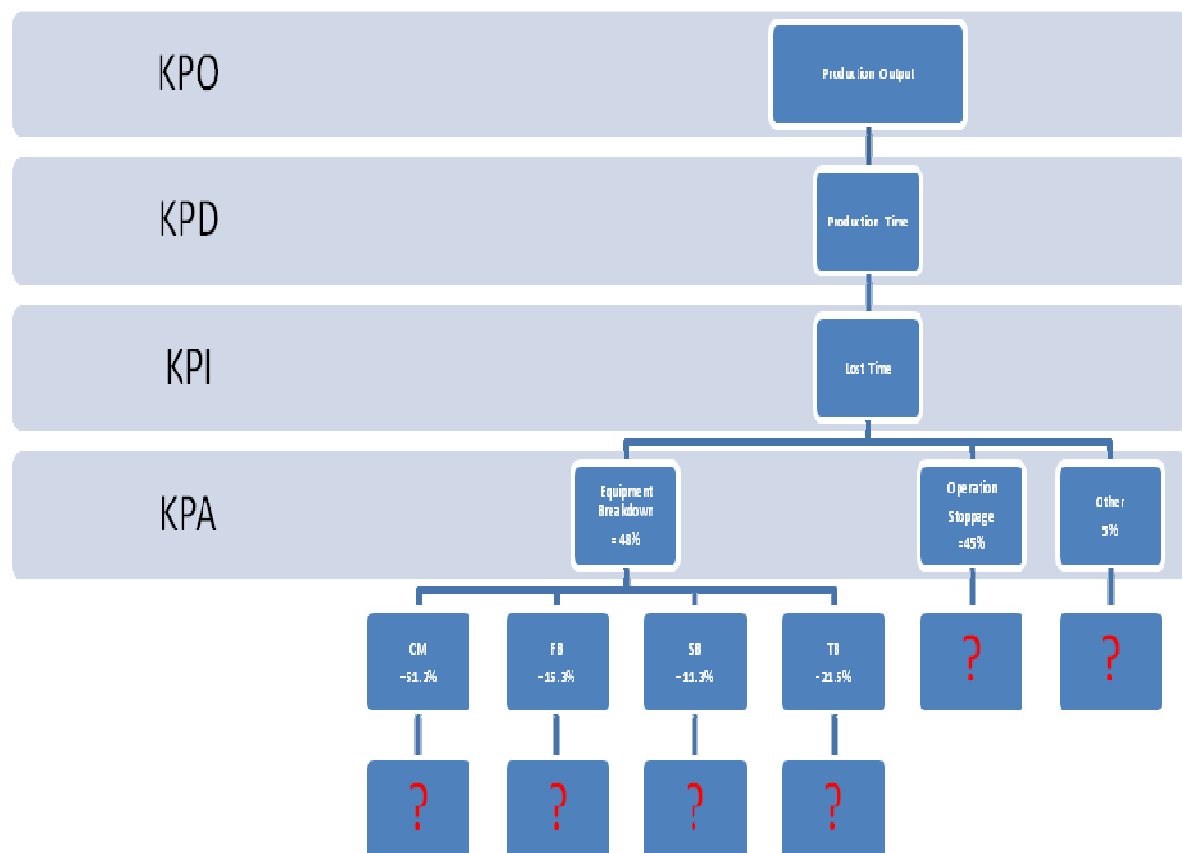
A study of all equipment stoppages relieve that all that six shuttle cars, stopped for a total of 2996.90 over a period of 18 months. 2725.84, 1527.77, 1059.54 and 317.31 hours for the 3 CMs, six Battery Haulers, Conveyor belts and Feeder Breaker respectively. It is however important to understand that each, section has only, one CM, 3 shuttle cars or 3 battery haulers, one feeder breaker leading to one trajectory of conveyor belts and the contribution should be calculated against such a breakdown occurring in a section, and not necessarily in the entire mine.

The above, table below was calculated. This table gives to affect, the probability of machines, and contribution to downtime. Meaning, in the event, that there is a

stoppage, where in the value chain is the breakdown likely to occur. The study was done, separately for SC and BH sections. The last column shows the contribution to downtime of the equipment that forms part of the critical value chain.

The data supports the held notion that most of the downtime in the underground coal mining value chain will occur on the primary machine, the continuous miner. As a result of its close proximity to physical strains, such exposure will invariably result in increased frequency and duration in breakdown most breakdowns will occur on this machine.

Figure 10 - Findings



A Pareto study was done to ascertain the most prevalent contributors to specific equipment downtime of critical equipment in the Critical Value Chain (CVC). Equipment Downtime Contribution included but was not exclusive to CVC. The downtime studies explicitly excluded Maintenance stoppages, Sundays, Holidays and stoppages related to equipment standby. The study (figure 10) conclusively found that 48% of stoppages that occur in the section are a result of breakdowns, 45% arising because of operational stoppages and just 5% of operational stoppages.

Guided by above, can pre-emptively conclude that breakdowns and Operational stoppage times should indeed be KPIs as most of the time is consumed by their respective KPAs. Noting the above one then went about to narrowing down the exact sources of the downtime to specific equipment.

Continuous Miner Downtimes

Table 11, further supports the argument that operational stoppages are the KPAs. Trimming and Pick Replacements are repetitive mining processes that consume a vast amount of valuable production time. While they cannot be completely removed, it is however possible to reduce the time through process reengineering.

10.8% of breakdowns reported as DOAC are related to Torque Shaft breakdown. The torque shafts acts a protection device, when the rotating cutter head or gathering arms experience excessive torque as a result of over sumping or overload. Believing this, all torque shaft breakdowns are reported as Operator related damages. Within this bucket, are other operator breakdowns, including bumping of equipment and cables.

Table 9-CM Downtime

Continuous Miner Downtime Patterns: Jan 2007-June 2008						
	Code	Description	Function	Quantum	Contribution	Cumulative
1	DOEM	Trimming	Operation	792.807	19.22%	19.22%
2	DOGT	Pick Replacement	Pit Stop	713.877	17.31%	36.53%
3	DOAC	Operator Breakdown	Breakdown	445.463	10.80%	47.33%
4	ECON	Electric Controls	Breakdown	376.993	9.14%	56.48%
5	DODP	Water System	Pit Stop	293.599	7.12%	63.60%
6	OCDO	Trailing Cable Damage	Breakdown	165.410	4.01%	67.61%
7	OCRE	Cable Handling	Operation	121.407	2.94%	70.55%
8	HHOS	Hydraulic Hose Damage	Breakdown	102.920	2.50%	73.05%
10	EM01	Electric Motor Damage	Breakdown	95.793	2.32%	75.37%
11	OSWE	Sweeping	Operation	90.987	2.21%	77.57%
12	MCHN	Driving Mechanism Damage	Breakdown	85.793	2.08%	79.65%
13	DSTK	Equipment Stuck	Pit Stop	70.18	1.70%	81.36%
56						

Shuttle car:

Table 10-SC Downtimes

Shuttle Car Downtime Patterns: Jan 2007-June 2008						
	Code	Description	Function	Quantum	Contribution	Cumulative
1	OCDO	Cable Damage/Faulty	Breakdown	292.32	17.22%	17.22%
2	ECON	Electric Control	Breakdown	207.09	12.20%	29.42%
3	OCRE	Cable Too Short	Operational	166.82	9.83%	39.25%
4	DOAC	Operator Damage	Breakdown	165.53	9.75%	49.00%
5	MWU1	Wheel Unit Damage	Breakdown	129.47	7.63%	56.63%
6	OCTR	Cable Damage	Breakdown	126.73	7.47%	64.10%
7	MCHN	Mechanical Damage	Breakdown	79.05	4.66%	68.75%
8	DONO	No Operator	Operational	73.00	4.30%	73.06%
9	ECAB	Cable Drum	Breakdown	49.31	2.91%	75.96%
10	MDS1	Spooling Device	Breakdown	41.31	2.43%	78.39%
11	ELEC	Electric Control	Breakdown	37.49	2.21%	80.60%
39						

Batter Hauler:

Table 11 - BH Downtimes

Battery Hauler Downtime Patterns: Jan 2007-June 2008						
	Code	Description	Function	Quantum	Contribution	Cumulitive
1	DOLY	Battery Change	Operational	818.10	37.44%	37.44%
2	ECON	Econ Controls	Breakdown	310.76	14.22%	51.66%
3	DONO	No Operator	Operational	208.35	9.53%	61.20%
4	DOAC	Operator Breakdown	Operational	179.86	8.23%	69.43%
5	HHOS	Hydraulic Hose	Breakdown	89.91	41.47%	73.54%
6	EM01	Electric Motor	Breakdown	79.49	363.79%	77.18%
7	HCYL	Hydraulic Cylinder	Breakdown	61.76	282.64%	80.01%
48						

Feeder Break:

Table 12-FB Downtimes

Feeder Breaker Downtime Patterns: Jan 2007-June 2008						
	Code	Description	Function	Quantum	Contribution	Cumulative
1	DOAC	Operator Breakdown	Breakdown	105.753	21.24%	21.24%
2	EM01	Electric Motor	Breakdown	90.233	18.12%	39.36%
3	DSTK	Stuck	Breakdown	61.167	12.29%	51.65%
4	MCHN	Mechanical	Breakdown	59.793	12.01%	63.66%
5	ECON	Electric Control	Breakdown	50.770	10.20%	73.85%
6	MECH	Mechanical	Breakdown	15.900	3.19%	77.05%
7	ETRP	Electric Trip	Breakdown	12.803	2.57%	79.62%
39						

Section Conveyor Belt:

Table 13- SB Downtime

Section Belt Downtime Patterns: Jan 2007-June 2008						
	Code	Description	Function	Quantum	Contribution	Cumulitive
1	DOCV Total	Belt Damage	Breakdown	197.91	50.91%	50.91%
2	DSTK Total	Stuck	Breakdown	65.98	16.97%	67.89%
3	ECON Total	Electronic Control	Breakdown	29.18	7.51%	75.39%
24						

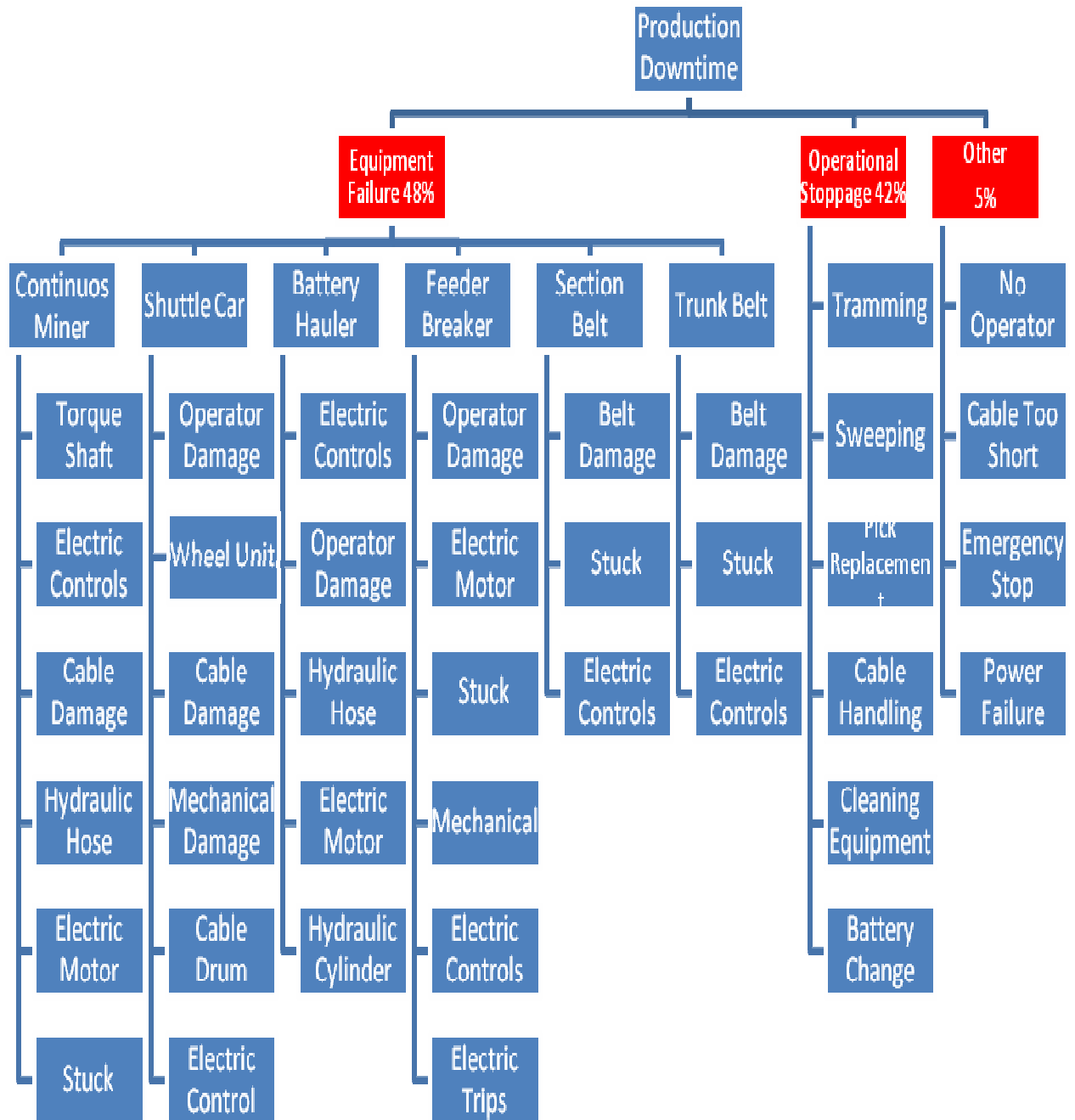
Trunk Conveyor Belt:

Table 14- TB Downtimes

Trunk Belt Downtime Patterns: Jan 2007-June 2008						
	Description	Function	Quantum	Contribution	Cumulitive	
1	DSTK	Stuck	Breakdown	224.437	27.86%	27.86%
2	DOCV	Belt Damage	Breakdown	134.263	16.67%	44.53%
3	OPUL	Pullkey	Other	97.180	12.06%	56.59%
4	ECON	Electroninc Control	Breakdown	61.477	7.63%	64.22%
5	XEPF	Eskom Power	Breakdown	42.910	5.33%	69.55%
6	DOAC	Coal Damage	Breakdown	36.917	4.58%	74.13%
7	ETRP	Overload Trip	Breakdown	35.657	4.43%	78.56%
8	INST	Instrumentation	Breakdown	21.350	2.65%	81.21%
35						

After due consideration to the contribution in of the different contributions, the KPAs were summarised in the table below. This table will be used as a communication tool in developing the new downtime management system.

Figure 11 - KPAs for Lost Time



Operational Stoppage KPAs:

1. Trimming
2. Pick Replacement
3. Sweeping
4. Cable Handling
5. Battery Changing
6. Cleaning of Equipment

Equipment Breakdown KPAs:

Continues Miner: Critical

1. Torque Shaft
2. Electric Controls
3. Cable Damage
4. Hydraulic Hose
5. Electric Motor
6. Stuck

Shuttle Car: Non Critical

1. Electric Control
2. **Operator Damage**
3. Wheel Unit Damage
4. Cable Damage
5. Mechanical Damage
6. Cable Drum Damage

Battery Hauler: Non Critical

1. Electric Controls
2. Operator Damage
3. Hydraulic Hose
4. Electric Motor
5. Hydraulic Cylinder

Feeder Breaker: Critical

1. Operator Damage
2. Electric Motor
3. Stuck
4. Mechanical Damage
5. Electronic Control
6. Electric Trip

Section Belt: Non Critical

1. Belt Damage
2. Stuck
3. Electronic Control

Trunk Belt: Critical

1. Stuck
2. Instrumentation
3. Belt Damage
4. Electronic Control
5. Electronic Trip

Other: Non Critical

1. Cable Too Short
2. Power Failure
3. Emergency Stop
4. No Operator

Recommendations and Conclusion

The front line of coal mining needs managers with above average operational management acumen. Anglo Coal, has face boss's and shift bosses that are highly skilled technically but are short of the operational management expertise needed to execute the complex process of underground CM mining. Middle and first line management need to have to the necessary skills to adapt quickly. Make the necessary changes and track progress continuously. The mining environment presents an array of physical, logical and management principles.

Recommends

1. The exercise of comparative analyses of sections can be achieved through operation research approach of variable isolation and Data Envelope Analysis. The two step process can be achieved by one:
 - Development Specifications
 - Software development, interlinking these specification with a graphic user interface.
2. Whenever any equipment is down in the section the miner is expected to report these downtime in the shift report. The downtime is however seldom recorded accurately. This can be attributed to the miner, being preoccupied with other activities. The use of walkie talkies must be used to communicate between section crew members as an interim measure.
3. Log of shift change over efficiency must be emphasized over just end and start of incoming shift. The shift change over process must also be guided by a standard agenda. Refer to appendix G. The need to define an SOP for what can be classified as a critical breakdown becomes quite important.
4. Downtime Closed must not have zeros or 0, (B02 or MBO2), MB01, MR01.
5. To counter this challenge the miners are responsible for reporting to the control every hour to provide a status report.
6. KPIS should not be used as canes to penalize parties, there are tools to monitor progress towards organizational objectives. The identification of these critical areas should be a collective effort between front line workers and management. The implantation of agreed action plans should be clearly communicated to frontline production crew, as they are directly responsible for the implementation of these action plans. These action plans should be clearly communicated. These should encompass safety, quality, utilization and efficiency plans. The feedback mechanism for suggestions of CI ideas should be improved as the team can take greater ownership of initiatives they directly influenced.

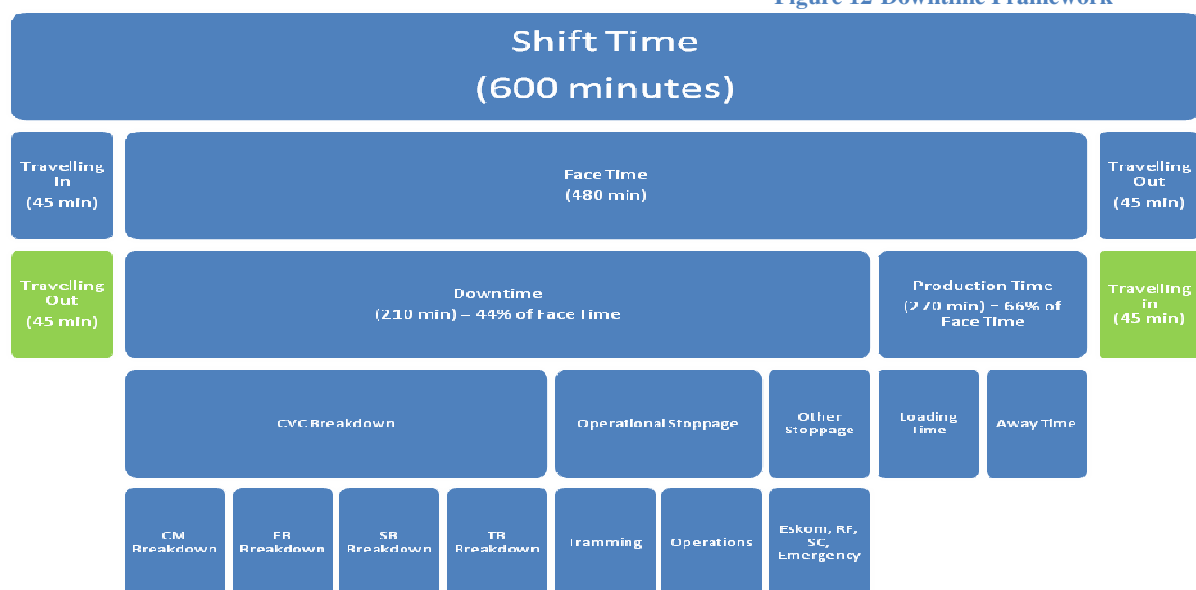
- The targets for each “bucket” of the KPIs are currently not consistently fashioned. Face boss reports The indicate the target for each as being 21 minutes. These are derived from dividing the allocated downtime times against the number of buckets. The cascading effects of each time usage bucket.

Targets used in the time utilisations metrics must not be assigned to a single process, with a definite start and end. The metrics targets must be guard against “multiple penalisation” of processes. It is rather incongruent, to have a fixed targets for all shift processes. If in a given shift, a team is unable to reach the section in time, and misses, it SOS target by 30min, evidence is abound, that the section is also most likely to miss the other rest of the KPI target by a similar quantum. Under the current system, these would be indicated with the red, on the faceboss report.

However, such measurement is grossly misleading and demoralising. The 30 late start of shift does and should not reflect in the measuring the crews’ ability to use, the time allocated for, tramming, operational stoppages, production and contingency breakdown.

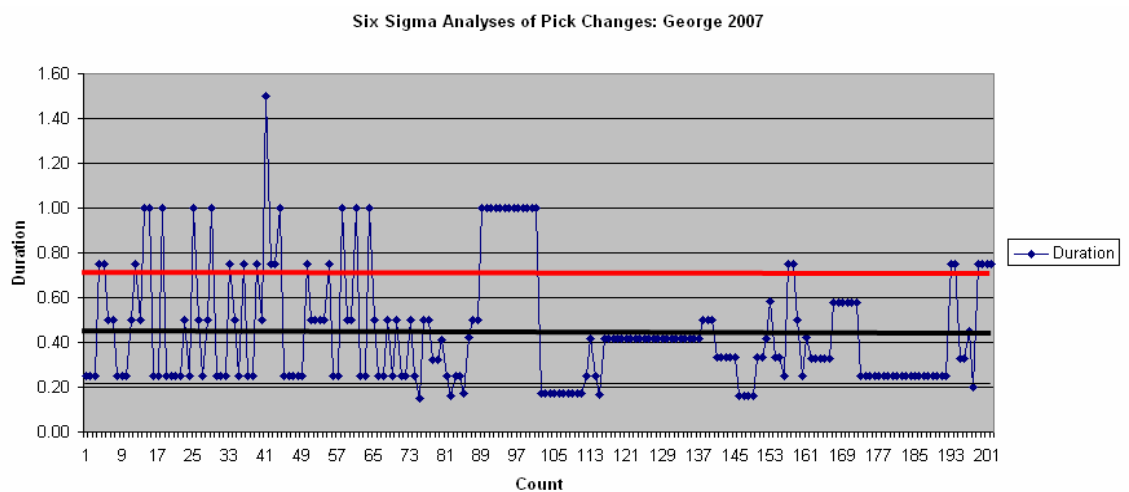
All downtime will fall with the following parts of the value chain, coal face, CM, shuttle car, conveyor belt, trunk belt or roof bolter these will be as a result of either a failure of machinery, material, human or material performance. Understanding that, the framework to used communication performance and thereof can be based on this framework.

Figure 12-Downtime Framework



8. To fully diagnose progress towards controlling and hence reducing KPAs durations, a method based on process natural behavior should be used to identify processes that are naturally out of control and can be further improved. This process will be based on six-sigma analyses. Individual and Moving Average IMA (R and X) charts:

S. Giltow (2003) states that these control charts for single variable value are ideal if such is used to determine process variability in progress regarding production processes as described in the diagram, where I used to determine variability in pick change times.



IMA charts have two parts; one charting the process variability and the other charting the process the process average for the single measurements. These measures are done within the intent of generation process stability, because it is this estimate of process variability that forms the basis of process control limits.

The estimates of variability are based on the point to point variation in the **sequence** of single values by the moving average. Where:

$$R = |x_i - x_{i-1}|$$

The average of this moving average is then used as the centre line. Where:

$$R \text{ (average)} = \Sigma R / (k-1)$$

Where k, represents number of single measurements. Based 3-sigma upper and lower control limits, the limits will be defined as:

$$UCL \text{ (moving average)} = D_4 R_{\text{average}} \text{ and } LCL \text{ (moving average)} = D_3 R_{\text{average}}$$

D_4 and D_3 depend on the subgroup size, and read on the table in Appendix D, (*ASTM manual on presentation of Data and control chart analyses*). However, guide by the intention of only measuring critical areas of downtime, KPAs should present themselves at least 50 times over a 12 month period, per production crew. All moving average charts should be based on 50 regressive average analyses. However 100 is recommended. Therefore; $D_4 = 3.267$ and $D_3 = 0$.

For the moving individual points:

$$\text{Centreline (x): } x_{\text{average}} = \Sigma x/k$$

$$\text{UCL(x) = } x_{\text{average}} + 3(R/d_2) = \text{UCL(x) = } x_{\text{average}} + 2.66 R_{\text{average}}$$

9. Noting that the report has concisely identified the KPAs, work studies must be done, specifically on pick changes and cable handling as there is great scope of reducing downtime related to these processes if these processes are reengineered correctly. From these works studies SOPs be developed and communicated n the best practice on pick change and cable handling.
10. The CI downtime recorder developed during the course of the study and endorsed by the planning department be implemented with immediate effect. The CI record in appendix D, will assist in forming a factual basis to assist in improving breakdown repairs.

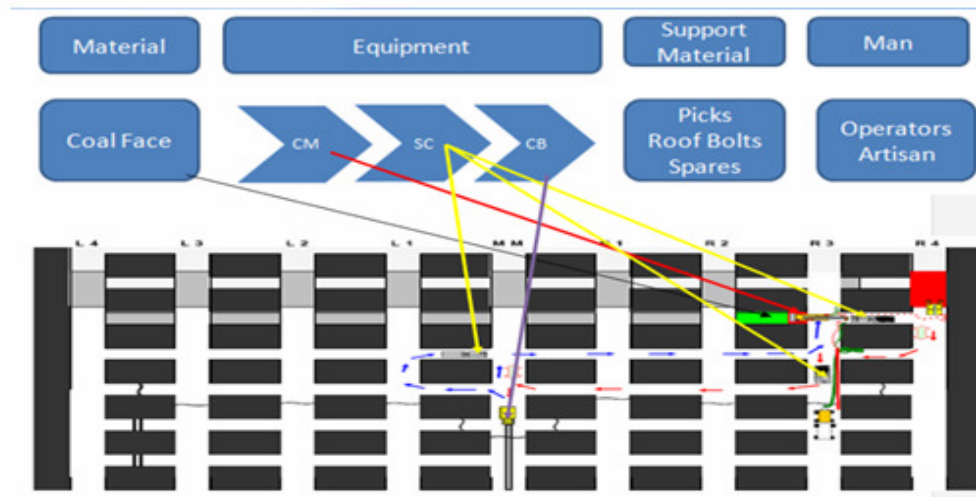
Bibliography and Cited Literature:

1. "Jack Welch's Lessons for Success", Fortune, January 25, 1999, pp 86 – 93
2. Ahlmann, H. (1993), *Increased Reliability and Efficient Maintenance*, (in Swedish), Lund Institute of Technology, Sweden.
3. Anglo America. (2007). *Coal Financial Results*. Retrieved 05 17, 2008, from Anglo American PLC Web Site:
<http://www.angloamerican.co.uk/ourbusiness/thebusiness/coal/financialresults>
4. Anglo America. (2007). *Coal Geographical Locations*. Retrieved 05 18, 2008, from Anglo America PLC: <http://www.angloamerican.co.uk/ourbusiness/coal/geographicallocations>
5. Anglo America;2007; Coal Financial results
6. Anglo America;2007; Coal Geographical Locations;
<http://www.angloamerican.co.uk/ourbusiness/thebusiness/coal/geographicallocations>
7. Anonymous; 15 June 2004; South Africa –Mining: Coal Mining; <http://www.mbedi.co.za/17/05/2008>
8. Anonymous; 2008; Integrated Definition Methods One; <http://www.idef.com/idef1.html>;
18/05/2008
9. Anonymous; 2008; Integrated Definition Methods Two; <http://www.idef.com/idef2.html>;
18/05/2008
10. Anonymous; 2008; Integrated Definition Methods Zero; <http://www.idef.com/idef0.html>;
18/05/2008
11. Barrads, S. (2007, 03 02). *Proposed Anglo Coal Expansion*. Retrieved 05 18, 2008, from miningweekly.com: <http://www.miningweekly.com/id=105353>
12. Beer, M., Eisenstat, R. and Spector, B. (1992), "Why change programs don't produce change", *HBR*, November/December.
13. Benjamin Neibel, 2003, *Methods, Standards and Work Design*; McGraw Hill
14. Bennett, D.J. and Jenney, B.W. (1979), "Reliability and its implication in production system design", *Omega*, Vol. 8 No. 4, pp. 433-40.
15. Bernolak, I. (1997), "Effective measurement and successful elements of company productivity: the basis of competitiveness and world prosperity", *International Journal of Production Economics*, Vol. 52, pp. 203-13.
16. Bitichi, U.S. (1994), "Measuring your way to profit", *Management Decision*, Vol. 32 No. 6, pp. 16-24.
17. BRASSARD, M. (1987) *The Memory Jogger Plus* (Methuen, MA, GOAL/QPC).
18. Breytenbach, 2004, Greenside Colliery – Walkthrough Super Sections in Coal Mining
19. Britton, 2003 *Practical Mine Management*, Wiley Interscience
20. Crawford, K. and Cox, J. (1990), "Designing performance measurement systems for just in time operations", *International Journal of Production Research*, Vol. 28 No. 11, pp. 2025-36.
21. Cross, K.F. and Lynch, R.L. (1992), "For good measure", *CMA Magazine*, April, pp. 20-3.
22. D Hunt; 1996; *Process mapping: how to reengineer your business process*; NY John Wiley
23. D M Mouton; 2001: *Benchmarking in the South African Corporate Environment*
24. Denkhous, M. (2007). *Review of current approach to measurement and reporting of Continuous Miner relocation Times as a Key Performance indicator*. Witbank: Anglo Coal.
25. Drury, C. (2004). *Magement and Cost Accounting*. New York: Thomson.
26. Ericsson, J. and Dahlén, P. (1993), *Disruption Reduction – An Important Tool in Order to Reach "Just in Time"*, Lund Institute of Technology, Sweden.
27. Fisher, T.J. (1990), "Business productivity measurement using standard cost accounting information", *International Journal of Operations & Production Management*, Vol. 10 No. 8, pp. 61-9.
28. FITZGERALD, L., JOHNSTON, R., BIGNALL, T.J., SILVESTRO, R. & VASS, C. (1993) *Performance Measurement in Service Business (London, The Chartered Institute of Management Accountants)*.
29. Fry, T.D. (1995), "Japanese manufacturing performance criteria", *International Journal of Production Research*, Vol. 33 No. 4.
30. G.J.L Krugel, 2000, *The Influence of Factors on Production*
31. Ghalayini, A.M., Noble, J.S. and Crowe, T.J. (1997), "An integrated dynamic performance measurement system for improving manufacturing competitiveness", *International Journal of Production Economics*, Vol. 48, pp. 207-25.

32. Gillow; 2005; Oppenheim; Quality Management; McGraw Hill
33. Goldratt, E. (1990), *Theory of Constraints*, North River Press, Croton-on-Hudson, NY.
34. Greg Brue; 2005; Six Sigma for Managers “24 Lessons to understand and Apply Six Sigma and Principals in any organization”
35. GREIF, M. (1991) *The Visual Factory: Building Participation through Shared Information* (Cambridge, MA, Productivity Press).
36. HARRINGTON, H.S. (1991) *Business Process Improvement* (New York, McGraw-Hill).
37. HEARD, E. (1993) Walking the talk of customer value, *National Productivity Review*, Winter, pp. 21± 25.
38. Hill, T. (1995), *Manufacturing Strategy: The Strategic Management of the Manufacturing Function*, 2nd ed., Macmillan, London.
39. J. Klingenberg, 2004, Kreil Colliery – Wet Head Progress
40. Jackson, M. (2000), “An analysis of flexible and reconfigurable production systems”, Dissertation No. 640, Linköping University, Linköping.
41. Jagdev, H., Bradley, P. and Molloy, O. (1997), “A QFD based performance measurement tool”, *Computers in Industry*, Vol. 33, pp. 357-66.
42. Joel M Stern; Measuring corporate performance; Financial Times; 1975
43. Johnson, H.T. and Kaplan, R.S. (1987), *Relevance Lost: The Rise and Fall of Management Accounting*, Harvard Business School Press, Boston, MA.
44. JONES, C.R. (1994) Improving your key business processes, *The TQM Magazine*, 6, pp.
45. KAPLAN, R. & NORTON, D. (1992) The balanced scorecard measures that drive performance, *Harvard Business Review*, Jan± Feb, pp. 71± 79.
46. KAPLAN, R.S. (1984) Accounting lag: the obsolescence of cost accounting systems. Harvard Business School,
47. Kaplan, R.S. and Cooper, R. (1998), *Cost and Effect: Using Integrated Cost Systems to Drive Profitability and Performance*, Harvard Business School Press, Boston, MA.
48. Kaplan, R.S. and Norton, D.P. (1992), “The balanced scorecard – measures that drive performance”, *Harvard Business Review*, January-February, pp. 71-9.
49. Keeping Score: Measuring the Business Value of Logistics in the Supply Chain, CSC, University of Tennessee, CLM 8
50. Kelton; 2003 ;Simulation with Arena; McGraw Hill
51. Laaing, D. (2008, 05 27). What are the Definitions of the Pick Six. (S. Khumalo, Interviewer)
52. M G Brown; beyond the balance scorecard: Improving business intelligence with analytics Productivity Press.
53. M. Denkhous, M. Eardley, C. Mufamadi, R. Raphulu; 2007 “Review of the Current Approach to Measurement and Reporting of Continuous Miner Relocation Time as a Key Performance Indicator”: Anglo Coal.
54. Manufacturing Engineering Group, University of Cambridge, Cambridge, pp. 313-18. Neely, A., Mills, J., Platts, K., Richards, H. and Bourne, M. (2000), “Performance measurement
55. Maskell, B. (1991), *Performance Measurement for World Class Manufacturing: A Model for American Companies*, Productivity Press, Cambridge, MA.
56. Mbedi. (2005, 03 05). *South Africa - Minig: Coal Minig*. Retrieved 05 17, 2008, from www.mbedi.co.za: <http://www.mbedi.co.za/indy/minig/coal/af/sa/p0005>
57. MCS. (2008). *Daylight Shaft Production Report-Greenside*. Witbank: MCS. Medori, D. and Steeple, D. (2000), “A framework for auditing and enhancing performance measurement systems”, *International Journal of Operations & Production Management*, Vol. 20 No. 5, pp. 520-33.
58. MCS; 27/03/2008; Daylight Shaft Production Report Moore, R. and Scheinkopf, L. (1998), *Theory of Constraints and Lean Manufacturing: Friends or Foes?*, Chesapeake Consulting, Severna Park, MD.
59. Mouton, D. M. (2001). *Benchmarking in the South African Corporate Environment*. Pretoria: University of Pretoria.
60. Naaidoo, M. (2008, 05 28). How do Mines use KPIs. (S. Khumalo, Interviewer)
61. Nakajima, S. (Ed.) (1989), *TPM Development Program*, Productivity Press, Cambridge, MA.
62. Ndiweni, A. (2006). *Defining the Anglo Coal front line performance measures for underground CM sections*. Witbank: Anglo Coal.
63. Neely, A., Adams, C. and Crowe, P. (2001), “The performance prism in practice”, *Measuring Business Excellence*, Vol. 5 No. 2, pp. 6-12.
64. Neely, A., Gregory, M. and Platts, K. (1995), “Performance measurement system design: a literature review and research agenda”, *International Journal of Operations & Production Management*, Vol. 15 No. 4, pp. 80-116.

65. Neely, A., Mills, J., Platts, K., Gregory, M. and Richards, H. (1994), "Mapping measures and activities: a practical tool for assessing measurement systems", Proceedings of the 1st International Conference of the European Operations Management Association,
66. Neely, A., Richards, H., Mills, J., Platts, K. and Bourne, M. (1997), "Designing performance measures: a structured approach", International Journal of Operations & Production Management, Vol. 17 No. 11, pp. 1131-52.
67. PETERS, J. (1994) Operationalizing total quality: a business process approach, *TQM Magazine*, 6, pp. 29± 33.
68. Phil Crous, F. O. (2007). *Underground Mining Method*. Pretoria: University of Pretoria.
69. Prinsloo , P. Steyn, A. Ndiweni. 2006. "Defining the standard Anglo Coal front line performance measurements for Underground CM sections". Anglo Coal.
70. R B Chase, F. R. (2005). *Operations Management for Competitive Advantage*. New York: McGraw Hill.
71. R B. Chase, F Robert Jacobs; 2005; Operations Management for Competitive Advantage; McGraw-Hill
72. Ross, S.A., Westerfield, R.W. and Jaffe, J.F. (1993), Corporate Finance, 3rd ed., Irwin, Burr Ridge, IL. Sink, D.S. and Tuttle, T.C. (1989), Planning and Measurement in Your Organisation of the Future, Ch. 5, Industrial Engineering and Management Press, Norcross, GA, pp. 170-84.
73. RUMMLER, G.A. & BRACHE, A.P. (1990) *Improving Performance: How to Manage the White Space on the Organization Chart* (San Francisco, Jossey-Bass).
74. S. Khumalo, 2007 "Using Theory of Constraints to Improve Productivity in Long haul Mining at Sasol Mining".
75. SEMI Semiconductor Equipment and materials International (1992) Semi Standards: Equipment Automation
76. SH Jansen van Vuuren, 2005, Effective Use of TIP Control System at Kleinhopje Colliery to Record KPI Information.
77. Shaffer, R. and Thomson, H. (1992), "Successful change programs begin with results", *HBR*, January/February.
78. Sheila Barrads; 02/03/2007; Proposed Anglo Coal Expansion, South Africa; <http://www.miningweekly.com/id=105353>
79. Skinner, W. (1986), "The productivity paradox", Harvard Business Review, July-August, pp. 55-9. Tangen, S. (2002a), "A theoretical foundation for productivity measurement and improvement of automatic assembly systems", Licentiate thesis, The Royal Institute of Technology, Stockholm.
80. Smithes, A. (1957), "Economic fluctuations and growth", *Econometria*, Vol. 25 No. 1.
81. Suehiro, S. (1992), *Eliminating Minor Stoppages on Automated Lines*, Productivity Press, Cambridge, MA.
82. Tangen, S. (2002b), "RATOC: a simple method for productivity improvement in robot workcells based on the theory of constraints", Proceedings of the 33rd International Symposium on Robotics (ISR2002), Stockholm, October 7-10.
83. Tangen, S. (2003), "An overview of frequently used performance measures", Work Study, Vol. 52 No. 7, pp. 347-54.
84. Toni, A. and Tonchia, S. (2001), "Performance measurement systems – models, characteristics and measures", International Journal of Operations & Production Management, Vol. 21 No. 1/2, pp. 46-70.
85. Underground Mining methods by Phil Crous, Fran Oliveir, PMY 210, University of Pretoria
86. Vuuren, S. J. (2005). *Effective Use of TIP control System at Kleinkopie to record KPI information*. Pretoria: University of Pretoria.
87. Walsh, P (2006) Finding key performance drivers: Some new tools, Total Quality Management, Vol 5
88. WALSH, P.K. (1995) Managing performance indicators: part II. What process was that?, *Benchmark*, 11, pp. 26± 27.
89. Welch, J. (1999, 01 25). Jack Welch's lessons on Success. *Fortune* , pp. 86-93.
90. White, G. (1996), "A survey and taxonomy of strategy-related performance measures for manufacturing", International Journal of Operations & Production Management, Vol. 16, No. 3, pp. 42-61.
91. Wiendahl, H.-P. and Winkelhake, U. (1988), "Permanent automatic supervision of assembly lines", *Developments in Assembly Automation*, March, pp. 289-300.
92. Wild, R. (1971), *Production and Operations Management*, Holt, Rinehart and Winston, New York, NY.

Appendix A: Production Section Equipment



	Thusanang	Thandeka	Vumagara	George
CM	1 x 12HM31 JNA 1Joy CM UCM3490	1 x 12HM31 JNA 2 Joy CM – UCM3500	1 x 12HM31 JNA 1Joy CM UCM3480.3520	1 x 12HM31 JNA 2 Joy CM UCM 3510
Shuttle Car	3 x 16 ton Un-A- Hauler (Battery haulers) UHL(5728,5729,5730)	3 x 22ton Joy Shuttle cars USC(4780,4790,4791,4790)	3 x 20 ton shuttle cars USC(4710,4750,4760,4770)	3 x 20 ton Stamler battery haulers UHL(5724,5725,5726,5727)
Roof Bolter	1 x Fletcher Roof bolter URB(1920)	1 x Fletcher Roof bolter URB(1870,1910)	1 x Roof bolter URB(1870,1890)	1 x Fletcher Roof bolter URB(1870,1940)
Section Belt				UCV445B

CM

The Continuous Miner is the primary production machine, with a rotary cutter drum affixed with tungsten tipped picks that chip away at the coal. The cutter head on the Popular Joy JNA model can be changed depending of the desired seam height and width. The CM is controlled via a remote control by an operator standing in view of the coal face. The operator has to try as far a possible adheres to the **cutting cycle** so as to ensure optimum production.

Greenside is one of the four underground mines taking part in the project and is being used as the front runner in the project because all four CM's are JNA 2 with full data being available for analysis. The CMs have an onboard PLC monitoring system in place that records all relevant production information, the two models in use are JNA 1 and JNNA. This information is relayed in real-time to the control room and displayed on screen by way of a simulation model. In the event of a breakdown a probable diagnostic can be created indicating possible causes and recommended steps to be taken.

The problem however becomes, that the software package can be able to give a detailed description of the exact cause of the stoppage. The general understating the stoppages are either: Engineering or Operational (mining).

The KPI guiding the CM operator is **loading time**.

Shuttle Car

The horizontal hauler used to transport coal from the CM to the feeder breaker. The shuttle car driver sits on board the shuttle car and steers the hauler by means of a joy stick. A typical section would have 3 shuttle cars.

A battery operated model of a “shuttle car” is also used at Greenside, these are referred to as “stamlers”. They offer an added advantage as there is no cable work to be considered when a change over point is selected and eases the process of relocation. The planning and scheduling of battery changes does however pose a unique challenge.

Roof Bolter

The Roof bolter forms part of the auxiliary support equipment. It is a machine that is the size of an industrial forklift. It possesses two protrusions directed towards the roof used to drill roof bolts in. The roof bolts are used to secure the roof and mitigate the chances of any roof falls. The machine is operated by two team members who work in synch to ensure that roof bolter remains in the mining sequence; it should always lag behind the CM so as to prevent production stoppage. The frequency and spacing of the roof bolts must be determined by a qualified mining engineer.

LHD

The LHD is an underground flameproof front-end loader. It is mainly used for cleanup operations. When the CM leaves a **face** the LHD usually comes and shovels the coal left by the CM into the front of the face so that when the CM returns the remaining coal can be reloaded and production can commence uninterrupted by uneven floor or debris.

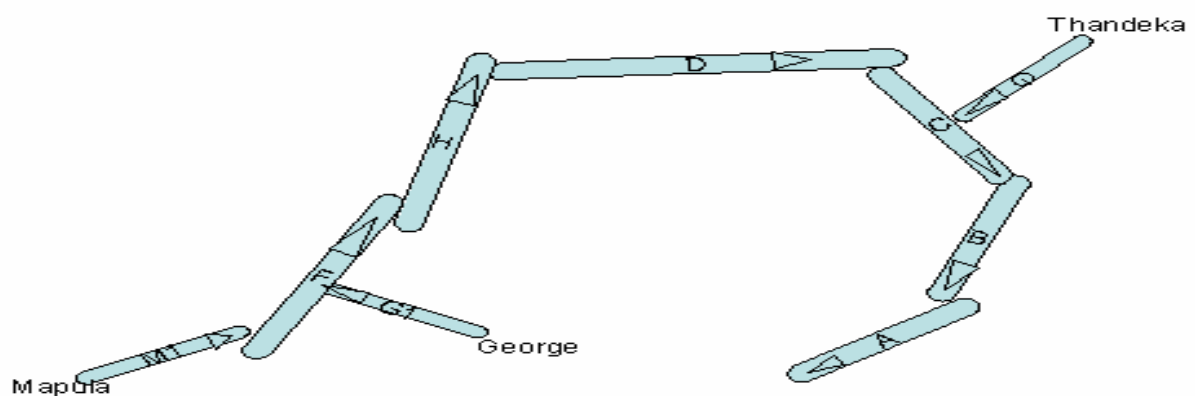
Feeder breaker

Each section has a feeder breaker. The feeder breaker consists of an armored face conveyor (AFC), the breaker drum, and the bin. The coal is tipped on the AFC, the flight chain moves the coal to the breaker where the coal size is reduced and it also controls the ‘flow’ of the coal from the AFC onto the conveyor belt. There are two

basic types of feeder breakers – the breaker used at George has one flight bar. While the other type of breaker has two flight bars each with its own drive and chain sets. This is a big advantage; in the event of a breakdown one AFC can be operated. If there is only one AFC the coal must be removed by hand – a time consuming operation.

Conveyor Belt

Conveyor belts are used to transfer the coal from the feeder breaker to the plant. Conveyors A, B, C, D, E, F and H are trunk conveyors. Their width is 1.5m while the section belts are 1.2m, indicated as G are the link between the feeder breaker and trunk conveyor. A basic layout of the conveyors is shown below.



There are water sprayers on the conveyor belts to help with the dust suppression. **Belt extensions** are done regularly in each section to keep the travel time of the shuttle car from the CM to the feeder breaker as low as possible. During a belt extension the feeder breaker and the switchgear must also be moved forward. Belt extensions are done during maintenance shift. The surveyors place pegs that assist with the alignment of the belt.

Appendix B: Production Personnel

A production crew consists of 11-12 personnel that is:

- **1 miner, face boss:** team leader that has to plan production with shift boss and manage in shift activities of the team members.
- **1 Fitter:** tradesman trained to fix mechanical breakdowns and to maintain all moving mechanical parts of equipment in the section.
- **1 electrician:** a tradesman specializing in electrical wiring of production equipment. Electricians can be tasked with the installation of new electrical components or the maintenance and repair of existing electrical infrastructure in the section. All production in the section, the cm, shuttle car and belts are powered by electricity.
- **2 CM operators:** A specially trained hand that operates the primary machine by means of a remote control. As the primary machine operator, the CM operator has a specific task of looking after multimillion rand machinery, as well as making the most of the production time available through apt cutting cycles. The performance of the CM/Operator is measured by means of the Loading Time, this KPI has limitations as it only measures the time utilization and not necessarily the effectiveness of the Operator and machine relationship.
- **3 Shuttle car/UN-A-Hauler drivers:** A specially trained hand that ought to have extremely good hand eye coordination to be able to maneuver a shuttle in a confined space in a team effort with of 3 shuttle cars. The KPI used to measure the operator is Away Time.
- **2 Roof-bolter operators:** These operators provide a strategic support service. There is no KPI to measure the performance as it is understood to be a support serve and has no effect on the production of a section. This assertion is however myopic as periodic events do cause production to be stopped or rerouted as a result of roof bolting operations.
- **1 General laborer:** The section hand is tasked to do miscellaneous operational tasks such as: Putting up brackets, cable handling and other tasks assigned by the miner.

Support Services

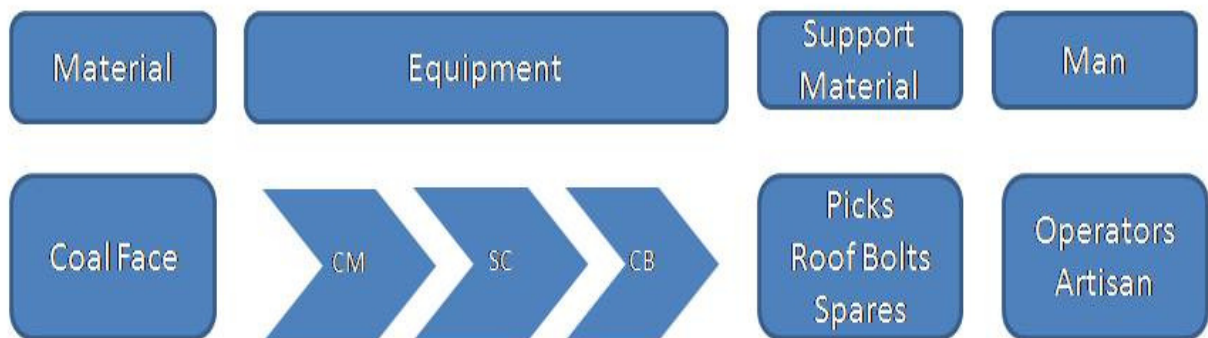
All non line functions, not directly related as referred to as “out by” services. The effects of the out by services should also be noted in the course of the development of a hypothesis.

Supplies

Surface based operations have the responsibility to plan control and deliver all production suppliers needed during a production shift. The effects of the poor or no delivery of the supplies is not any. This will also be investigated in course and reported in the course of the report.

Control Room

A Control Room situated on surface. Every hour the face boss in the section gives the Control Room operator an update on how many meters have been cut. All breakdowns must be reported immediately so that no delays in response can occur.

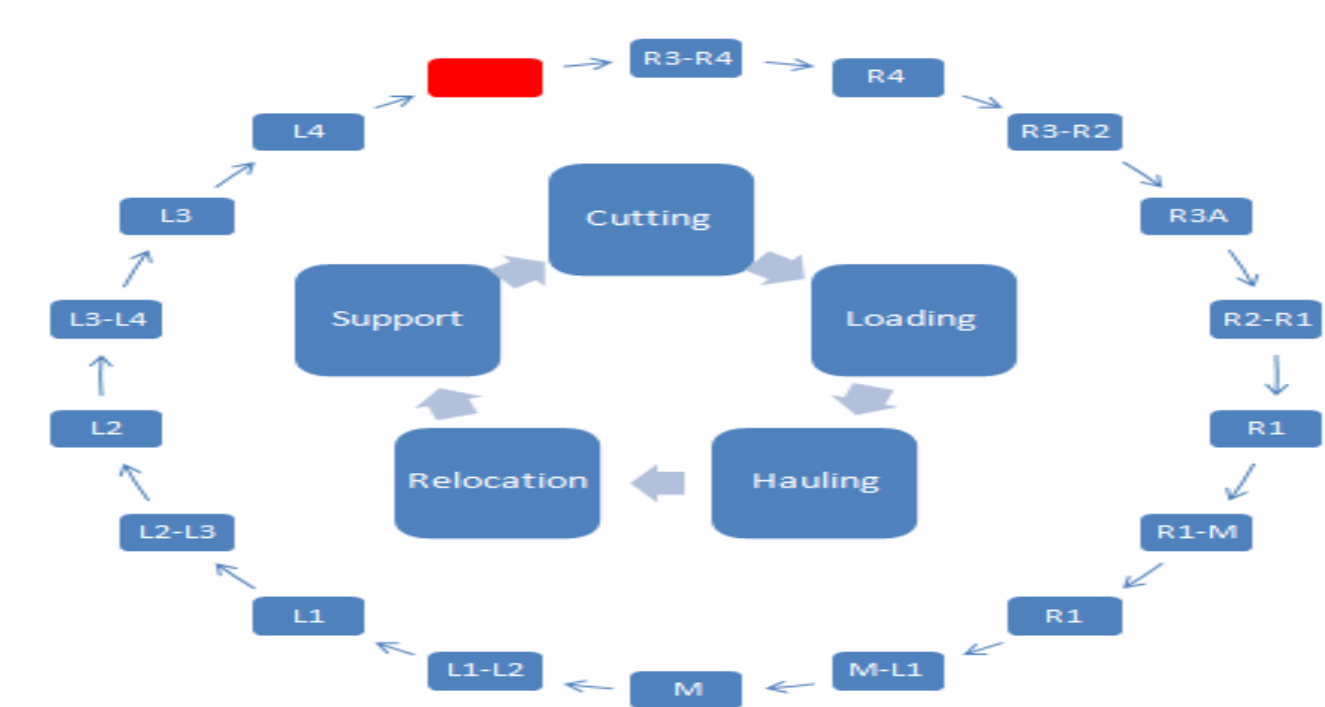


The **system** in the mining environment is made of, the coal as the material. The CM as the primary machine. The 3 shuttle cars are the support machinery as is the, section belt, and roof bolter. It is important to note that the critical value chain is made of the, CM, Feeder breaker and the Section Belt. If any of these machines are down, the entire production value chain will stop.

Appendix C: Mining Sequence Process Flow

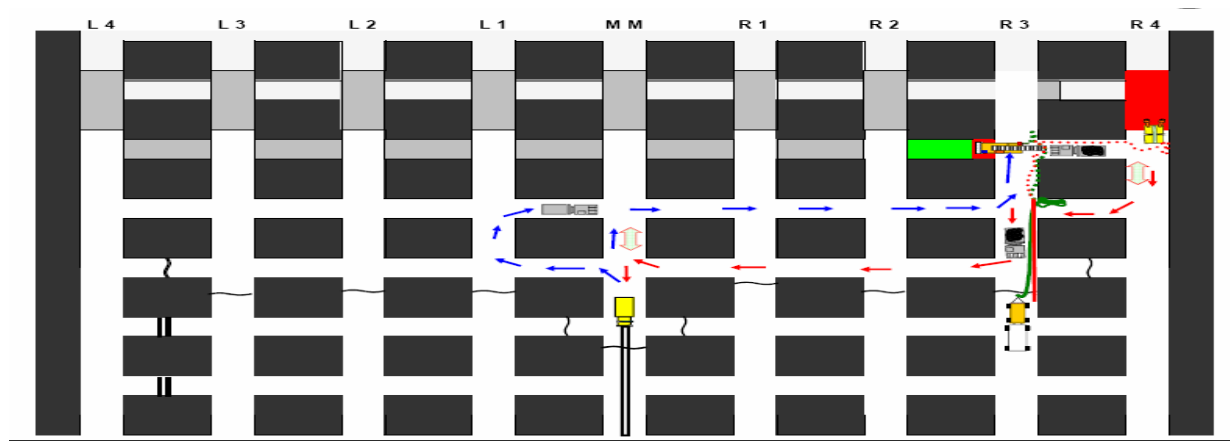
Coal mining is a cyclical process, with consists;

- Mine life cycle
- Section life cycle
- Nine Road life cycle
- Face cycle
- Cutting cycle



The order in which the roadways are cut is referred to as the **mining sequence**. The mining sequence is selected with consideration to productivity, safety, ventilation and minimising tramming distances. Greenside makes use of a nine road mining system.

The CM will cut only 12m at a time. Since a road is 7m wide the CM must cut it in three steps. Firstly the right hand side is cut in for 8m, and then the left hand side is cut in for the full 16m. Then the CM goes back to the right and cuts the last 8m. The operator stands under supported roof the whole time and operates via remote control.

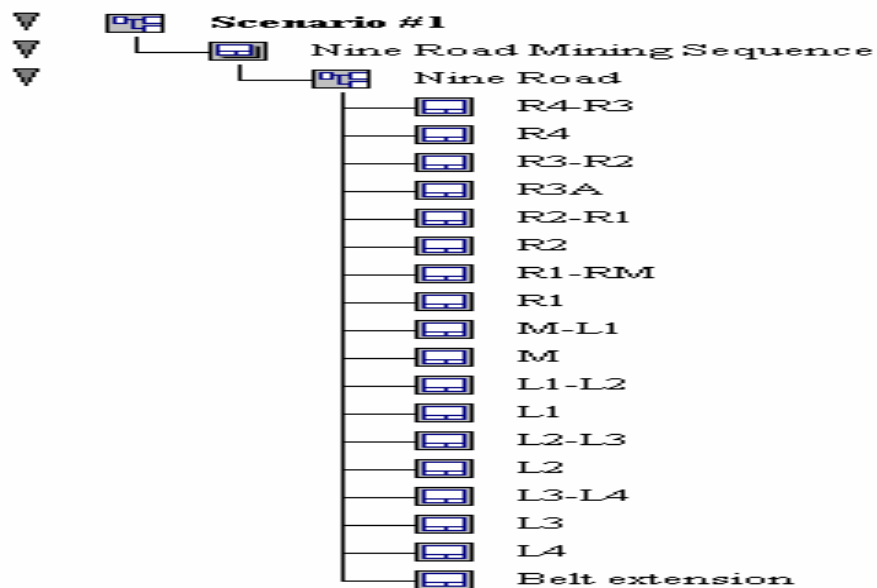


The Mining sequence for the whole section is illustrated in figure 6. The reason for cutting the split so early is that it gives a little leeway if the roof bolter breakdown. The law says that one can only have 16m of unsupported roof at a time. Thus this cutting sequence allows for the maximum cutting to be done in case a roof bolter is standing. Up to 40m can be cut while not supporting. The mining operations will always start with the cable as short as possible, thus the reason for placing the transformer in the middle of the section. Furthermore they will always ‘cut for ventilation’. This is the reason for cutting from the middle to the right hand side – the ventilation intake is at the right-hand side. The roof bolter will support the section that the CM cut after he is retrieved and start with the next cut.

The three shuttle cars allow the CM to be continuously cutting. While the CM is cutting one shuttle car is standing behind it being loaded, the time it takes to fill one shuttle car is referred to as **Loading Time**. At the same time the second shuttle car is on its way to the feeder breaker and the third is busy offloading at the feeder breaker at the belt, this time spent away from the CM, is referred to as **Away Time**. Ideally, the **idle time** that is a result of the CM waiting for a shuttle car should not be longer than 1 min. The summing up, loading time of a shuttle car, and its way time will result to what is referred to as **cycle time**. The efficiency of the CM operator is determined by the loading time while the efficiency of the shuttle car drier is determined by the loading time.

Belt extensions are periodically commissioned to reduce the tramping distance.

Mining Sequence: Idef 1 Model

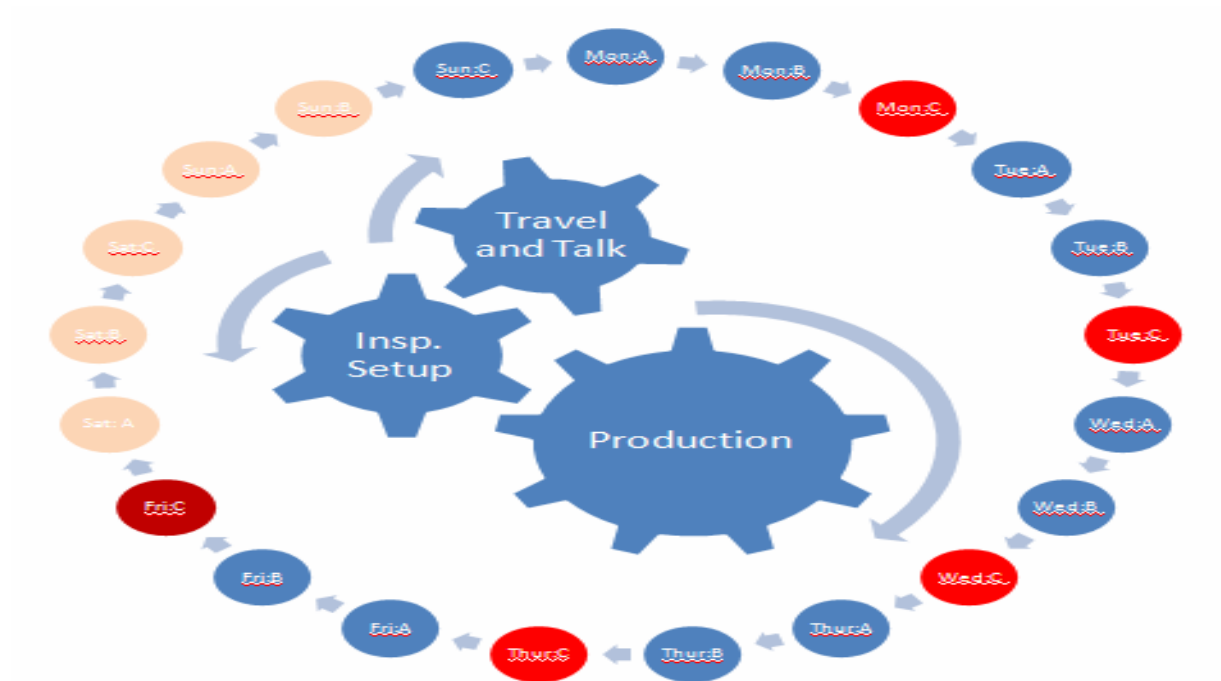


CM Cutting Cycle

- The cutting head is sumped in at the top of the face
- It then shears down to the bottom of the face
- It then cuts the floor clean
- And then it trams forward for the next cut

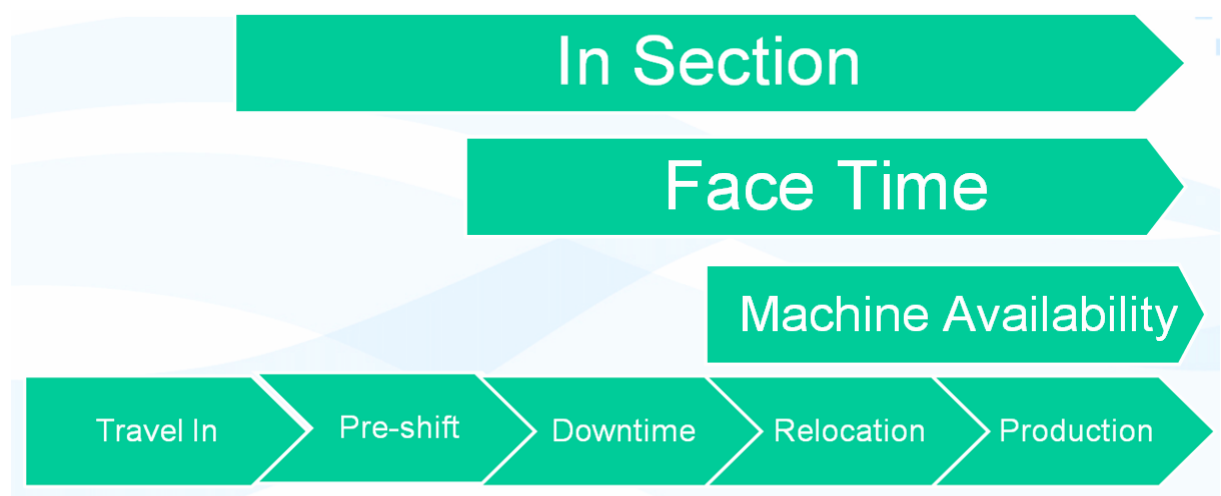
Obviously during the whole cutting cycle the gathering arms at the bottom of the CM gathers coal, sends it through the CM, onto the conveyor at the back and onto the hauler. The cutting cycle can be viewed as a measure of the effectiveness of the CM operator. An effective operator will fill one shuttle car in one cutting cycle.

Weekly Activities

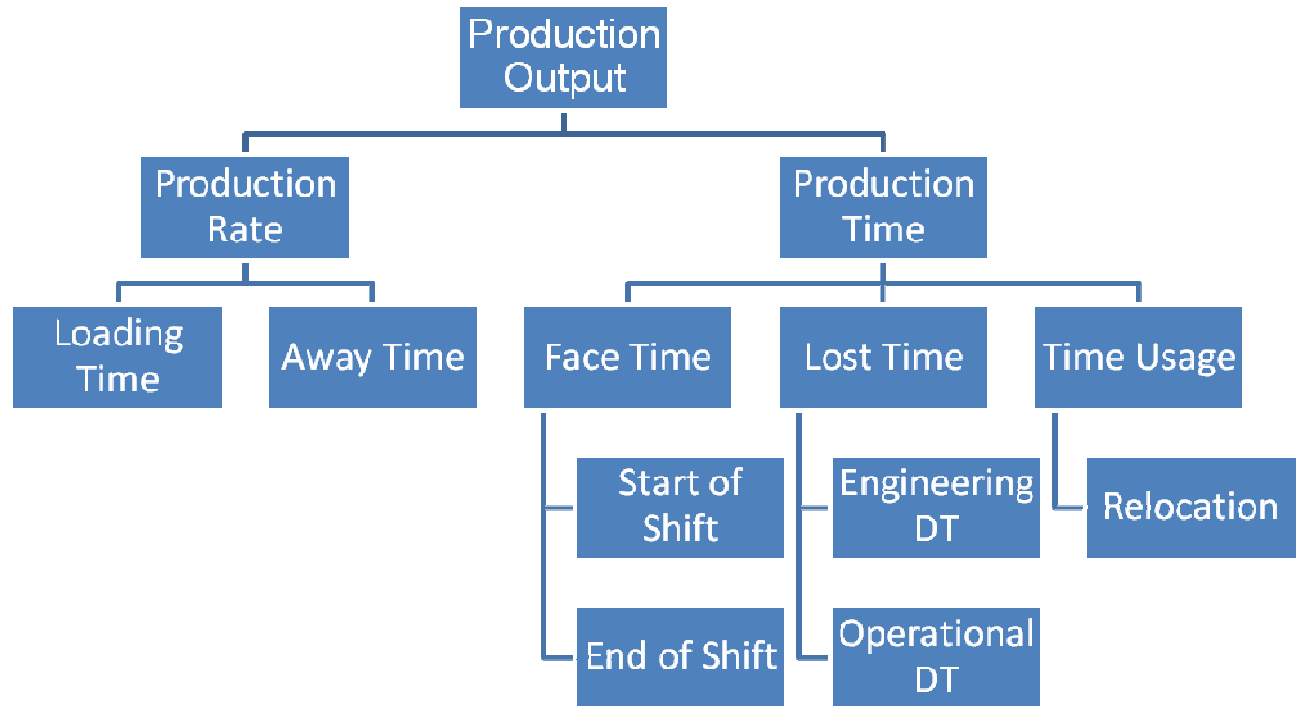


Greenside makes use of a 3 shift system. Figure above illustrates the flow of the production shifts. Each day has two 8 hour production shifts, which will hence be referred to as shift A and B. Shift A starts at 6:00am ending 14:00pm, the afternoon shift follows directly after, from 14:00pm-22:00pm. Maintenance shift is used to conduct maintenance and belt extension.

Shift Activities



KPIs Vs. Shift Activities



Appendix D: CI Downtime Recorder



Greenside Stoppage Recorder: CI



Date: ____/____/2008 Shift:

A	B	C
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 Section:

George	Yumagala	Thandeka	Thudaniang
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Job:

Breakdown (B)	Planned Maintenance (P)	Fit Stop (F)
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 Type:

Mechanical	Electrical	Hydraulic	Operational
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Continuous Miner Shuttle Car Trunk Belt Roof Bolter Other:

	1(min)	2(min)	15(min)	30(min)	1(hour)	2(hour)	3(hour)	4(hour)	1 shift	Specify
Diagnosis (min)										
Repair (min)										

	Description	Quantity	Delivery Lead Time				
Spare 1			In stock	30(min)	1(hour)	2(hour)	Specify:
Spare 2			In stock	30(min)	1(hour)	2(hour)	Specify:

Does this stoppage stop production? Yes No

Does remedial action need to be taken now? Yes No

Fault Area:	
Valves	
Gearboxes	
Control system	
Cable	

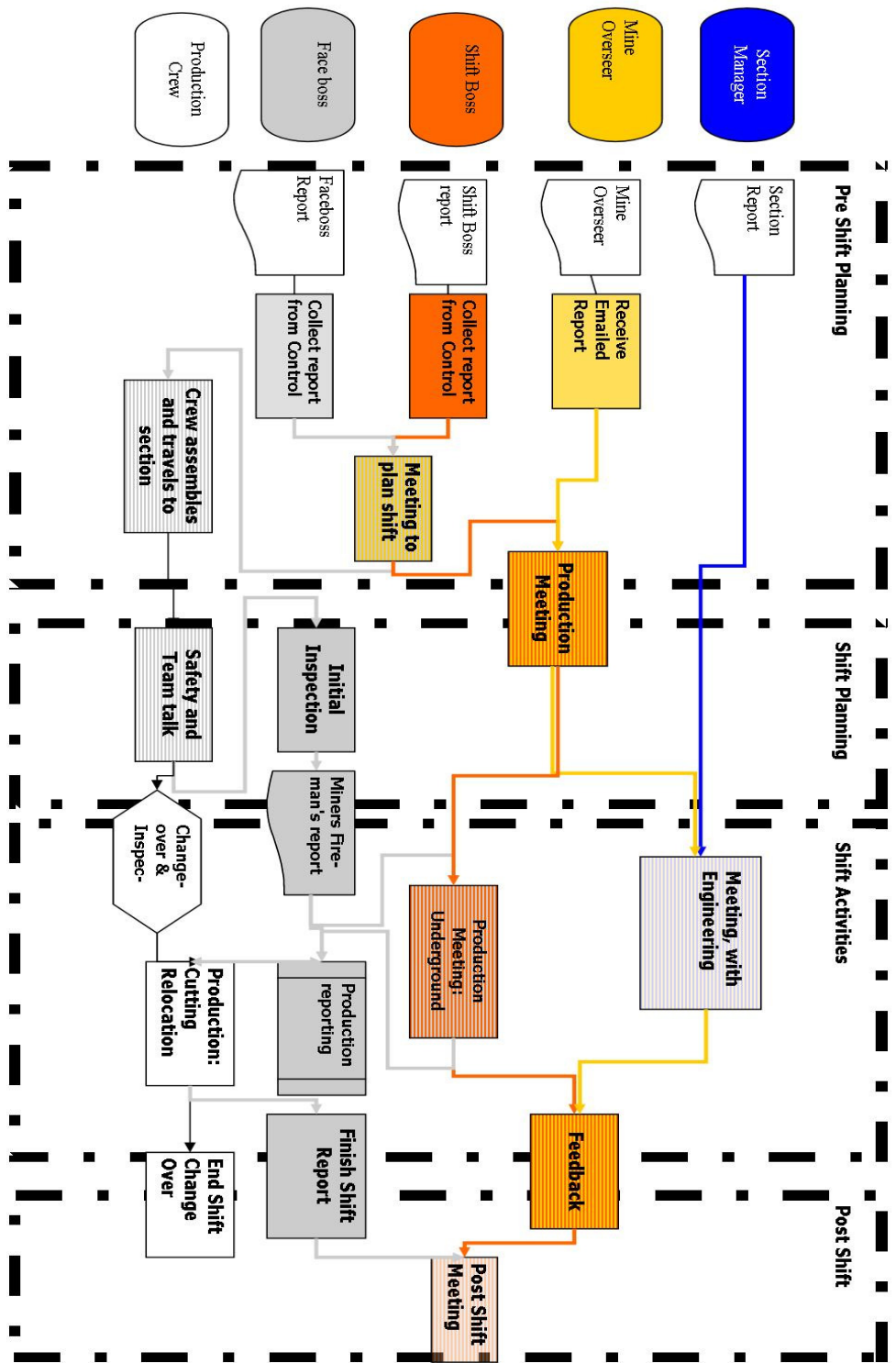
What in your opinion caused breakdown	
Wearing/Aging	
Operator Practice	
Lubrication	Level Type
Poor Design of Component	
Dirt/Foreign Body	
Excess Load	
Incorrect Setting	
Accident	
Water- source	Known Unknown
Other: Specify	

How long ago could the defect be detected in inspection/operator?			
15(min)	1(hour)	2(hour)	1 shift

If yes, how?	
Modification of Operator Practice	
Preventative Maintenance	
Preventative Replacement	

Can recurrence be prevented? Yes No

Appendix E: Information Flow Chart



Appendix F: Downtime Codes
Engineering Stoppages

Breakdown	Code
Workshop Welding	BMAK
Workshop Bodywork	BBOD
Torque Shaft	DOAC
Underground Conveyor	DOCV
Continuous Miner Water Systems	DODP
Cable damage, Roof Fall	DOND
Wheel	DOTR
Blockage in Value Chain	DSTK
Cable	ECAB
Electronic Controls	ECON
Power Supply Faulty	EGEB
Lights on vehicle	EL01
Electrical Breakdown	ELEC
Power Supply	ENOP
Electrical Motors	EM01
Conveyor Tripping-Blue Line	EPUL
Methane	EPST
Electrical Trips	ETRP
Transformer breakdown	ETXF
Traction Seals	HBLS
Hydraulic Cylinder	HCYL
Hydraulic Hoses	HHOS
Hydraulic Oil	HOIL

Hydraulic Valve	HVDC
Hydraulics	HYDR
Faulty Breaks	MB01
Bearing	MB02
Bolt Mounting	MBLT
Boom Conveyor	MBRP
Steering jack Pin	MCF2
Mega Head	MCHD
Flight Chain	MCHN
Spooling Device	MDS1
Water system	MECH
Gearbox Faulty	MGO1
Spooling Pump	MFDC
Motor Pump	MPPP
Mechanical Pulley	MP01
Water System	MR01
	MSP1
Steering cable	MSTE
Wheel	MWU1
Trailing cable	OCDO

Operational Stoppages

Stoppage	Code
Continuous Miner Water Systems	DODP
Methane sensors	DOEG
Continuous Miner Tramming	DOEM
Belt Extension	DONM
Tramming	DOEN
Cleaning Water Spray	DOER
Continuous Miner, pick replacement	DOGT
Battery related	DOLY
Tail end	DSTK
Conveyor Stop	DOEV
Cable Handling	OCRE
Shuttle Car Cable	OCTR
Cutting Floor	OCUF
Sweeping	OSWE
Open Block Sprays	OSPY
Replace Sprays	OSPY

Other Downtime

Downtime	Code
No Artisan	AART
No operator	DONO
Bad Conditions	DOND
No Access for stamler	DONA
Inspection	DOPS
Industrial Action	DOIA
No roof bolters in section	DORB
Batteries in Bay	EB01
Battery Empty	EB02
Methane Sensors	EPST
Public Holiday	NHOL
Maintenance Shift	NHOL
Electrical and Mechanical Maintenance	NMNT
Sunday	NSUN
Emergency Stop	OPUL
Planned Maintenance	PLMA
Machine on Stand-bye	STEP
Due to 12 Shaft Fan	XDEL
Stop Switch	OPUL
Methane	PLEG
Eskom	XEPF

Appendix G : Downtime Recording

Breakdown Reporting: IDEF 3 Process Model

This is an illustration of the “Faceboss Report” these are printed in the control room and the miner is expected to collect them from the control room before going LDV and to the section. The target audience of the report is the Faceboss and the shift boss. The faceboss and shift boss are expected to discuss the contents of the report before commencing of shift. Normally, these meetings are brief, as the information contained is already familiar with both the shift boss and the faceboss, as the miners report that is used to draft this report does speak to a great deal of what is contained in the report.

The report contains:

1. Shift Credentials (Top of Reporting)
 - a. Date, Section Name, Team (crew number), Operator

These elements are in general captured correctly, but the CM operator and the miner in the team are not.

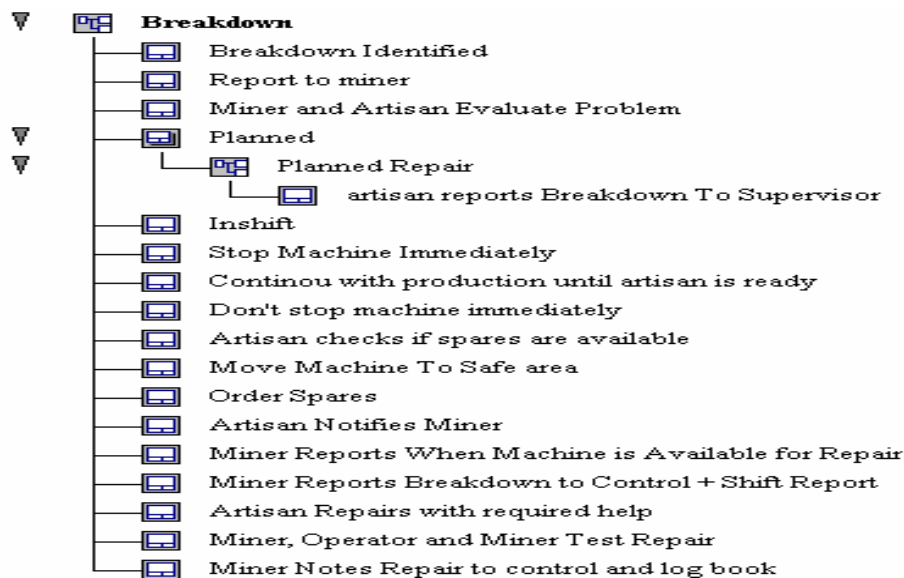
2. Shift Summary (Table below shift credentials)
 - a. First Sump, Last Sump, Meters Booked and the estimated shift production, these metrics are compared to the set target and the difference if reported as the variance. A positive (good) variance is indicated with a green block, while a negative (bad) is indicated with a red.
3. Time Utilization Waterfall graph
 - a. The table aligned with the graph illustrates the usage of during the course of the shift:
 - i. Face Time, is the difference between the achievable shift time. In the case of Greenside, being 480, less the time lost because the shift started late or finished early.

In practice however the metrics has been used inconsistently and in turn leading to a great deal of confusion.

- ii. Trammimg time, is reported as the summation of the time the CM spent moving in the section and not in the cutting cycle.
- iii. Engineering, breakdowns understood to have been caused by mechanical, electrical or hydraulic failures and the related duration are attached.

While the communication of this metric may be understood in the organization through the shared institutional culture, its use however remains insignificant as engineering downtime as only subscribed through retrospective terms, whereby downtime is only subscribed to the “department” that is responsible for causing then breakdown, rather than the function, machine or process that caused the breakdown. Theory of Process based management tells use that sustainable improvement can only be achieved if organizations strive to monitor and control “process” and not necessarily “department” performance.

Operational Downtime, all stoppages in the production shift calculated in minutes



Downtime Reporting: Faceboss Report: 27/03/2008

