11 MINING MODEL – APPLICATION

11.1 INTRODUCTION

In this chapter actual data from a coal mining section is used to provide an example of how the mining model is be applied. The actual data is used as a basis to identify deviations, and the techniques as prescribed by the mining model are demonstrated with fictitious examples.

11.2 UNIT INFORMATION

The production unit (Unit 1) is a single continuous miner development section (pillar-and-board) mining in an area with normal geological conditions. The equipment used in the unit is:

- 1x continuous miner (CM)
- 2 x roof bolters (RB)
- 1x in-section crusher and feeder
- 3x shuttle cars (SC)
- 1x in-section conveyor
- 1x switchgear and transformer
- 1x maintenance service unit
- pumps and other portable equipment

The seam height is approximately 3.5 meters, with some minor dolerite intrusions. The floor is soft sandstone and the roof is stable.

The section operates on a 2-shift system, working 6 days a week.

The organisational structure of the unit is shown in table 20.

Table 20 : Section organisational structure

PRODUCTION		MAINTENANCE	
Shift Boss	3	Foreman (over 2 sections)	4
Miner: production	2	Artisan	6
Miner: general	1	Helpers	5
Continuous miner operator	5		
Roofbolter operator	5		
Shuttle car operator	7		
Crusher & feeder (tip) operator	2		
Belt operator	2		
General worker	4		
TOTAL	**32**		**16**

The first line supervisor of this section is one of the shift bosses, and his deputy is one of the foremen.

The financial year of the mining company stretches from July to June, and all production and cost planning are done accordingly.

The company's vision is "To be a respected mining enterprise, harnessing our talents in applying competitive technologies to excel in selected coal markets"

The company has five core values, namely:

- Integrity
- Winning with people
- Excellence in all we do
- Continuous improvement
- Customer focus

11.3 TEAM FOCUS

In July of every year the first line supervisor holds an Indaba where the whole team gets together to work through the vision, values, and process definition steps of the mining model. Following that the first line supervisor with his deputy and his line manager discusses the process management aspects.

The vision of Unit 1 is: "We achieve excellence in all we do through participation and continuous improvement."

The unit has decided that they embrace the company's five values as their foundation values, and added the following defining statements:

We as Unit 1 believe that:

- All waste is evil
- Constraints govern our decisions
- Decisions are based on facts
- We all own the unit

11.4 STRATEGIC LEVEL

Step 1 – define the process

After all the team members have affirmed their commitment to achieve the team's vision and values they have a small team building exercise. This is to ensure that no barriers exist between individuals and between operations and engineering. During this session it emerges that the one roofbolter operator have a passion for the engineering field. The first line supervisor takes a next step to discuss this with the HR department, but provisionally assigns the one foreman as the roofbolter operator's mentor.

The first line supervisor and the team have previously mapped out the activities of the unit and allocated responsibilities to it. During the Indaba they re-visit the process map to ensure that it is still valid (refer to figure 26).

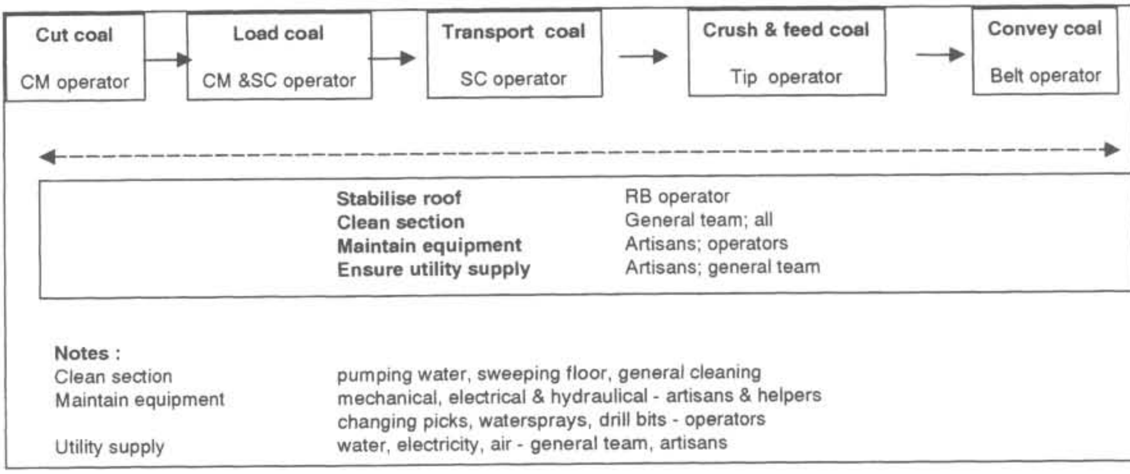

Figure 26 : Process map Unit 1

Step 2 – manage the process

After the Indaba the first line supervisor, his deputy and his line manager plan for the next year, by clearly all the process management rules for the unit as depicted in A and B below.

A: Customer requirements

▪ Production target	930 000 tonnes/annum
▪ Production schedule	Equal tonnes per shift Tonnes per month according to tonnes per shift Increase in production before Easter and Christmas period
▪ Cost	R14/ton
▪ Quality	Reducing fine coal generation and contamination
▪ Unit layout and movements	According to the geological mine planning the section will experience a dyke (major dolerite intrusion) of 3 meters thick in month 7.
▪ Major initiatives	Implementation of an EMIS (enterprise wide management information system) Investigation into the implementation of an on-board roof bolting system (roofbolter and continuous miner combined)

B: Measurements

Based on the customer requirements specific measurements need to be defined. These are in the categories of quality, production and cost.

Quality KPIs

• Fine coal	<28%
• Contamination	<2%

Production KPIs

• Cutting minutes	253 minutes per shift
• Cutting tempo	7.3 tonnes/minute
• Production	Avg. 77 500 tonnes/month
	Avg. 18023 tonnes/week
	Avg. 1638 tonnes/shift

Also track the following:

• Maintenance delays	minutes per shift
• Breakdown delays	minutes per shift
• Operational delays	minutes per shift
• Geographical delays	minutes per shift

Cost KPIs

➢ CM major overhaul	R1.80/tonne
➢ SC major overhaul	R0.68/tonne
➢ Inventory	R20.05 million
	Capital cost of section (R20 million) + cost of in-section stock (R50 000)

A budget for the year for Unit 1 is drawn up, of which the summary is shown in table 21

Table 21: Budget for Unit 1 for the financial year

CATEGORY	RAND MILLION
Labour	4.48
Sundries	0.07
Operating materials	0.71
Maintenance	5.56
TOTAL	*10.82*

Step 3 – measure the process

The team will continuously measure the KPIs utilising the different tools as prescribed in the mining model. Some examples are shown in figures 27-29.

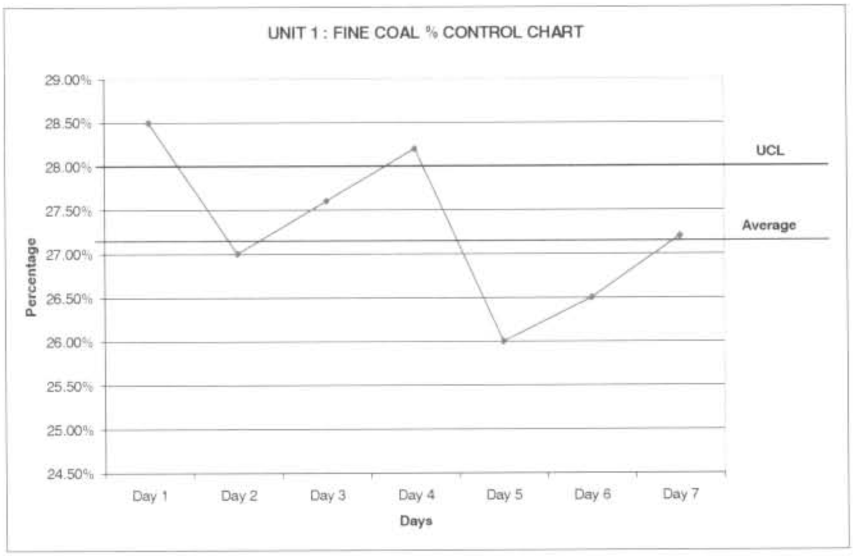

Figure 27: Fine coal % control chart

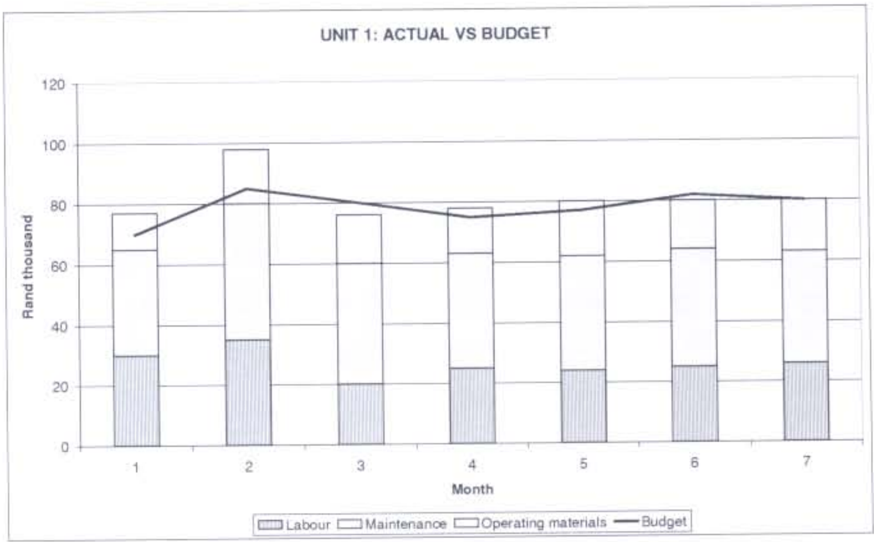

Figure 28: Actual versus budget figures

Figure 29: Production figures

Step 4 – improve the process

From the regular measurement of the KPIs deviations from target are identified. These deviations need to be corrected. To do this the step-by-step improvement process can be followed. Deviations can also be detected during the operational cycle, and the same improvement process utilised. To illustrate the improvement process a problem that is identified by to the constraint management activities will be used. Refer to step two in paragraph 11.5.

11.5 OPERATIONAL CYCLE

Due to a previous improvement project a shuttle car with a small capacity was exchanged for one with a bigger capacity. The shuttle cars were identified as being the constraints and by introducing the bigger shuttle car the total constraint capacity was increased. The first line supervisor knows that this major change could cause the constraint to shift, and therefore decides to go through the whole cycle again.

Step 1 – identify the constraint

The first line supervisor pulls various reports from the management system to determine if the introduction of the bigger shuttle car did improve throughput. Figure 30 shows the average tons per shift per machine for the production unit.

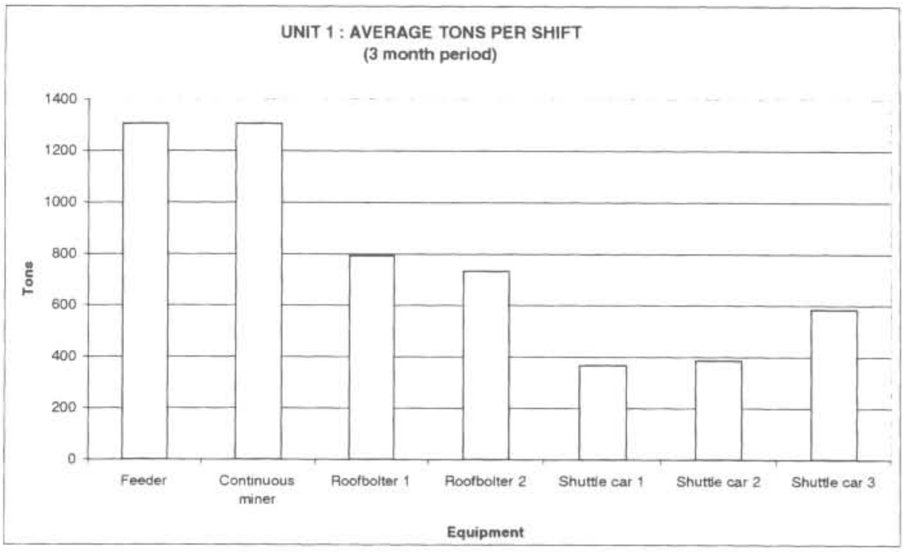

Figure 30: Average tons per shift per equipment

It is clear that shuttle car 3, the new shuttle car, is carrying more tons per shift that the other shuttle cars. The combined average tons per shift of the shuttle cars are 1336 tons, in comparison to the continuous miner's 1306 tons. Therefore the shuttle cars are no longer the constraint.

The customer requirement averages 1638 tons per shift; therefore the market demand is not the constraint. The feeder is currently operating to 65% of design capacity (avg. 2000 tons per shift) and can accommodate the shift to avg. 1638 per shift throughput without any problems. The roof bolters may be the constraint, but after careful analysis of the downtimes of the last three months (table 22) it is agreed that the 31 occurrences of waiting time for a roofbolter is not a cause for concern, or the reason for the throughput target not being met.

By method of elimination it is determined that the continuous miner is the new constraint of the unit.

Table 22: Top 15 downtimes recorded over three months

Downtime description	Occurrences	Total Duration (minutes)
Normal traveling time	144	3822
Tramming between faces	179	3807
Change picks /sleeves	190	2601
Trailing cable faulty	16	1965
Maintenance	10	1914
Wheel unit LH rear	4	1850
Inspections start of shift	96	1774
Waiting for roof support	31	1685
Crew station talks	115	1146
Tail end full of coal	8	1089
Structure	2	1065
Extension / shortening conveyor belt	12	1052
Hydraulic pipe / fitting	14	960
Water valve closed or faulty	8	925
Wheel unit RH faulty	3	904

Step 2 – exploit the constraint

The first line supervisor decides to use the process improvement cycle (paragraph 10.4.4) as a tool to generate solutions on exploiting the continuous miner. He nominates members from the team to form a quality circle with the instruction to improve the production output of the continuous miner. The next paragraphs illustrate the process improvement cycle.

<u>Clearly define the deviation.</u>

To answer the questions in this step of the improvement process the quality circle team members analyses the scatter chart of the production figures versus the cutting minutes, as well as the production over time line chart. Refer to figure 31.

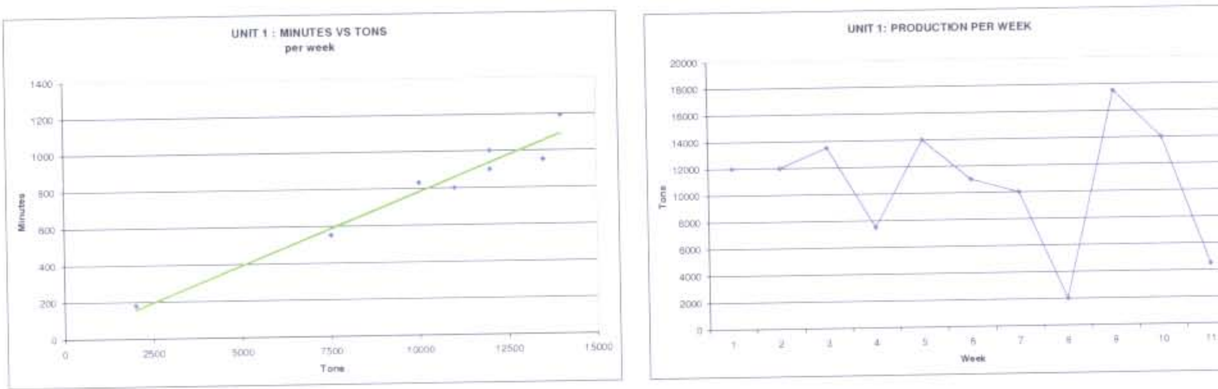

Figure 31: Analysis of production data

From the analysis the quality circle team members deduce that as soon as more than 12500 tons per week is mined the cutting minutes start to vary indicating instability in the process, and a dip in production follows soon after. To fully clarify the deviation the quality circle answers the questions as depicted in table 23:

Table 23: Summary of deviation

QUESTION	ANSWER
When did the deviation occur?	When production per week exceeds 12500 tons
Was it a once-off, or did it occur more than once?	It occurred twice in a 11-week cycle
Is there a pattern in the occurrences?	Yes, see question 1
Where did the deviation occur? What resources were involved?	At the CM. Resources are the CM operator, artisans, helpers
What were the symptoms?	Production decreased

Possible reasons for the deviation

The quality circle team members decide to utilise a fishbone diagram to determine possible causes for the deviation. Refer to figure 32.

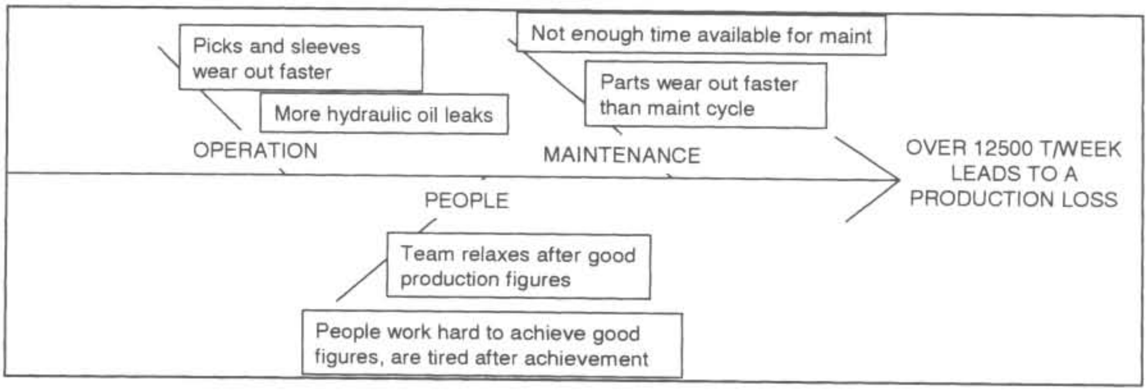

Figure 32: Fishbone diagram of possible reasons for the deviation

Test each possible reason to identify the core reason.

To determine if a possible reason is the core reason the quality team studies the downtimes of the last three months (table 22). Starting with the operational reasons they determine that the downtime for changing picks and sleeves are disproportionate to the rest of the downtime reasons. This supports the possible reason of "picks and sleeves wear out faster" as the core reason. The downtime "hydraulic /pipe fitting" do not constitute to a major downtime, and is rejected by the quality team as the possible core reason for the deviation. Next they examine the maintenance related possible reasons. To determine if the maintenance cycle is too long (parts wear out faster than the maintenance cycle) they consult with the mine engineer. He informs them that the maintenance cycle was determined together with the original manufacturer and that it conforms to the design specifications. Therefore it is not a possible cause for the deviation. The last possible reasons are all people related issues. The quality circle discusses the possible reasons with the Human Resources officer of the mine, as well as with the unit members during the regular crew station talks. Based on the feedback of these discussions they all agree that the people related issues couldn't be the reason for the deviation, as the whole unit is fully committed and motivated to achieve the production targets.

As a result of the analysis the quality circle to comes to the conclusion that with high production figures being achieved per week (more that 12500), the picks and sleeves on the cutting drum wear out considerably faster than if the production per week were less. This is due to the wear pattern on the picks and sleeves that are not linear in relation with the production output. The increase in worn out picks and sleeves led to an increase in downtime to change them, to such an extent that almost all the picks and sleeves had to be replace simultaneously. This explained the drop in production shortly after the 12500 tons/week level was reached.

Develop a solution to prevent the deviation from occurring again

The quality team knows that three alternatives exist to prevent the deviation from occurring again:

- Redesign the picks and sleeves to extend their lifetime
- Change the picks and sleeves in a shorter time
- Extend the lifetime of the picks and sleeves as currently designed.

As alternative one is a long-term activity outside their scope of expertise the quality team requests the in-house design specialists to register a project to increase the lifetime of the picks and sleeves. To find a solution for alternative two and three the quality circle decides to benchmark with other production units in their mine. From this benchmarking exercise they develop two solutions:

- Change sleeves on a preventative basis in the off-shift.
    - Picks that are in new sleeves do not wear out as easily.
    - It takes very long to change a sleeve. By changing the sleeves on a scheduled basis in non-production time it will prevent production time loss.
- Utilise a pick tray to have new picks available at the continuous miner.
    - When changing picks the pick container is fetched from the in-section storeroom, which is not close to the coal front. By having a pick tray with a certain amount of picks in it close by, the picks can be changed as soon as the continuous miner stops. The added benefit is that the helper can quickly see when the tray must be filled up (principle of poka-yoke)

Develop an implementation plan for the solution/s

To ensure that the solutions are implemented successfully the quality circle develops basic project plans to implement both the solutions. Neither of the solutions require major changes, and the solutions can be implemented within the next few shifts.

Step 3 – sub-ordinate everything else to the constraint

From the training on constraint management the first line supervisor knows that the scheduling of the whole section should be according to the drumbeat of the constraint. As the continuous miner is the first workstation in the production process, this is easy enough to manage. The first line supervisor ensures that the feeder speed is adjusted to the new throughput quantity, and also that the speed of the section conveyor belt is increased. As a lot of time is wasted when the continuous miner trams (moves) from one coal cutting area to another it is necessary that the whole team assists during this operation. The first line supervisor for that reason assigns each available team member with a specific task during the tramming process. This allows the continuous miner to start cutting again at the new cutting area with minimal time delay.

Step 4 – elevate the constraint

It is not possible to add another continuous miner to the section, as the return on capital expenditure is not high enough. It is however possible to increase the output of the continuous miner by upgrading some of the parts on it. To do this the first line supervisor together with the engineering team implements the following:

- Limit switches is installed on the continuous miner to prevent the cutting drum from cutting into the floor or roof, which would result in time going to waste by cutting stone. It also improves the quality of the product.
- More robust cutting drum gearboxes is installed on the continuous miner, to increase the turning speed of the cutting drum, thereby cutting more coal per minute.

Step 5 – re-evaluate the system

During and after all the changes have been made the supervisor constantly measures the performance of the unit to check if any other deviations occur. He also re-evaluates the system to check if the continuous miner is still the constraint, by returning to step one of the constraint management cycle.

11.6 CONCLUSION

In this chapter an actual production unit with actual results were taken and the use of the mining model illustrated. The whole process starting with the strategic cycle setting the targets for the year, and the operational cycle for the day-to-day management of the unit is demonstrated. Some of the problem solving techniques as well as the process improvement steps are shown. It is clear that the logical, easy to follow steps of the mining model enable the first line supervisor to continuously improve the performance of the unit.

12 REVIEW

The coal mining industry faces many challenges. There is increased pressure from the market for higher quality coal at lower cost and increased volume. To satisfy these requirements the mining company needs technically skilled first line supervisors who have the operational managerial skills necessary to cope with these demands. The problem is that first line supervisors possess the technical skills, but not the necessary operational management skills. Various operational management philosophies exist that provide world-class practices on how to manage in a production environment. It is unfortunately not possible to implement these philosophies as-is in a mining company due to the various differences between manufacturing and mining. The solution is to provide an operational management model adapted from these philosophies to the first line supervisor. The design of the mining operational management model is based on selected building blocks borrowed from the operational management philosophies. Implementation of the easy to use mining model is illustrated by means of real data from a coal mining production unit.