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Thesis

Analysis of Longwall Development Systems in Australian Underground Hard Coal Mines

- Benchmarking and Optimisation -

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Aachen, July 2003

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Topic:

Analysis of Longwall Development Systems in Australian Underground Hard Coal Mines

- Benchmarking and Optimisation -

Task:

- Overview of the Australian hard coal industry
- Identification and classification of performance drivers (e.g. legislation, geotechnical parameters, equipment and organisation / layout aspects)
- Description of longwall development systems of state-of-the art coal mines and benchmarking
- Theoretical evaluation / analysis of two-entry development systems
- Discussion of results and potential of optimisation
- Comparison of results with US-type three-entry development systems
- Conclusions

I submit this thesis as my own work. Where I have drawn on the work of others, this has been appropriately and fairly accredited. This thesis has not been presented to any examination authority in this or a similar form.

Aachen, July 2003

Content

Abbreviations

ABM	Alpine Bolter Miner (first simultaneously cutting and bolting CM on the market from VA)
ACARP	Australian Coal Association Research Program (Industry funded)
cf.	confer, according to
CM	Continuous Miner
CMTE	Cooperative Research Centre for Mining Technology & Equipment (Future Name: CRC)
CSIRO	Commonwealth Scientific & Industrial Research Organisation – Division Exploration and Mining
IMM	Integrated Mining Machine (simultaneously cutting and bolting CM from JOY)
JOY	JOY Mining Machinery - Equipment Manufacturer (no abbreviation)
NGCM	North Goonyella Coal Mine
NSW	New South Wales – State in south-east Australia
QLD	Queensland – State in north-east Australia
RAG	RAG Australia Coal - Mining Company
SAMs	Standard Area Methods
SC	Shuttle Car
TLV	Threshold Limit Value
UCS	Uniaxial Compressive Strength
UNSW	University of New South Wales (School of Mining)
VA	Voest Alpine - Equipment Manufacturer
PCI (coal)	Pulverised Coal Injection
TBM	Tunnel Boring Machine

This study was written in Australian English.
For decimal divisions points the syntax (#.#) is used.

1 Introduction

Longwalls are becoming faster as well as wider. Simultaneously improvements in roadway development are quite small, so that development is comparably expensive. To compensate for the increased longwall retreat rate, in recent years many operations had to increase the number of development panels, as well as, the number of continuous miner crews causing additional costs.

This thesis describes roadway development systems in its entireness, and tries to identify improvement potential by determining the best practice in the industry. The aim is to trigger and support changes in management procedures and contribute to the improvement in mine performance by cutting costs.

In the first place, an overview of the Australian hard coal industry is given, where market needs are defined. Furthermore, locations of different mining districts are given and coal production is quantified as well as their occurrence divided by different mining methods.

In chapter 3 the current standard roadway development method used in Australian underground hard coal mines is explained. The current available equipment and recent research projects are explained to point out the middle term future in roadway development.

A systems approach is conducted in chapter 4, where all important parameters and their interactions in roadway development systems are identified and described. As an integrated part, it shows up alternative roadway development systems. The approach includes legal conditions as they strongly affect and direct the development.

A benchmarking survey tries to establish the best practice. A questionnaire was developed and distributed to all Australian underground hard coal mines, requesting a variety of geometrical, technical, organisational and performance key figures. The results are compared with studies conducted in Australia a decade ago.

In the chapter 6 the different options discussed in the optimization approach (chapter 4) as well as the results from the benchmarking survey (chapter 5) are applied in a case study for the North Goonyella Coal Mine. Finally, recommendations to improve the overall efficiency in roadway development and a summary of this thesis is given.

2 Australian Hard Coal Industry

In this chapter the Australian coal mining Industry is characterized. First an overview is given on mining methods. Production figures show the origin by method and by the state followed by a description of historical market prices and the latest price trends. Finally the major coal producing companies are listed with their market shares.

A map of Australian coal districts is given in the following figure. Details regarding these districts are given later.

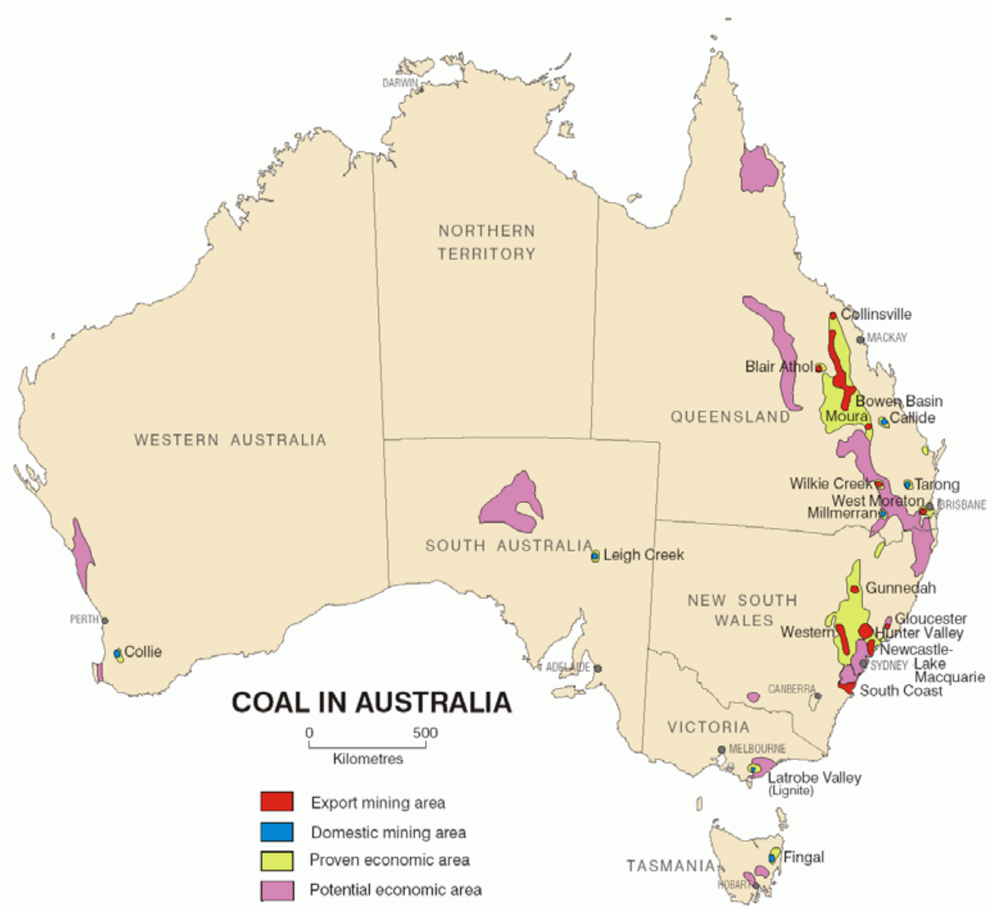

Figure 2-1: Australian Hard Coal Industry and future prospects [I01ITR][1]

2.1 Mining Method

The easiest form of mining coal is by open cut operation. Here only the overburden has to be removed to allow the mining of the underlying coal seam. This is usually removed by dragline or truck and shovel. The exposed coal is then loaded by power shovels or front end loaders into off-

[1] The syntax [?_Number/Year_First three Characters of the Authors Surname] is used for a reference to a **B**ook, **a P**aper, a **M**eeting, a **C**ontact or an **I**nternet document. All references are listed in alphabetic order.

road trucks for haulage out of the pit. As a rule of thumb, open cut coal mining is feasible until 70 m depth of cover.

Underground mining is more complex, but with increasing depth of cover this mining method becomes feasible. Other driving parameters in the decision to go underground is the thickness of coal, the dip of the seam or the coal quality. Many underground mines were open cut mines earlier, but some coal seams are not outcropping so that underground mining had to start in the first place. There are two major methods used in underground mining – “bord and pillar” also referred to as “room and pillar”, and longwall.

In bord and pillar mines underground roadways (“bords”) are cut into the coal seam with pillars of coal being left to support the roof. Continuous miners are used for coal extraction. Once as much coal as possible has been extracted during the first workings, the pillars and surrounding coal are extracted, working back towards the main access roadways. This method is referred to as second workings or pillar extraction, where the roof in the goaf then collapses.

Because the mechanisation and automation of longwall equipment has reached a high level, this second mining method is dominating in Australia today and will even further increase in the future (figure 2-2). The panels in longwall mines are between 1-5 km long and coal is extracted by a drum shearer travelling along a face of 200-300 m length. The roof is allowed to collapse once the longwall has passed.

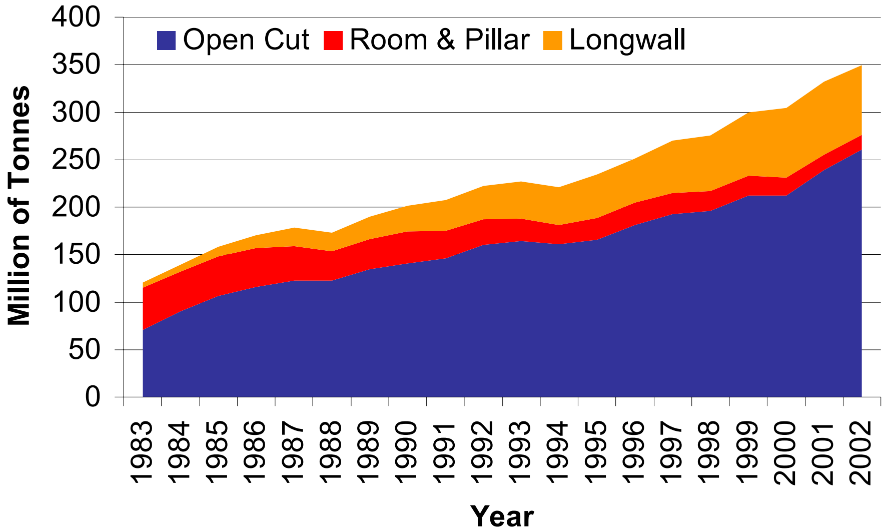

Figure 2-2:
Australian raw coal production by method of mining
data [C02CRA]

2.2 Coal Districts

Australia’s coal resources are about 80 billion tonnes. Almost 90 % of them are found in either NSW[2] (New South Wales) or QLD (Queensland). The identified underground reserves in these states are about 21 billion tonnes each, with approximately 75 % as opencut resources [P03BAR].

[2] Abbreviations are also explained on page IV.

2 Australian Hard Coal Industry

The traditional underground coal mining districts are the coalfields near Newcastle in New South Wales and the Bowen Basin in Central Queensland. Only one mine is found in South Australia, three in West Australia and three in Tasmania. Since the last decade, more and more mines were opened in Queensland. Good coal quality and comparably cheap transportation are the drivers for the development of the Queensland coal mining industry.

Because roadway development is not an issue in open cut mining and only particularly in bord and pillar, the focus in this thesis is set on longwall mines. In 2003 NSW longwall mines employed about 2 000 men, QLD longwall mines about 2 500 men [P03JOH]. The history of coal production as well as the number of faces in these two states are illustrated in the following graph. In 2003 several mines closed however new mines like Beltana in NSW or Grasstree in Qld will keep the underground coal production on the same level.

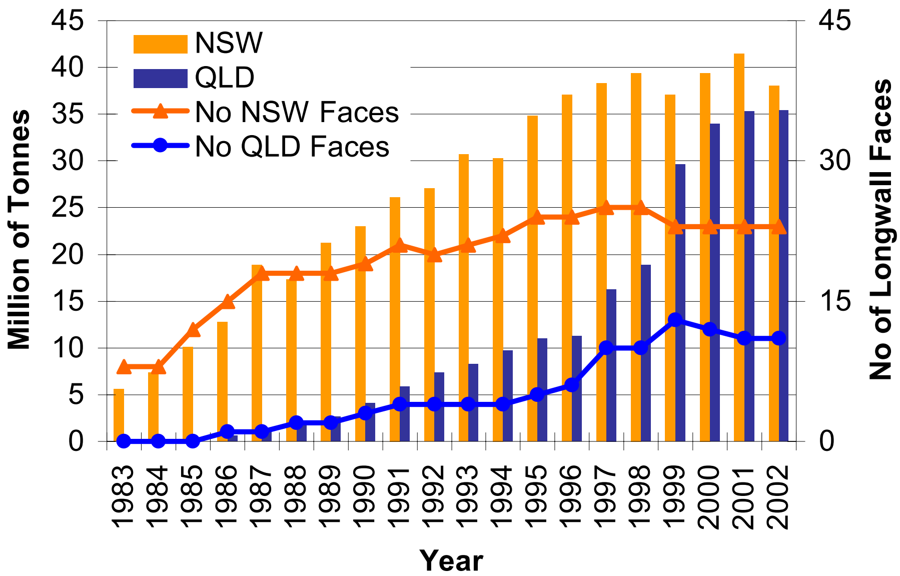

Figure 2-3: Production from longwall faces in Australia [C02CRA]

Detailed graphs of the two coal mining districts NSW and QLD can be found in the appendix 1.

2.3 Coal Market

Marketability is based on the type and quality of the coal and drives the revenue. There are tree different coal qualities: Thermal coal for power plants, PCI coal as a blast furnace enhancement and coking coal. Some mining companies blend cheap low quality coal from open cut operations with high quality coal from other operations, so that the final product specification meets coking coal requirements, by not overachieving them.

The Australian coal market is driven by the decline of the Australian Dollar in relation to the US Dollar. The Australian export industry benefits from this and along with it the Australian coal mining industry.

For every 5 cent increase in the A$/US$ exchange rate, the cost of steam coal rises by 1.5 US$/t, the cost of hard coking coal about 1.8 US$/t. Steam coal producers would suffer much more than the hard coking coal producers, because their margins are thinner [P03BAR].

The market price in 2002 for thermal coal in Australia FOB (free on board) was about 30 US$/t. The price for coking coal is with a price of 45-50 US$/t more than 50 % higher (figure 2-4). This is caused by high quality requirements (very low sulphur content, low ash content) resulting in less suppliers for coking coal [P03JOH].

Additionally, a huge increase in the US$ hard coking coal price can be noticed. Especially the underground mines in QLD, as producers of high quality coking coal, are taking the profit.

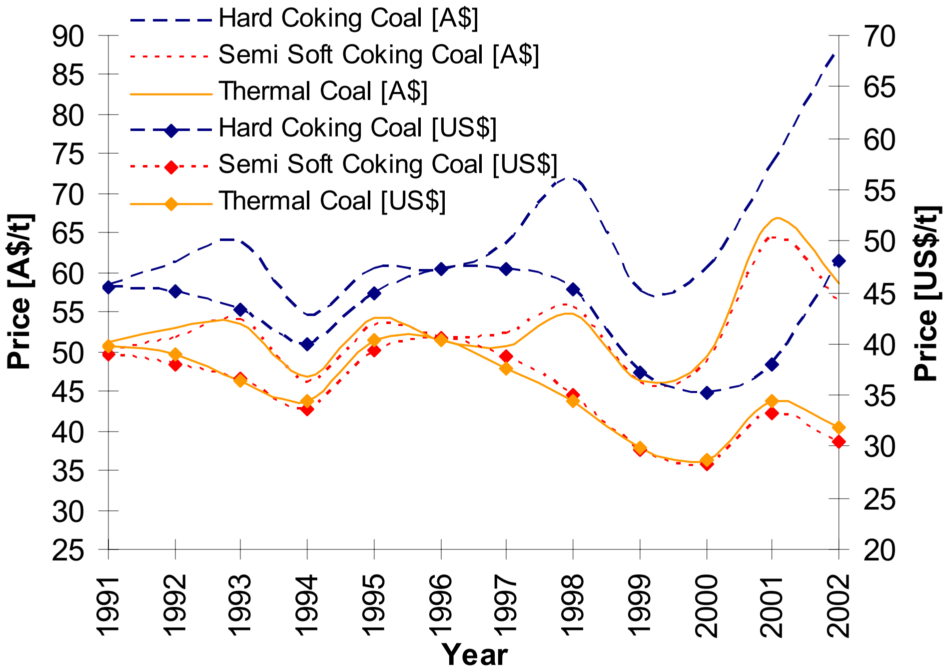

Figure 2-4:
Coal market prices - Australia to Japan. data [P03JOH]

Between 1995 and 2002 the cash cost FOB for Australian coal has fallen by about 25 %. The main drivers in reducing costs were reductions in work force and rail freight costs. In this period the average QLD mine labour cost fell from 11 A$/t to 6.5 A$/t, in NSW only from 11.5 A$/t to 8 A$/t. The average cost of rail in QLD fell from 13.2 A$/t to 6.2 A$/t; whereas in NSW from 7.3 A$/t to 3.8 A$/t. However in QLD the government took a higher share - in January 2002 royalty payments rose about 2.5 A$/t [P03BAR]. The state changed the target of its royalties from conventional free on rail (FOR) to a free on board (FOB) basis - although the rate remained unchanged at 7 % [I03EEJ].

2 Australian Hard Coal Industry

The Australian coal market is characterized by a strong market concentration process. In July 2003 Xstrata took over the last major Australian owned mining company MIM. Before that it already acquired Glencore and Enex. The four biggest underground coal producers now have a longwall production share of about 73%. In the Australian coal export market the same companies are the majors (figure 2-5/2-6).

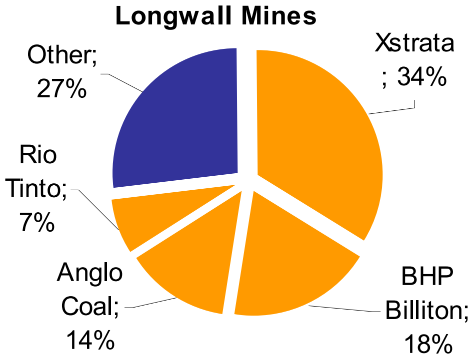

Figure 2-5: Australian Longwall coal production market share 2002 data [P03ALM]

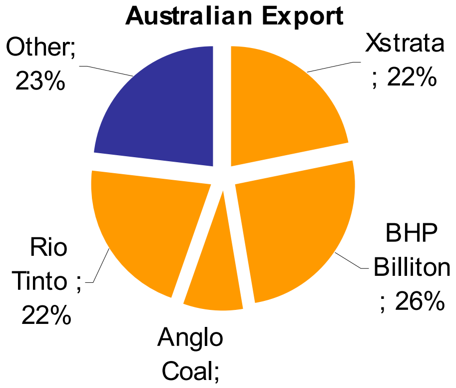

Figure 2-6: Australian Coal Exports Market Share 2001 data [I03EEJ]

A detailed description of the Australian hard coal mining industry is provided by the Productivity Commission of the Australian Government [P98PCA].

3 State-of-the-art Roadway Development

The term roadway defines all underground roads. Gateroads are the roads at both sides of the longwall. Mainroads (mains, dips) are connecting all the gateroads with each other as well as the shaft and/or ramp to the surface.

The roadway development methods applied in the Australian mining industry differ from methods used in other parts of the world. Roadway development is applied in a geologically virgin and unknown environment – it is only known by a very rough pattern of drill holes. As tectonic structures are encountered during the development, the conditions for the longwall retreat are quite well known already in advance.

Roadway development has more variations and is less continuous than longwall retreat, where a high grade of standardization has been achieved. The state-of-the-art roadway development is a function of the individual coal deposit, mining technology, expertise, tradition and politics.

This chapter begins with giving a development equipment overview – focusing on the continuous miner as the central part. Later the roadway development method is explained: The different tasks in roadway development are repeated regularly. Abstract this is comparable to regular street cars where all parts are inspected after a certain interval. Subdividing the field of roadway development into cycles enables a better understanding of the processes involved (figure 3-1). In this study the focus is set on the following three cycles:

The face cycle consists of the tasks cutting, haulage and support. The pillar cycle describes the system configuration like in-place or place change, single-section or super-section and panel extension services. The panel cycle is pointing to more generalized engineering design aspects like panel layout, ventilation and rock mechanics. The mine cycle is integrated in the scheme just to emphasize the influence of more global topics like logistics, geological aspects or the mine plan.

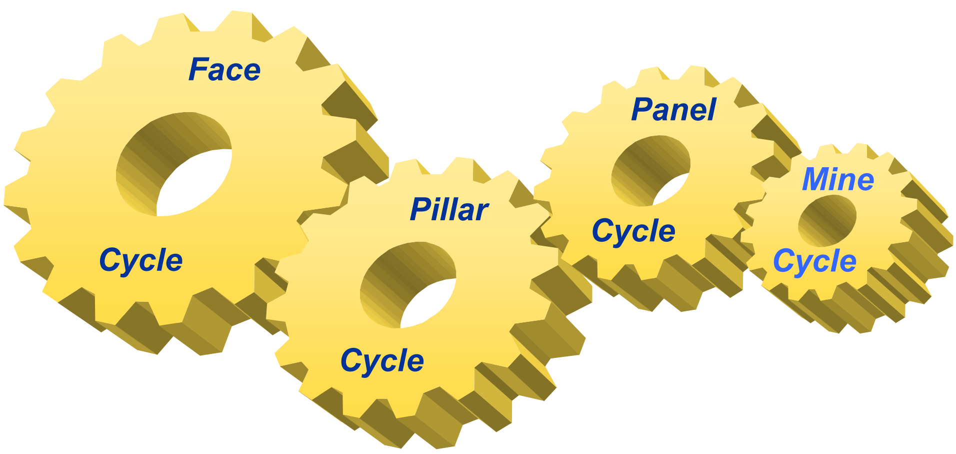

Figure 3-1: Integration of cycle processes

The size of the gearwheels shows the authors preference, namely topics most affecting the daily underground production. The tasks behind the mine cycle should be seen as services, which just have to guarantee that development can take place.

Finally an outlook is given concerning research and development, prospective methods and technologies by explaining selected examples.

3.1 Cutting Equipment Overview

Over the last decades, the design of continuous miners has not changed very much. No fundamental changes in the technology haven been realized. A minor change was for example to put a drive in the drum instead of driving it by a ripper chain and changed thereby from centre drum mounting to two- or three-point mounting.

However, simultaneous cutting and bolting was successfully introduced in development. Bolter miners, both JOY and VA ABM, are equipped with four roof and two rib bolting rigs and have a width of about 5 m. Standard cut&flit continuous miners, like the DBT (Jeffrey) CM, are usually more narrow and have no onboard bolting rigs.

The trend in development of continuous miners is to install more motor power, reduce ground pressure by using wider undercarriages, the application of remote control and logging systems as well as the utilisation of more modular construction and containerized material supply systems [P02NIC].

VA Alpine Bolter Miner 20 & 25

The most common Voest Alpine continuous miner is at present the ABM 20. VA was the first manufacturer offering simultaneous cutting and bolting and still by far the major. A theoretical performance evaluation is sketched in the in chapter 4.6.1.

The newest ABM20 model is the series-3 with an improved canopy, better rib protection for the operator and better consumables storage. Since a couple of months the ABM 25 as the most recent development from Voest Alpine, is available on the market (figure 3-2). The main improvement is more installed power which leads to a higher cutting capacity.

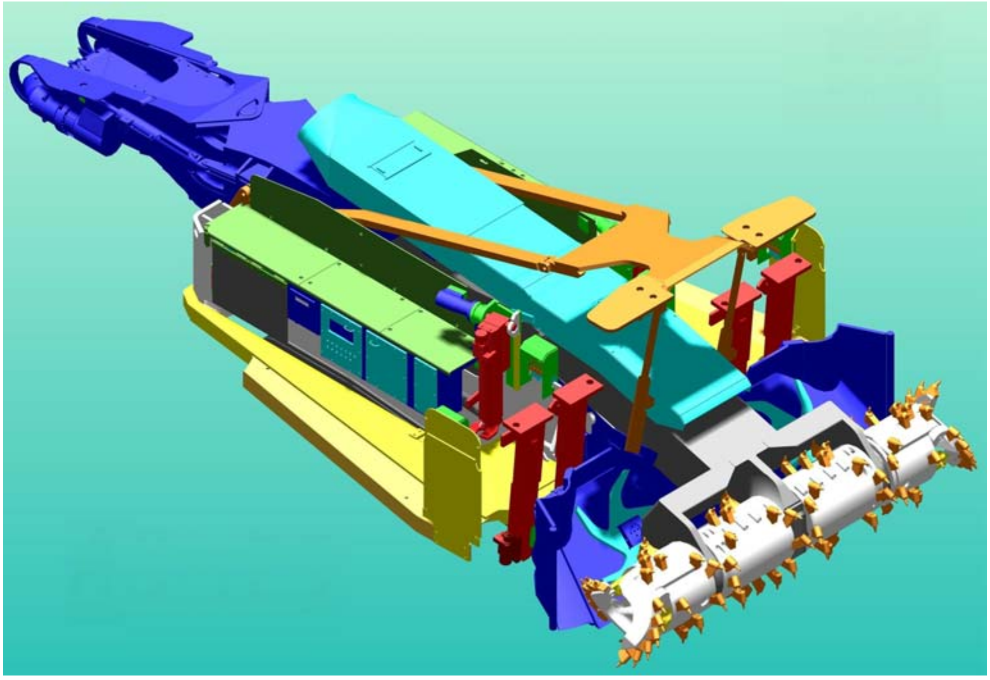

Figure 3-2:
3D Drawing of an ABM25
[M17MEL]

JOY continuous miner and Integrated Mining Machine (IMM)

The Joy continuous miner like the 12CM30 can be widely found in Australian underground coal mines. It has slightly more cutting power than the ABM 20 because it has to cut all the coal when the SC (shuttle car) is waiting.

The Joy IMM equipped with attached bolters is a further development of the JOY Bolter Miner. The machine features are simultaneous cutting and bolting, 1.5 m depth of cut, and onboard storage for over 600 Bolts and associated hardware. Two onboard material pods hold the bolting consumables which can be exchanged with full pods by an LHD. Operators are onboard behind a full-face shield and under a canopy with the width of the machine [P01SOR]. Until so far only a prototype is in use at SUFCO Mine (USA) since three years (figure 3-3).

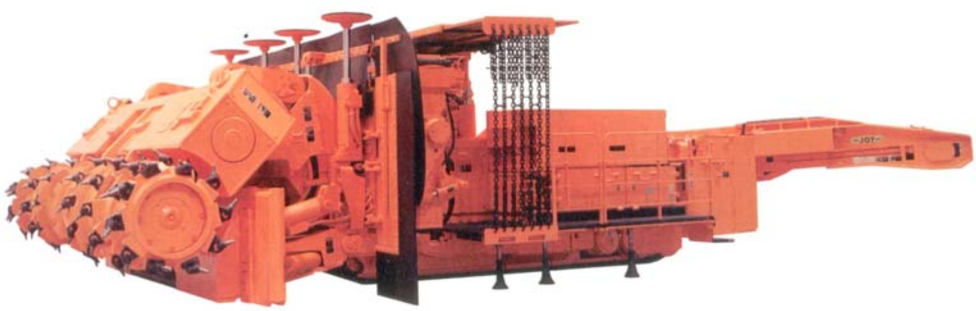

Figure 3-3:
Picture JOY IMM
[M10ALD]

3.2 Face Cycle

The face cycle has three elements: cutting, haulage and support. The traditional roadway development face cycle has not changed much since decades. In this system a continuous miner is cutting the coal and parallel feeding it into a shuttle car which off-loads it at the boot end of a conveyor. During haulage bolting takes place. The holes for the rock bolts are mostly drilled with onboard drill rigs. Simultaneous cutting and bolting can reduce the face cycle time. In a standard operation one operator is needed for the CM operation, one for each shuttle car and usually two to four men for bolt installation.

This shows that roadway development is not (yet) completely continuous – even when the main machine used in the process is called "continuous miner". This continuous miner is usually cutting coal only 10 % of the time.

3.2.1 Cutting

The first method of development was the use of hammer and wedge. Advance rates increased significantly by the introduction of the drill & blast method, which is still applied in some coal mines. It is a very flexible technology - especially for the development of narrow seams with strong faulting and changes in rock properties. For example in Germany about 60 % of the 80 km developed each year is done by drilling & blasting. The average is about 4 m/day [P02EIK]. But, today more and more mechanized equipment is used, which cuts the rock and prevents cracking of the surrounding strata much better.

The SME Handbook classifies continuous miners into rotating drum machines, auger machines, boring machines and roadheaders [B92SME]. Because of the insignificance of boring machines, using the term continuous miner implicates rotating drum machines with roadheaders standing next to them. This linguistic practice, using the prevalent terms, is applied in this thesis as well.

Continuous miner technology can mainly be found in the United States and Australia. In the European coal mining industry the roadheader mostly supersedes the continuous miner. The roadheader is more flexible and among other things round roadway profiles can be driven. The average advance rate in German hard coal mines with roadheaders is about 6-8 m/day [P02EIK]. In Europe mains are occasionally driven by the use of TBM's (tunnel boring machine). This becomes feasible by mining long roadways. Roadheaders and TBM's are much better suited for harder rock. An overview of the different development techniques is given in the table 3-1.

Table 3-1:
Overview development techniques.
cp. [B00RAD]

Technology	Advantages	Disadvantages
Continuous Miner	▪ higher mobility ▪ higher undercarriage velocities ▪ higher cutting power per m² face	▪ higher floor impact by cyclic movements
Roadheader	▪ higher cutting power per m² impact area ▪ stronger rock > 40 MPa	▪ suited only for middle to high seams
Drill & Blast	▪ highest flexibility ▪ strongest rock	▪ discontinuous ▪ manual process ▪ rough surface

In the Australian coal mining industry the continuous miner is the only machine used for roadway development. Roadheaders are only applied when dykes have to be cut through. Newstan Mine used roadheader for mining a 3 m thick dyke with a UCS of 180 MPa in the coal seam by developing a roadway along the dyke. Before the mine used to omit these zones, so that the longwall had to be relocated within the same panel, it caused loss of deposit and production as well as extra expenditure [M15STE].

The installed cutting power on the continuous miner is mainly sufficient for cutting thick coal seams in Australia. A coal storage capacity in front of the front shield is quite useful to stockpile one SC load of coal to be able to complete the cycle. Some problems are related to the gathering devices, when material gets stuck above it. Because of its sensitivity to the cycle time, a detailed picture will be shown in chapter 4.6.2.

3 State-of-the-art Roadway Development

In the following figure the most common cutting procedure is shown. In the appendix 2 the cutting sequence for good and bad roof is given.

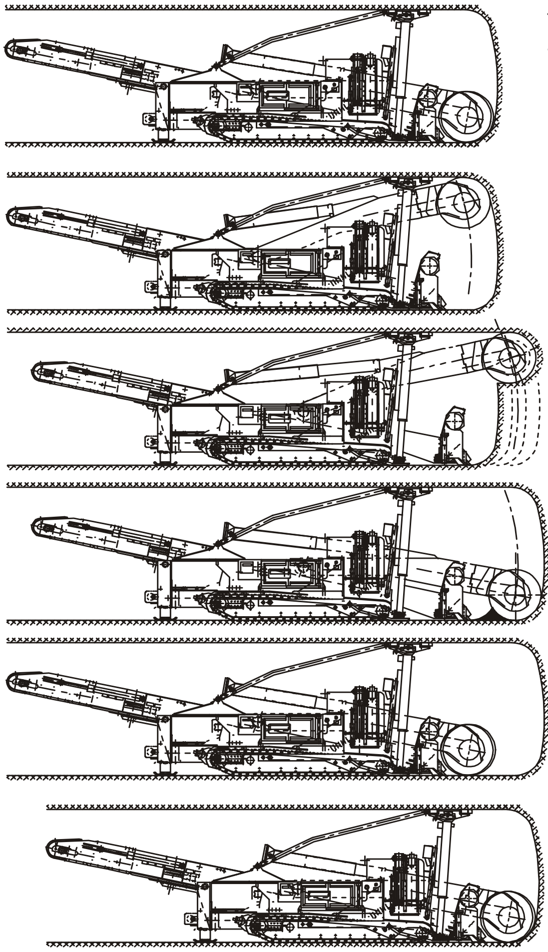

Figure 3-4: cutting sequence of a ABM20 [M17BAR]

3.2.2 Coal Haulage

The choice of the haulage system has a huge impact on the productivity of the CM and the overall cycle time of the panel advance.

Different equipment is available on the market, however the most common one is the first of the following options:

- shuttle car (electric)
- ram car (battery, diesel)
- scoops (LHD's)
- coal hauler
- continuous haulage system

A shuttle car is a rubber-tired haulage vehicle that is loaded/unloaded by a built-in conveyor. This allows loading and dumping without turning the vehicle. All SC's in Australia are manufactured by JOY. The JOY 15SC for example can load between 12 and 15 t (figure 3-5). Due to the cable run a maximum of two SC can be used within a two entry system. The cable is as well constantly subject to damage.

A ram car is also a rubber-tired haulage vehicle but it is unloaded through the use of a movable steel plate located at the back of the haulage bed. In contrast to a shuttle car, it is usually diesel powered. While ram cars have a better circling freedom of movement by having no cables and a break joint between engine and operator set and basin, the disadvantage compared to the SC is that only two wheels are driven. The man manufacturer is DBT – former Jeffrey (figure 3-6) and can load approximately 10 t [B00BAY].

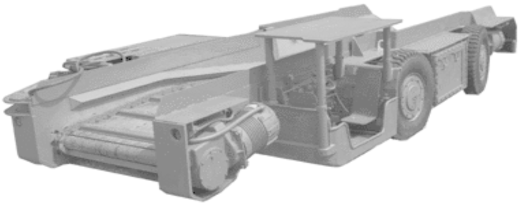

Figure 3-5:
left: JOY Shuttle Car

Figure 3-6:
right: DBT RAM Car

A scoop is a rubber-tired haulage vehicle used in thin coal beds and has a front shovel similar to a LHD. In Australia the most common type is manufactured by Eimco. It can be used for all kind of auxiliary work, too.

Usually one or two vehicles are used in a development panel. The demand is increasing with longer wheeling distances and decreasing with a higher bolting density. If diesel or battery vehicles are used, more than two cars can be utilized because there are no restricting cables. The disadvantage is the contamination of the mine air with exhaust.

Continuous haulage systems from different manufactures are available on the market. In Australia some of them have been tried, but the technical break-through is still pending.

3.2.3 Support

For roof and rib support usually fully resin encapsulated high tension steel bolts are used. However, at the longwall side of the roadways fibreglass bolts are installed to enable the longwall shearer to cut through them. Southlands, the deepest mine in Australia, is still installing mechanically point anchored steel bolts. This is done, because the experience showed that the resin disappears into voids which are opening when the coal peels at both rib sides during development.

The following figure 3-7 shows the bolting pattern used at Southlands. Quite a lot of mines use six roof bolts per metre advance, whereas only up to two rib bolts are common.

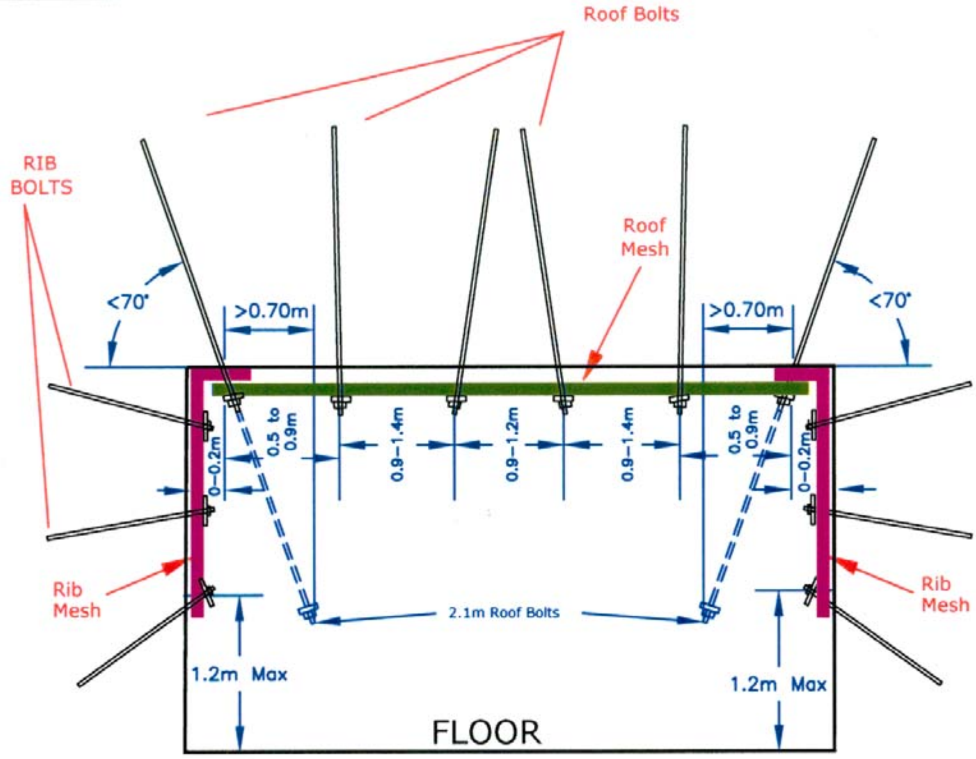

Figure 3-7:
intensive bolting pattern
[Southlands Colliery]

In Australia, the borehole is cleaned and the drill bit cooled by circulation of water. Only one Australian mine regularly practices dry drilling because drilling does not comply with the mining law so that an exception is required. Furthermore special equipment like vacuum pumps etc. is required to reduce the airborne dust. Hence, in the United States sucked dry drilling is very common. The main advantage of this technique is that excessive water on the roadway is avoided. This man made water accelerates the deterioration of the roadway floor and forms a clayey and sticky coal slurry.

3.3 Pillar Cycle

The pillar cycle describes the basics of the processes happening within the pillar area. It includes the equipment system configuration which defines the arrangement and the number of equipment used in the pillar. Services involved to complete the pillar during the panel extension belong to this cycle as well.

A commonly used term to define a location is “inbye” and “outbye”. It refers to a reference point. If something - for example a car - is outbye of the longwall, it means that it is situated in the direction to the mine entrance. Something is “inbye” if it is located further inside of the mine than the related object.

3.3.1 System Configuration

In-Place / Place-Change

There are two general procedures of developing a roadway by means of a continuous miner (CM). In a "place-change" operation the CM is relocated to the other heading after the cut out distance is mined. The cut out distance depends on the competence of the roof. Then roof and rib bolting take place. In Australia this method is referred as “cut & flit” [3].

In an "in-place" operation the cut/load/bolt cycle is completed sequentially as the roadway is advanced. Because of the unsupported roof in a place change operation, the operator usually handles the CM by remote control.

The decision between in-place and place-change can be explained by the adoption to the geological conditions. It has also a relation to the number of entries – the more entries the more advantages are resulting from the place change method.

In-place operation require a different design of the CM, with onboard bolting rigs and thereby a higher capital investment. On the other hand relocation time can be saved and the advance rate can be higher. The traditional method in Australia has been the in-place operation. A few years ago it looked like the industry might switch to place change mining, but this did not occur, especially for gateroad development.

In the United States there are mostly place change operations, because most of the US seam’s hanging wall roof conditions are excellent due to the competent sandstone except for the Pittsburgh seam. This experience enables up to 36 cuts before bolting. With two gateroads, place change is generally less efficient than with tree gateroads as the short flitting distances preferred for place change mining require short pillar lengths, hence more cut-throughs per gateroad [M07ROB].

In the US mining industry a cut-out distance of 6 m[4] is common. A safety restriction with no one allowed to enter unsupported roof is postulated by the US as well as Australian law [B00RAD]. In Australia a cut-out distance of about 12-15 m is referred as feasible, whereby good floor and roof conditions are presupposed. The place change method is often suffering poor productivities due to weak immediate mudstone roof. (Glennies Creek Colliery, partly Goonyella Riverside,..)

Glennies Creek Mine expects from the introduction of an in-place continuous miner with on board bolting rigs a better quality gateroad properties for the longwall [P03EGA].

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[3] The term “flit” means to bring the continuous miner from one face to another.

[4] A “extended” cut is 40 feet long which equates about 12 m.

Super-Section / Single-Section

If more than one continuous miner is used in a panel this method is referred to as a "super-section" or "super-panel". If only one of the two continuous miners is used at a time, this is called single crew super-section. If each continuous miner has its own crew it is called "tandem super-section", in the US referred as "dual section".

The idea of the single crew super-section is that if one machine is not available, the crew will go on working with the other one. This happens for example if the machine is in maintenance or while flitting. At every time maintenance can be carried out on one of the machines. A tandem operation is used to achieve higher advance rates however doubling the crew is not doubling the advance rate. This indicates that the cost per metre might be higher. A super-section setup is usually chosen, if the mine is delayed with development to keep up with the longwall retreat rate.

Single-Pass, Dual-Pass

In a single-pass operation the cutting drum has the same width as the entry. In Australia most entries have a width of 5.2 m. If the CM is smaller, it has to cut the face in two passes. This operation is called dual-pass. This type is much easier to flit in another heading so it has its advantages in a place change system configuration.

Roadway quality is important for gateroads, hence the use of 5.2 m fixed width heads on in-place miners. With a wide head machine an easier control of the width is achieved. Only longwall installation roads need to be cut wider (about 8 m) through taking a second pass. This allows enough space for the chocks.

3.3.2 Services and Panel Extension

In every gateroad development, various services have to be carried out outbye of the continuous miner. Not all of these can be done parallel to the face cycle, therefore the face cycle has to be interrupted regularly. A comprehensive list of the panel extension procedures can be found in appendix 3.

For most of these tasks an LHD is used. Different attachments are available to perform tasks from rock dusting, material transport and auger drilling. The most popular LHD in Australia is build by Eimco (figure 3-8).

Figure 3-8:
Photo of an Eimco LHD [WINKEL]

Road Construction and Water Handling

There are two origins of water in a mine. These are man made and in situ water. The main origin at the most mines is man made water which results primarily from dust suppression measures while cutting and drilling. If methane drill holes are encountered substantial amounts of seam water are discharged, too.

If the water stays on the ground and equipment is tramming, it result in a very thick slurry. This massively hampers the complete development process and makes work strenuous. An Eimco with a shovel attachment can be used to clean the inbye roads.

Outbye, where no SC traffic occurs, some mines are constructing a drainage trench,. Such a trench is cut as close as possible to the block side and is approximately 0.7 m deep and 0.2 m wide. It is then equipped with a drainage pipe and filled with ballast. Subsequently the roadway is also covered with ballast and graded with a mine grader like shown in the picture.

Figure 3-9:
Underground grader
[WINKEL]

In depressions, a hole is augered with an Eimco auger-attachment (figure 3-10). Pressured air pumps located in these auger holes feed the water into a sewage water pipeline. It discharges into “fish-tanks” from where the water is pumped by an electrical pump to the surface.

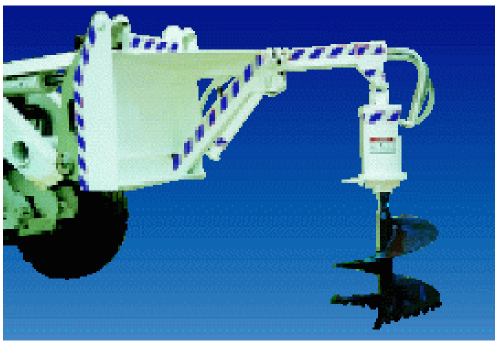


Figure 3-10:
Eimco auger attachment
[M17WRI]

Rockdusting

Rockdusting is legally required to prevent coal dust explosions by applying inert rock dust to the walls. The mix of limestone with coal dust arrests a flame propagation when the dust is dispersed by the pressure wave running ahead of an explosion. This can be done by one man with special equipment attachment to the LHD or with three men using a manual Quickduster [I03ALL]. Limestone is used because it causes no lung cancer compared to other inert rocks. Additionally water barriers are installed.

Belt extension

One of the most time consuming parts of the panel extension services is the belt move. This includes the installation of idler stands, rollers, the belt safety line, the repositioning of the feeder breaker and a boot end. Some boot ends have a crawler unit attached – termed as MBE (mobile boot end).

Pipes & Cables

The infrastructure demand in coal mines in comparison to ore/hard rock mines is quite high. Not only communication and high tension cables as well as water pipes have to be installed but also pressured air, sewage and methane gas pipes. To protect the installations from damage and to minimize the space requirements, the pipes are attached to brackets with chains. The brackets are screwed on roof bolts (figure 3-11).

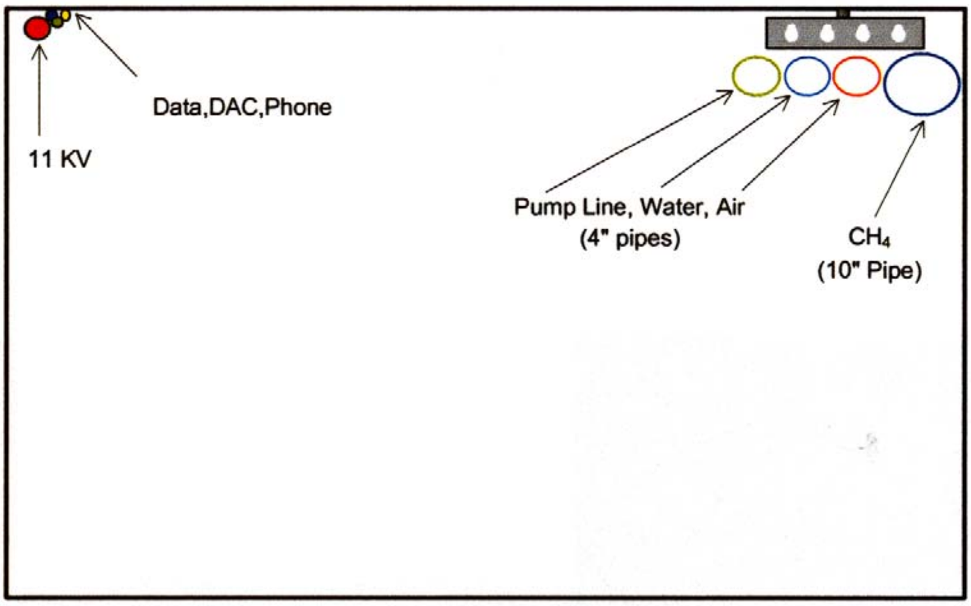


Figure 3-11:
Cross section of travel road (looking inbye)
[B99KEL]

The distribution control box (DCB) respective power centre is moved parallel to the belt move one pillar forward.

Ventilation

In the outbye crosscuts permanent stoppings are constructed. These are either steel mesh / brattice / shotcrete or brick stone walls. Building up a stopping needs about half a day with two or three men.

New ventilation pipes are installed within the face cycle like shown in the following figure. The pipes are fit together and sealed by a velcro fastening rubber strap. Furthermore the auxiliary fan has to be repositioned in the vicinity of the new boot end location. The ventilation sequence is integrated in figure 3-13 on the next page.

3.4 Panel Cycle

The Panel Cycle describes all design aspects which are defined in the planning phase. These issues are concerning different departments within the mine. Some aspects like layout and organisation is done by mining engineers, others like rock mechanics have to be completed by geoscientists. This field is also strongly influenced by the legislation.

3.4.1 Organisation

A typical Australian mine has one longwall operation and two to three active development panels. At each of these panels about eight men are employed, whereby some external contractors are used additionally (table 3-2). The miners (continuous miner operators) at the face belong to the operators or inbye crew. The other miners (tradesmen) belong to the services crew – colloquially referred to as "bull gang".

Table 3-2:
Typical Shift Manning for an in-place development

Management	(1/2 Shift Coordinator)
At the Face	1 Deputy 1 Operator 2-3 Miners (Drilling) 1-2 Shuttle Car
Services	1 Fitter 1 Electrician
SUM	8-10 men

3.4.2 Layout and Geometry

A common dimension for the chain pillar between the belt road and the travel road is 100 m*35 m. Roadways are driven usually 3.5 m length and 5.2 m wide (see Benchmarking Survey Chapter 5). The boot end is usually installed 20 m behind the last intersection. From there on the coal is conveyed via a conveyor belt to the main road.

Figure 3-12 is showing a two entry panel layout. This is the most common entry system in Australia. Because of the significance of this issue, it is discussed in an extra paragraph coming up next.

The panel extension procedure is illustrated in the figure 3-13. Here the belt road is driven prior to the travel road.

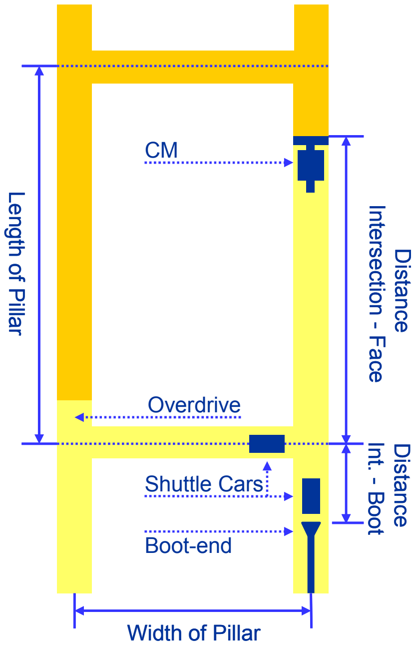


Figure 3-12: Two-entry panel layout [WINKEL]

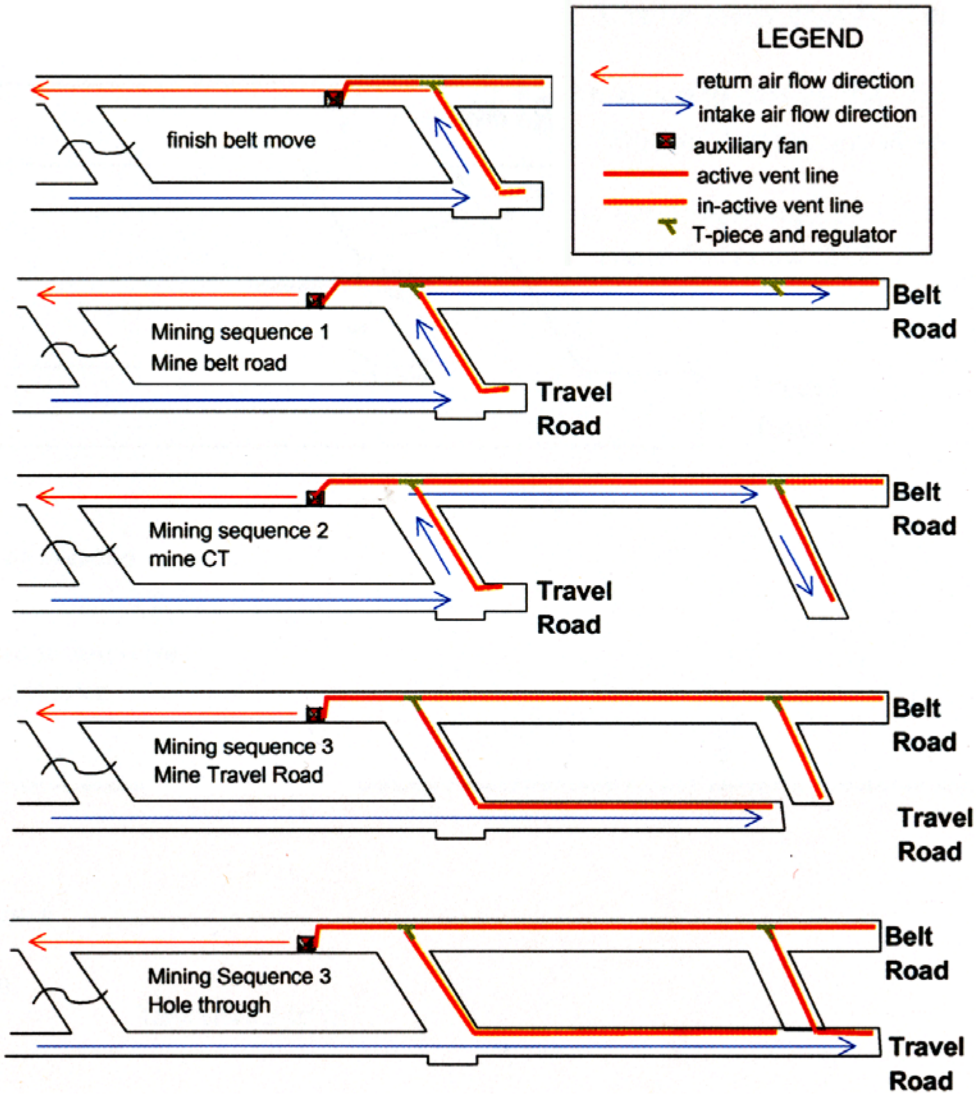


Figure 3-13: Panel extension and ventilation sequence [B99KEL]

3.4.3 Number of Entries

It should be defined that the number of entries reflects the number of connected parallel roadways. For example in the UK, two parallel gateroads are driven. But because these are not connected, it is here defined as a double single-entry system[5].

In the Australian mining industry the two-entry system is the norm. In contrast to that, in eastern US coal mines the standard is a three- (or four-) entry system, whereas in western US coal mines two entries are common. German mines are unexceptional using the single-entry concept. In Australia the single-entry system has been employed[6] and is now considered as a usual method to avoid delay of the longwall.

Multi-entry systems have a large number of advantages. However the additional value is decreasing with the number of entries. The more entries are driven, the more flexibility during development and longwall retreat is gained. Congestion problems are reduced significantly and more space is provided for vehicles, material, etc.

A very important issue is the increase in safety. Additional emergency escape ways are available. Potential hazards are reduced by spreading out activities. Simultaneous operations like panel extension services can be done parallel because their interdependence is reduced. For example, a secondary support installation in the tailgate can be done in fresh air. Another issue is that the lowest entry can be used as a water collector.

Due to high seam gas levels respectively high temperatures it may be necessary to use a three-entry system. This situation will be encountered usually in deeper, gassier areas.

Where increasing depth of mining and in-situ stress may cause stability problems an extra stress relief road may be required. This may be necessary in single-entry longwall installation roads.

The crosscut angle is usually 90°. Some mines are driving some or all crosscuts are driven with an angle of 70°. Such a crosscut makes it easier for the SC to drive around the corner. Because of the large dimensions of longwall transformers an angle of 70° every fourth crosscut might become necessary, like at Moranbah North Mine [M12COL].

[5] A more detailed explanation can be found in [B03LAU].

[6] Ellalong Colliery (NSW) 1996 merged with the adjoining Bellbird South lease named Southern Colliery. A single-entry was chosen because of a change in longwall orientation. In the 1.3 km panel the retreat rate dropped from 4.0 to 2.4 m/shift. Ventilation was not an issue. It is the deepest mine in Australia with a depth of 560 m [P94POR].

3.4.4 Ventilation & Methane Gas Drainage

The ventilation is usually done in form of a U-ventilation system. The whole air flow is guided to the last open crosscut. From there, fibreglass ducting is installed up to the face to allow sucking ventilation. An auxiliary fan is installed outbye close to the feeder in the belt road. In contrast, Moranbah North Mine uses brattice ducting and blowing face ventilation, which is much easier to install but all the hot and humid air passes by the operator of the continuous miner.

The methane gas content in the seams mined in Australia is usually about 5 m³/t. Occasionally the gas content may go up to 10 m³/t. Gas drainage has to be carried out in areas of high seam gas content. All areas with over 7.5 m³/t methane content have to be drained.

A common air quantity at a continuous miner face is 5-8 m³/sec[7], the exact quantity required depends on the cross section and the equipment installed. Additionally, hazardous gases must be diluted below the legal threshold values. The following table provides an overview of the mine gases occurring and their legal limits.

Table 3-3:
Mine gases table
[M15STE]

Name of Gas	Symbol	Relative Density	Legal Limits
Oxygen	O_2	1.11 g/cm³	19% Lower Limit
Carbon Dioxide	CO_2	1.53 g/cm³	1.25% Upper Limit
Carbon Monoxide	CO	0.97 g/cm³	50 ppm Upper Limit
Methane	CH_4	0.55 g/cm³	1.25 %Power Off 2.00 % Men Withdrawn
Nitrogen Oxides	NO_X	1.80 g/cm³	5 ppm Upper Limit
Sulph. Hydrogen	H_2S	1.19 g/cm³	10 ppm TLV
Sulphur Dioxide	SO_2	2.26 g/cm³	2 ppm TLV

Heat is a huge issue in Central QLD. An effective working temperature over 27°C reduces the allowed working time at the face. The typical demand for a current development section is 30-50 m³/sec.

The temperature gradient in Australia is about 5.5°C per 100 m vertical depth of cover, but this only has a minor impact on the mine climate. The main source of heat is the solar heat in summer months, where the wet

[7] See Systems Approach chapter 4.2 legislative restrictions.

bulb temperature can exceed 25°C. The third factor is the heat of the equipment, especially where diesel ram cars are used.

Cooling systems are only in use at German Creek Central Colliery and Moranbah North Mine. These mines presently use a simple and cheap solution for cooling parts of the intake air at the surface. In summer the company rents snow cannons from the Victoria ski-resorts, where they are only used in winter. By this means the wet bulb temperature can be decreased to below 20°C [M08MIT].

3.4.5 Rock Mechanics

During the past ten years, different design techniques have emerged from statistical analyses of databases of historical pillar successes and failures.

The major contribution of the original Analysis of Longwall Pillar Stability (ALPS) was a formula for estimating the longwall pillar load based on numerous underground measurements by Mark in 1990.

The calculated stability factors had a wide range (approximately 0.5 to 1.2) in which both successful and unsuccessful designs occurred. This may conclude that other variables in addition to the ALPS stability factor were influencing tailgate behaviour.

The Coal Mine Roof Rating (CMRR) overcame this restriction by providing a quantitative measure of the structural competence of the coal mine roof. The CMRR applies many of the principles of Bieniawski's Rock Mass Rating (RMR) [P99MAR]. This system is widely applied in US mines.

Because of the geotechnical and mine layout differences between United States and Australian coalfields the ALPS model was calibrated. The final outcome was the model called Analysis of Longwall Tailgate Serviceability (ALTS). It has a strong relationship to the CMRR [P99COL].

On this basis of historical pillar failures from South Africa and Australia plus the ALTS Model, in 1996 the University of New South Wales developed a methodology for Australian conditions. This limit between stable pillars and instable pillars is illustrated in the figure on the next page.

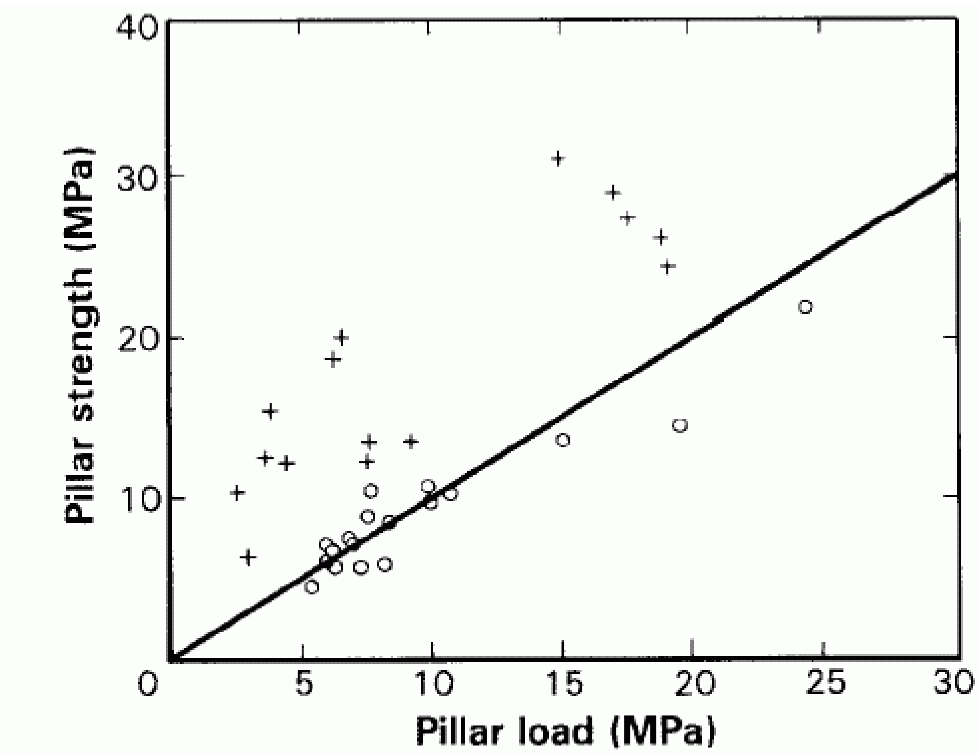


Figure 3-14:
Pillar strength and pillar load relationship for both the failed (o) and unfailed (+) Australian cases. [P99GAL]

The outcomes were the following strength formulas which were found to best describe the observed behavior of pillars in New South Wales and Queensland. The following formula was developed for square pillars:

$$\bullet_{s2} \bullet 8.60 \frac{(w\bullet\ )^{0.51}}{h^{0.84}} \quad (\mathrm{MPa})$$

Figure 3-15:
UNSW formula for square pillar stability
[P99GAL]

The corresponding expression for squat pillars (length ≠ width) is given by:

$$\bullet_{s2} \bullet \frac{27.63 \bullet^{0.51}}{w^{0.220}\, h^{0.110}} \left\{ 0.290 \left[\left(\frac{w}{5h} \right)^{2.5} \bullet 1 \right] \bullet 1 \right\} \quad (\mathrm{MPa})$$

Figure 3-16:
UNSW formula for squat pillar stability
[P99GAL]

There is a high level of confidence associated with its application. The following correlation in table 3-4 has been established between the probability that the refined formulae will yield a successful design versus the respective design factor of safety.

3 State-of-the-art Roadway Development

Probability of Failure	Factor of Safety
8 in 10	0.87
5 in 10	1.00
1 in 10	1.22
5 in 100	1.30
2 in 100	1.38
1 in 100	1.44
1 in 1 000	1.63
1 in 10 000	1.79
1 in 100 000	1.95
1 in 1 000 000	2.11

Table 3-4:
Probability of failure with UNSW system [P96GAL]

Faulting

Faulting is an important issue in almost every coal mine. Compared to German coal mines the mines in Australia are less exposed to faulting. Usually coking coal mines have a stronger faulting than other mines, because of the conditions under which this type of coal is composed. Faults can be documented only very roughly by core drilling but most structures are first encountered during roadway development.

The effects of faults on roadways differ and can only be predicted in a very limited way. If hard stone has to be cut at thrust faults, intrusions or seam splits other equipment than a continuous miner may be necessary. In fractured zones additional support is required. The following sketch (figure 3-17) gives an overview about the different structured and their location of occurrence.

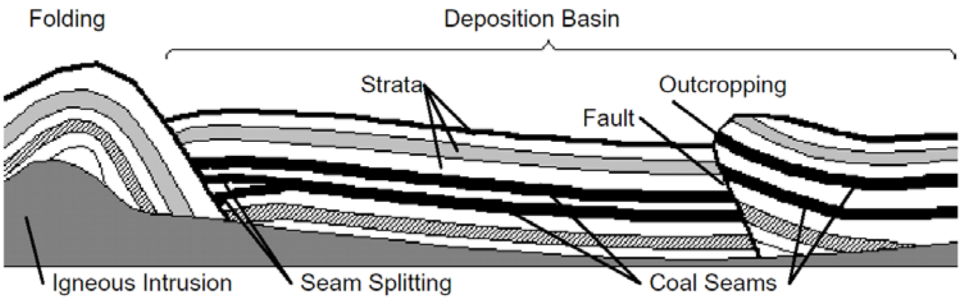


Figure 3-17:
Geological formations related to coal mining [P98PCA]

Rock Movement

The roof movement is recorded with simple two-cable extensometers. One end is set in the lower part of the roof – the other one in about 5-8 m above the roof.

In critical areas like longwall installation roads or intersections, a more exact magnet based extensometer might be required. These areas are sensitive because of the large roof span of up to 8 m. The readings still have to be taken manually, but this provides a better forecast and the data can be processed at a PC. A common displacement rate in the beginning is around 5 mm up to 10 mm per week [M12COL].

The graph 3-18 shows that the movement rate is decreasing. The main displacement is between the coal beam and the overlying strata (in about 2 m depth). Above 7 m the displacement is insignificant.

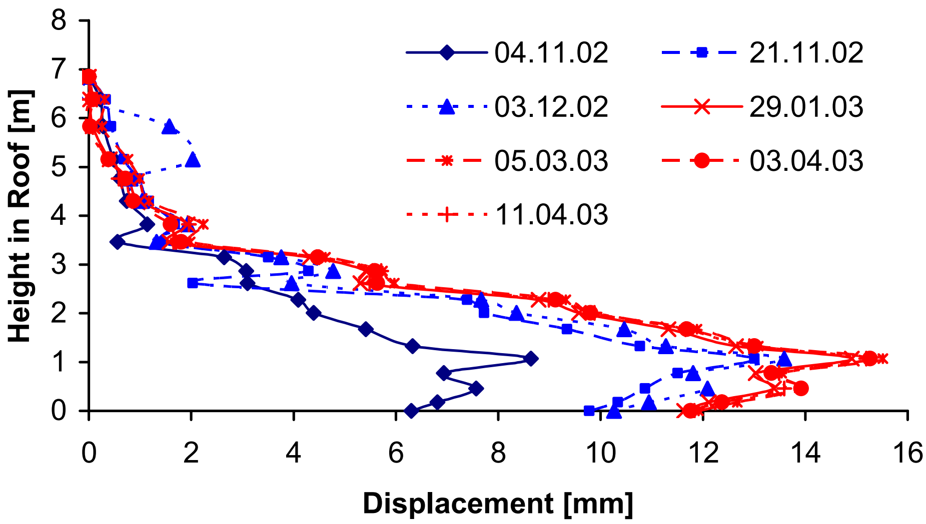


Figure 3-18: Extensometer installed in longwall installation road [WINKEL]

Secondary Support

The standard roof support is usually supplemented by additional cable or mega bolts where conditions require this. It is particularly important at intersections from the gateroad with the crosscuts, in longwall installation roads and around geological fault areas. For example, the longwall installation roads at Moranbah North are reinforced with 9 m double cable bolts about every metre.

3.5 Future Outlook

High efforts in research and development are undertaken by mines, manufactures and universities to increase the efficiency of the roadway development process. Research and development projects in Australia are mainly industry funded by the Australian Coal Association Research Program with considerable financial support from the governments.

The research is conducted by manufacturers and/or by various research institutes like the CSIRO, CMTE or Universities. The areas include automation, organisation and new equipment concepts. Just a few projects are explained in detail here.

3.5.1 Bolting and Surge Car

CSIRO is developing a new machine called autonomous conveying-bolting module (ACBM), which will insert the roof bolts concurrently with coal cutting and coal haulage systems. The machine consists of an automatic roof and rib bolting system and will be located behind the CM. A conveyor is integrated into the machine to allow the coal to pass through. From there the coal is passed over to a continuous haulage system or a shuttle car.

The ACBM will convey coal at 25 tonnes per minute and insert four roof bolts and two rib bolts autonomously in less than 5 minutes. It will have 200 roof bolts and 100 rib bolts onboard [M05CUN].

It works together with a remote controlled miner (for example and ABM20-S3) up-front and it can install a light pattern of bolts remotely from two 25-bolt carousels. The use of self-drilling roof and rib bolts and bulk chemicals are an integral part of this project which is also the main problem in developing this machine. The production target is to develop 12 – 15 metres per hour. 3d drawings of the ACMB and its integration in the face cycle can be found in the next two figures.

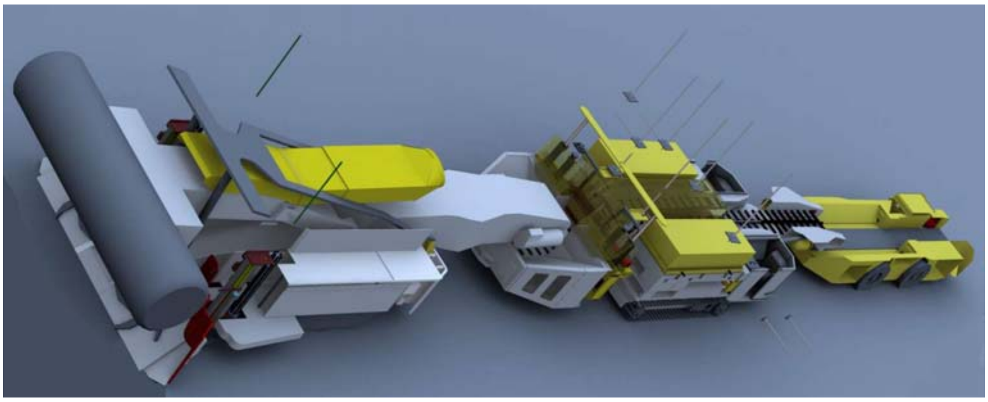


Figure 3-19:
3D drawing CSIRO ACBM with continuous miner and shuttle car
[M04KEL]

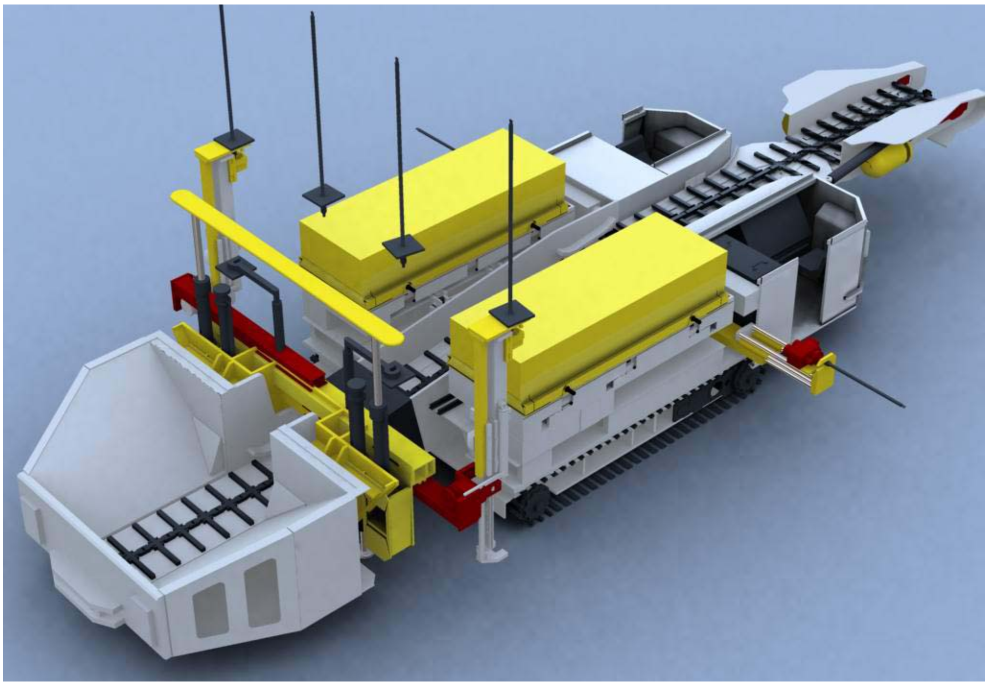
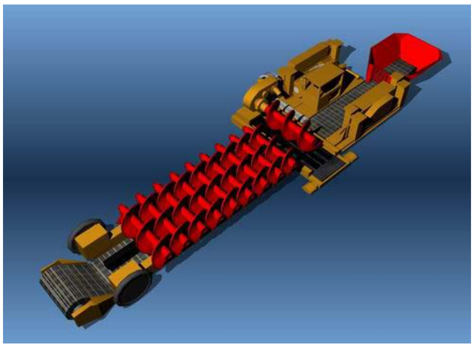


Figure 3-20:
3D drawing CSIRO ACBM
[M04KEL]

3.5.2 Roadway Development Auger Mining System

Underground auger mining is not new, tests have been conducted as far ago as the 1950's. The main issues which limit a wider use of underground augers were a lack of sufficient power, a missing method of cutter head steering, an effective flight handling system and coal clearance system and finally problems with methane gas management.

The company CET, located in Brisbane, carries out research and development of a Roadway Development Auger Mining System (RDAMS) to improve roadway development rates in underground longwall coal mines. The project was particularly funded by the Australian government. The partner in the new auger concept is BryDet, a major surface auger manufacturer. The prototype has already been tested successfully; however, firstly more experience has to be gained in underground production augering before the system is capable to be used in development.



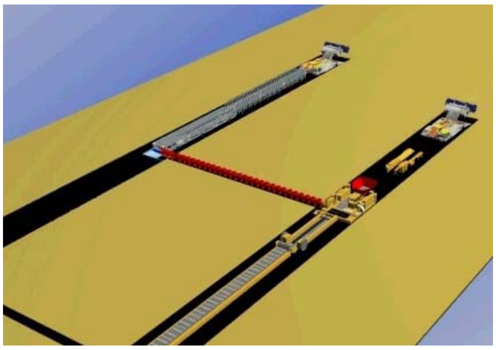


Figure 3-21:
left: RDAMS underground auger system
[M19SEE]

Figure 3-22:
right: Roadway development concept using an auger
[M19SEE]

The RDAMS system consists of a drill and storage unit, linked to a central chain conveyor and has a 35 m auger flight storage capacity. The concept includes two bolter miners and one shuttle car. The coal from the 2nd continuous miner is passed through the Ø1.6 m auger hole. The continuous miner will be supplied via monorail, as well as services & ventilation. A single crew, 8 hr shift, 15 shifts/wk can perform with 355 m per week.

The advantages are circular crosscuts which are more stable than rectangular ones (figure 3-23). This leads to more stable gateroads because no intersection (figure 3-24) is formed which reduces secondary support costs. More crosscuts provide better ventilation, easier sealing and increased means of egress [M19SEE].

Figure 3-23:
left: Smooth surface in auger hole
[M19SEE]

Figure 3-24:
right: Auger holes in roadway
[M19SEE]

3.5.3 Surface to In-seam Gas Drainage Technique

The current drainage technique, in seam drilling, is undertaken semi parallel in the active roadway development panels. This method is quite expensive and sometimes slows down the development panel. Also the gas has to be collected underground and ventilated to the surface.

Currently the first mines are applying the medium radius drilling method, which is derived from petroleum drilling. The drilling is done mechanically by conventional drill joints and drill bits.

CMTE is presently developing a Tight-Radius Drilling Technique (TRD). It uses vertical wells drilled into the earth by conventional methods. A drilling apparatus, which has the ability to turn in a 30 cm radius, is lowered into the well to the depth of a coal seam. A water jet cutting device then drills into the coal seam, rotating and propelling itself forward as it cuts through the coal. The holes that are drilled should increase the permeability of the coal seam starting a degassing process. This flow of methane begins when the well is dewatered using conventional pumping equipment.

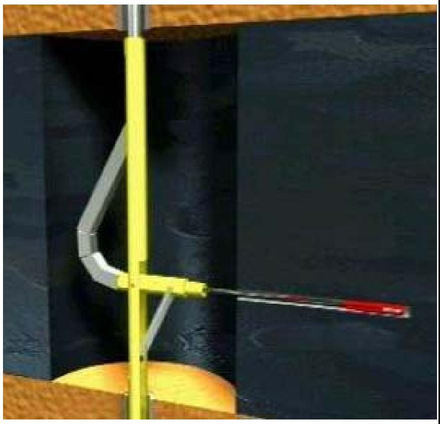


Figure 3-25:
3D Animation of the water jet cutting horizontally in the seam.
[M19HOO]

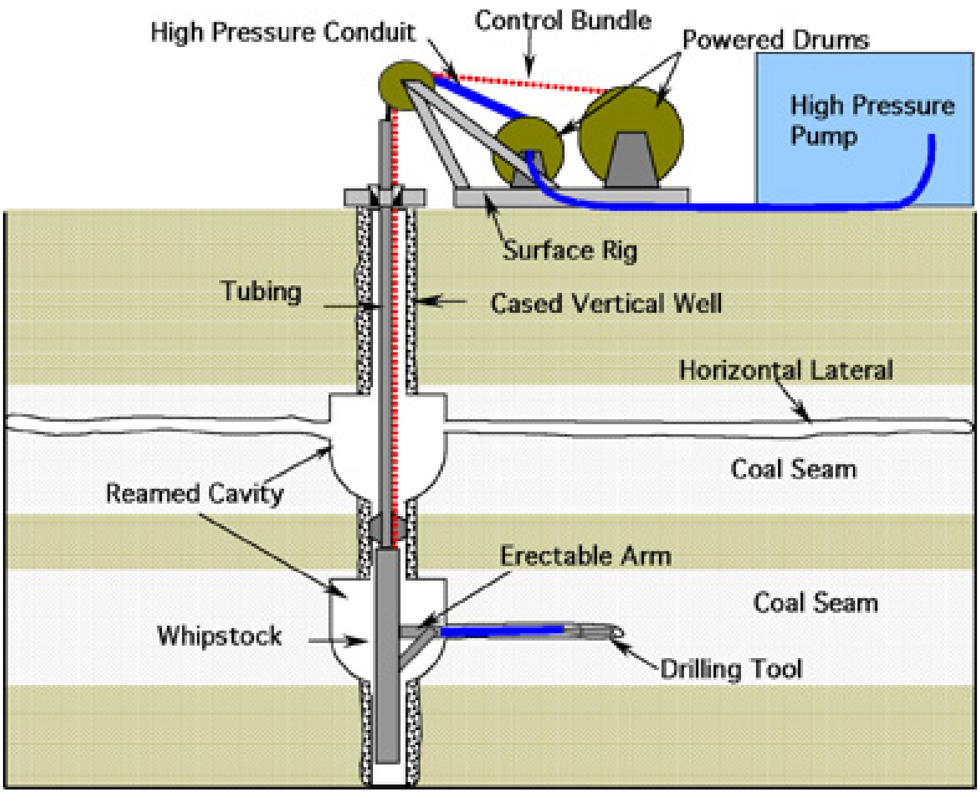


Figure 3-26:
Scheme of the CMTE TRD drilling concept
[M19HOO]

Three wells have been drilled at AngloCoal's Grasstree Mine in March 2002 from which one has been completed successfully. Fast drilling rates of 1-2 metres per minute could be achieved. [P02MEY].

3.5.4 New Rapid Roadway Development Concept

The CSIRO is developing a concept for future rapid roadway development systems. This integrates continuous haulage systems in the gateroad. The mining sequence and ventilation details are the same for pillar cycle with discontinuous haulage. From the continuous miner the coal is passed to a series of 10 m long bridging conveyors. These are parked over belt structures and linked in position as required.

With this system an advance rate of 15 m/h should be reasonable. Every 50 m the process has to be interrupted for one hour for consumables supply. The time to flit the continuous miner in the other heading is assumed with 8 h. The panel advance will take place every 24 h so that the overall performance will be 680 m / week (1 1/2 x 200 m pillars).

The assumptions for support are:

- Pillar Size - 200 metres @ 40 metre centres
- Support density - 4 x 2.0 m roof bolts + 2 x 1.2 m rib bolts per metre

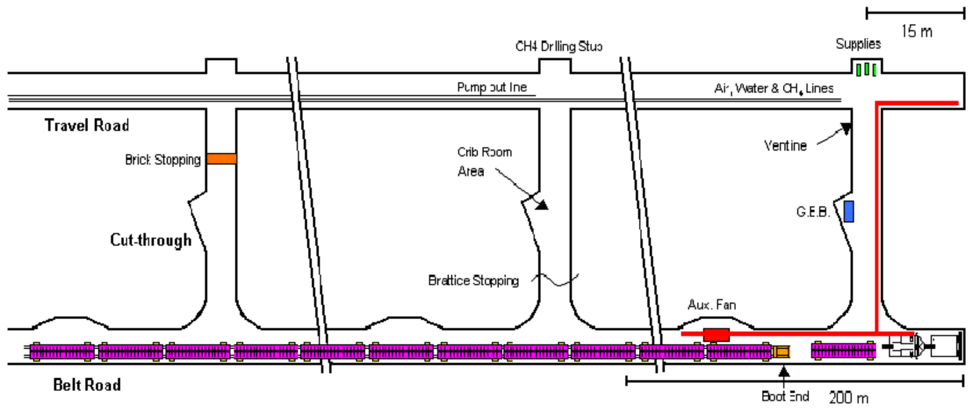


Figure 3-27:
Panel layout CSIRO concept
[M04KEL]

4 Approach to Optimize Roadway Development Systems

In this chapter different parameters in roadway development are discussed to show potential for the optimization in the field of roadway development. The suggested modifications are mostly applied somewhere in the worldwide coal mining industry and have largely proved itself.

This approach is beginning with a description of the analytical method used here and other methods applied by other authors. Then legislative restrictions are summarized to define the legal framework to the engineering design and the organisational potential.

Attention is then paid to the financial aspects of development, by doing a cost calculation for a typical development panel. Ongoing in the following section suitable performance indicators were chosen to evaluate the panel performance and optimize the use of uptime and downtime.

Consecutive layout aspects are discussed with the focus set on the evaluation of the number of entries. It is tried to analyse why the strategy of US mines diversify entirely in the number of entries as well in relation to the pillar length.

In the section equipment & technology first two important continuous miner modifications are discussed. These are simultaneously cutting and bolting as well as loading systems. Secondly, other haulage technologies are evaluated and their range of application is determined. This section includes also a summary of the use of cooling systems, which are not yet used in Australia.

Actual recommendations in this field require a more case based cost/benefit-analysis and a risk-analysis. Therefore only a very condensed overview is given in this field. The same applies for the area of roof support: Changes in geotechnical design like rockbolts require a very detailed analysis customized for each mine site.

Following, operational recommendations for the day-to-day work schedule are given. The topics here are procedures for careful materials handling and the tasks involved in the panel extension like road construction and water drainage. Some parts are continued in the next section.

The approach is completed by looking at organisational aspects which seems be the biggest issue in some mines. These are communication, education but not at last the scheduling of tasks. The aim here is to show much work can be done parallel or during downtime.

The benefits of this analysis should be to show potential options for decreased costs, improved productivity, safety and finally increased the return on investment.

4.1 Optimization Approaches

Many studies were conducted in the last ten years, to get to grips with the underperforming area of roadway development. Many of them tried to solve single problems, without looking too much on their interactions. By solving one problem, it often happened that another one was created.

The conventional management concept of evaluating processes is mainly limited by looking on the input and output side. The input side stands for money, labour, material, etc – the output side for the product quantity and quality. A Systems Approach[8] is trying to analyse what is happening in the "black box" to make processes transparent.

The idea is to understand the different magnitude impact of the parameters in the process and their interactions. But because all sub-processes cannot be expressed fully in an "analytical" way, there are still smaller "black boxes" remaining in the system. The result of a so called Systems Approach is much better than the sum of its components, because interactions are considered – also between people and technology.

4.1.1 Approach in this Study

The more parameters are included in the approach, the more exact the system can be adjusted. Including even those who are supposed to have only little influence or low probability of strong influence reduces the overall risk and provides system stability as well as system reliability [M17BW].

The key issue is the understanding of the processes in each level and their interactions. The following simple graphic on the next page is focuses on the main processes involved in roadway development. The separation of the responsibilities is illustrated by the dotted lines to show that the responsibilities are overlapping and not absolutely defined.

[8] It was first proposed under the name of "General System Theory" by the biologist Ludwig von Bertalanffy who noted that all systems studied by physicists are closed [I98HEY].

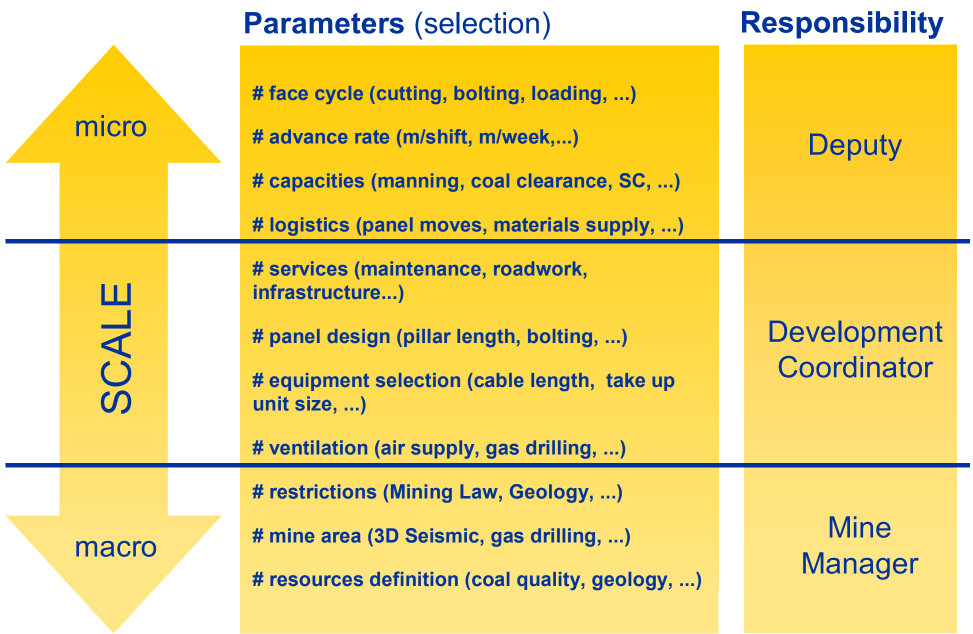


Figure 4-1: Parameters and responsibilities in a development system [WINKEL]

Most of the aspects in this Systems Approach are in the responsibility of the Deputy or the Development Coordinator. The implementation of the recommendations has to be done by them. Lower and middle management are the key factor for success.

4.1.2 Other Approaches

The CSIRO as a major research organisation in Australia developed an industrial plan to increase the productivity in the area of roadway development. The main strategies are shown in the following table:

Table 4-1: Implementation of a roadway development strategy as a part of the ACARP Project [B99KEL]

Information	the requirements, practices, capabilities and precision
Technology Implementation	through commercial sponsors, reviews, partnerships
Face Downtime and Uptime	underlying systems reasons for downtime, improvement and consistency of uptime rates
Project Management	identifying tasks where applicable, case study examples
Parallel Operations	the use of systems and new technology to reduce the critical path of face activities
Implementation	through presentations, industry discussions, education / awareness, middle management role
Automation	setting long term priorities, technology roadmaps, initiating technology development

To implement a strategy with a large variety of single parameters some key components have to be set to make the development process manageable. The key components selected by Kelly are shown as follows [B99KEL].

Table 4-2:
Key components in the development process. cp. [B99KEL]

Key components
▪ Mining Systems (cutting, bolting, transporting)
▪ Organisational Factors (manning, monitoring, motivation)
▪ Machinery Supply and Support
▪ The Human Element (workforce, management, culture, workplace)
▪ Maintenance Practice
▪ Systems Support (panel layouts, extensions, roadwork)
▪ Strata Support and Gas Control
▪ Safety Systems

4.2 Legislative Restrictions

Mining has to follow like other industry branches legal restrictions. To be aware of the regulations helps understanding and designing methods applied in roadway development.

In Australia the mining law is under the responsibility of the states. Therefore the mining law differs between the coal mining regions in New South Wales and Queensland like shown in table 4-3.

Table 4-3:
Acts affecting underground coal mines operational

Queensland	▪ Coal Mining Safety and Health Act 1999 (CoalMinSHA99) ○ Coal Mining Safety and Health Regulation 2001 (CoalMinSHR01)
New South Wales [P03BAL]	▪ Coal Mines Regulation Act 1982 Coal Mines (Underground) Regulation 1999 ▪ Coal Mine Health and Safety Act 2002 (CMHS Act 2002) *CMHS Regulations (delayed to end of 2003 at best)* ▪ Occupational Health and Safety Act 2000 (OH&S Act 2000) OH&S Regulations 2001

The mining laws in Queensland as well as in New South Wales require setting up a health and safety management system. This must include - but is not limited to - health and safety policy, risk management (identification of hazards, assessment of risks arising from those hazards, development of controls for those risks, reliable implementation of those controls), training and competence.

The New South Wales Coal Mine Health and Safety Act 2002, Part 5 “Duties relating to health, safety and welfare at coal operations” is specifying this need:

Section 20: Duty of operator to prepare health and safety management system

“The operator of a coal operation at which mining is carried out must prepare a statement in accordance with this Act and the regulations, stating how the health and safety of the people who work at the coal operation, or who are directly affected by the coal operation, will be protected. This is a "health and safety management system".

The adequate regulation in Queensland is the Coal Mining Safety and Health Regulation 2001, Part 2 “Safety and Health Management System” as part of the appropriate act.

Section 6: Basic elements

“A coal mine’s safety and health management system must provide for the following basic elements: risk identification and assessment; hazard analysis; hazard management and control; reporting and recording relevant safety and health information and data.”

Besides the general acts and the own regulations resulting from the health and safety management system, there are special regulations affecting the area of development. These are on the one hand side equipment requirements like the need of special safety circuits and safety time delays on the continuous miner and on the other hand side organizational regulations.

Because underground coal mining commenced in QLD just 10 years ago, the NSW law as an older low containing much more case specific restrictions. Some important regulations are listed in part as follows. The complete paragraphs can be found in appendix 5. These are taken from the NSW Coal Mines (Underground) Regulation 1999.

- (28) Inspection by a mining official (usually the deputy) for the presence of flammable gas in any working or temporary standing place before connecting power to any machinery in that place and
    - intervals not exceeding 2 hours, of each face area where coal or stone is being mined
    - intervals not exceeding 5 hours, of all places where people are working
- (38) The dimension in plan of a pillar must not be less than a distance that is equal to one-tenth of the thickness of the cover (to the surface), or 10 metres, whichever is the greater.

- (39) The prescribed maximum width of roadways is 5.5 metres[9] except for that part of a roadway forming an intersection with another roadway.
- (85) Mine ventilation must be so arranged that each production district in the mine, and any longwall or shortwall face at the mine that is being worked, is ventilated by a separate current of air.
    - The air volume passing through each continuous miner working place must not be less than 0.3 cubic metres per second for each square metre of normal roadway cross sectional area
    - The air volume in each place where a diesel engine operates must be such that a ventilating current of not less than 0.06 cubic metres per second for each kilowatt of maximum output capability of the engine, or 3.5 cubic metres per second, whichever is the greater.
- (171) means in place to prevent any explosion underground at the mine involving coal dust and to suppress any such explosion should it occur. Such means must include, but are not limited to, the following: the application of sufficient quantities of stone dust to surfaces in roadways, the prevention of accumulations of coal dust that may contribute to an explosion, the installation and maintenance of explosion barriers.
- (176) The incombustible content of that portion of roadway dust that is finer than 250 micrometres must be maintained at the following levels through the application of stone dust in the case of dust in an intake roadway within a face zone not less than 80 per cent by mass.
    - The distance advanced between applications of stone dust at each working face must be kept to not more than 30 metres but in no case is a working place to remain without an application of stone dust for a period in excess of one working day.
- (180) An explosion barrier must be installed and maintained in the part of any roadway containing a conveyor belt within a face zone.
- The Cutting speed have to be reduced f the methane content in the air is higher than 1 vol. %. All electrical Equipment have to be switched out at 2 vol. %
- If the shift has no overlap, the power of the panel have to dropped off. The next shift have to retest the electrical system (fan, miner etc.)
- Every 100m a fire hydrant have to be installed.
- If the effective working temperature is exceeding 27°C, the working time in certain areas is restricted.

All of these procedures require time – in cases where they cannot be carried out parallel they will cause loss of production time.

Like many other regulations the mining law is steadily growing and is covering more aspects at more detail. It is developed by positive experience with the advance in technology as well as the reaction on historical events like accidents. Such extensive regulations are difficult to maintain up to date so that many regulations still exist even when their originae is not there anymore. Mining authorities became aware of this development and the future trend is going away from a prescriptive and detailed law to a proactive law [M17WRI].

The main element of such a proactive law system is risk management. The mining law will then insist more on guidelines than on punctual obligations. Risk assessments have to be conducted before changes are made on the

[9] It has been suggested that the legislated maximum width of underground coal mine roadways in NSW (5.5 m or 20 ft in earlier legislation) was originally determined by the distance men could shovel coal into a skip in the middle of the roadway [P97HEB].

mine site. The responsibility is therefore delegated to the mine in accordance to the “duty of care” principle. Thus operations have to be completed under self control. It is not sufficient anymore to do it just due to the minimum authority’s standard. This procedure follows the idea “people on site know the risks much better than the bureaucrats in the authorities”.

4.3 Development Cost

The cost evaluation in roadway development consists of many components. These are equipment ownership, labour, roof support material, entry infrastructure, consumables, etc. In this paragraph a cost evaluation for Australia is conducted. Additionally the estimated costs are set in relation to expenses in greater depth like in Germany.

Carr mentioned development cost of about 2 000 A$/m for BHP Billitons Appin Mine 1994 [P94AMM]. Nicholls estimated the cost in 2001 to mine owners for roadway development in Australia with 1 200 A$/m drivage. This equates by about 400 km/year a 500 Million A$ business [P02NIC]. The true development cost of a good performing mine with 15 m/shift in NSW are about 2750 A$/m [benchmarking survey WINKEL].

To estimate the single components, costs on a low level have been used and were added up to four categories. The values were provided by the industry or have been assumed. The calculation is based on a drivage of 400 m/month, 4 crews (12 hr shifts) and a single section configuration. The depreciation rate was assumed width 15 %, the interest rate with 11 % and management overhead cost with 15 %. In the following tables the calculation is summarized. The complete Excel model can be found in appendix 6.

Table 4-4: Development cost model Equipment cost

Equipment cost	**A$**
Continuous miner	$2 700 000
Shuttle car	$600 000
Feeder breaker	$500 000
LHD	$550 000
PJB drift runner	$250 000
Fan (two)	$120 000
Gopher and other accessories	$80 000
Load centre	$500 000
Total cost of ownership per m	$435

Table 4-5:
Development cost model
Labour cost

Labour cost	**annual salary**	**benefits, tax, leave**	**A$**
Operators (seven)	$85 000	$25 500	$773 500
Tradesmen	$85 000	$25 500	$110 500
Deputy	$105 000	$31 500	$136 500
Supervisor	$120 000	$36 000	$156 000
Sub total			*$1 176 500*
Management fee (15 %)			$176 475
Labour cost per meter			$1 127

Table 4-6:
Development cost model
Entry infrastructure cost

Entry infrastructure cost	**units per m**	**$ per unit**	**A$ per m**
Belt structure and rubber			$350
Pipes and cable			$20
Ventilation tubes (10x reuse)	0,33	$300	$10
Ventilation stoppings			$16
Cut gas drainage stub	1/ 700 m	$50 000	$71
Six drill holes from stub	1/ 700 m	$240 000	$342
Link stub to surface	1/ 700 m	$450 00	$64
Total entry infrastructure per m			$874

Table 4-7:
Development cost model
Support cost

Support cost	**units per m**	**$ per unit**	**A$ per m**
Roof/rib bolts (spacing 1.2 m)	10	$8.50	$71
Cartridges	8	$3.00	$25
Plates and accessories	8	$1.00	$8
Mesh and straps			$20
Secondary support			$50
Total support cost per m			$174

4 Approach to Optimize Roadway Development Systems

Summing up the individual cost categories results in estimated development of 2 650 A$/m. On the basis of the categories, a graph was produced showing the distribution of development cost in Australia. These percentages are very close to the analysis of Misra [P96MIS]. He only estimated the support cost much higher like shown in the appendix 7.

The other column in the graph is showing the distribution in a German coal mines - as well for rectangular roadways. Here the cost is varying in a very wider range from 8 000 to 16 000 A$/m. The equipment owning costs are depending on the interest rate and tax. Hence, among other things, a much slower development in the German mines is causing the higher equipment ownership cost.

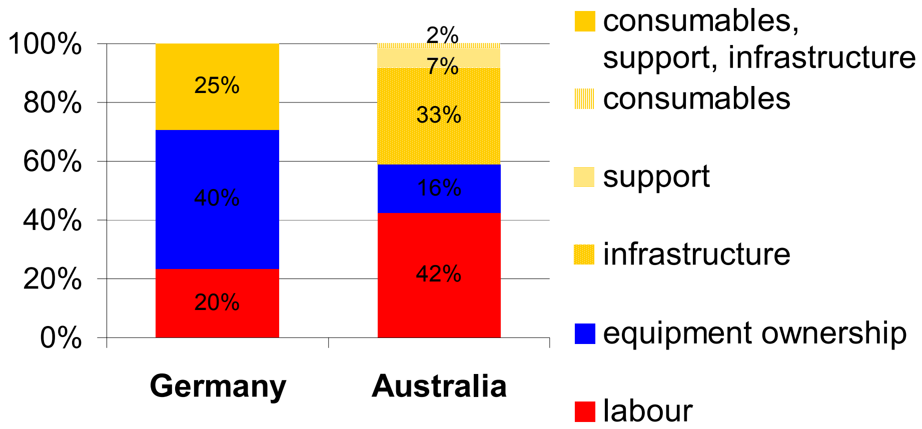
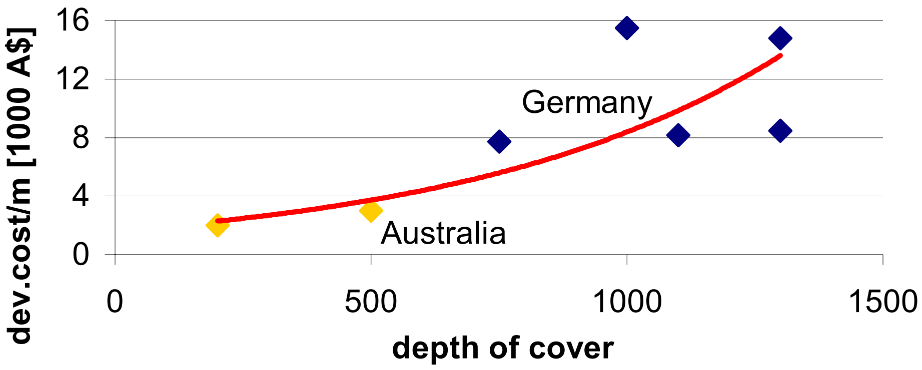


Figure 4-2:
cost distribution in German and Australian Roadway Development

Increasing demand of support and decreasing rates of development in greater depth as well as other factors result in higher development cost. To demonstrate this effect, the costs of developments in various depths are drawn in a scatter plot. The data basis are Australian development cost of about 2 000 to 3 000 A$/m (200 m respective 500 m depth of cover), development cost in the United States (Pennsylvania, 100 m depth) of 1 500 A$[10] and the development cost in German coal mines of 8 000 to 16 000 A$/m (750 m to 1300 m depth of cover).

All costs utilized are without costs for logistic, haulage and primary machine setup. Using this cost correlation to depth can be detected - illustrated by a trend drawn in the graph. The cost increase with depth is more exponential.

[10] In the US cost are based on US$/t for longwall as well as for development. By 40 US$/t in development (20 US$/t in longwall) [M01LAU], 2,5 m roadway height, 5 m width, a coal denstity of 1,8t/m³ and a exchange rate of 1,8 A$/US$ the cost will be about 1 500 A$.



4.4 Performance Evaluation

It is not always in the interest of a mine, or even necessary, to maximize the advance rate in road development. Basically the objective is to minimize costs. The advance rate only has to equal the longwall retreat rate. These are besides gateroads also longwall installation roads and mains. However, sometimes the mine is in danger of a delay in longwall production created by a shortfall in development, which may cost up to 1 Mio. A$/day [P02NIC].

Cutting costs by half sounds better then doubling the development rate. But a higher development rate does not automatically implicate higher costs – there is no clear anti-proportional or proportional relation. A faster development with the same input enables to save labour and machine time. Saved labour capacity can be used by the block to reduce the demand for contractors in longwall moves. Time windows in machine utilisation make unscheduled maintenance possible.

To make this strategy transparent a performance management system with the right indicators should be established. The performance indicators (PI's) have to be adjusted to the target:

Table 4-8: Examples of performance indicators for a mine

	Examples
Economic PI's	cost/tonne, NPV/shares
Safety PI's	accidents/labour year
Environmental PI's	emissions/production unit
Quality PI's	ISO 9001 standard
Production & Development PI's	tonnes/hour, meter/shift,
Organisational PI's	detailed job descriptions

The development strategy of setting and achieving development targets has different points of interaction. The figure following on the next page is a simplified model showing the single elements in the process.

The corporate objective is given by the management of the company or group. This have to be translated by the mine management in different targets for development, production etc. Ongoing the engineering level has to define a strategy and indicators to be able to compare the congruence of the base case with the real case. Out of it an actual system has to be implemented and maintained and continuously improved.

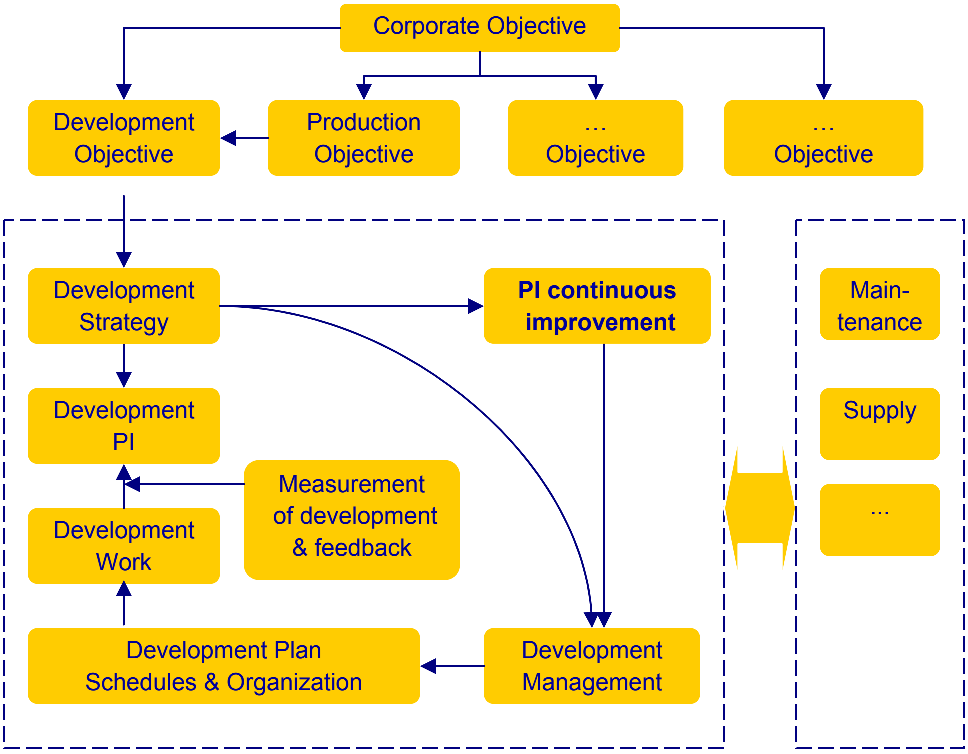


Figure 4-3:
Development performance indicators in the big picture [P01WIN]

4.4.1 Performance Indicators

The use of performance indicators is essential to evaluate the performance of the development management and development work by adjusting them to the development strategy. The key performance indicators could be:

- Number of development units
- Shifts per week
- Advance in metres per week or days per block
- Lost time injury frequency rate
- Total workforce
- Total cost

The most frequent used performance indicator is the rate of advance in metres per time unit. To improve the advance rate different variables in the system can be changed. However the human capacity for change management is limited, the effort has to be focused on selected issues. The graph placed on the next page shows the performance matrix and gains which can be made in each of the following issues for a typical mine:

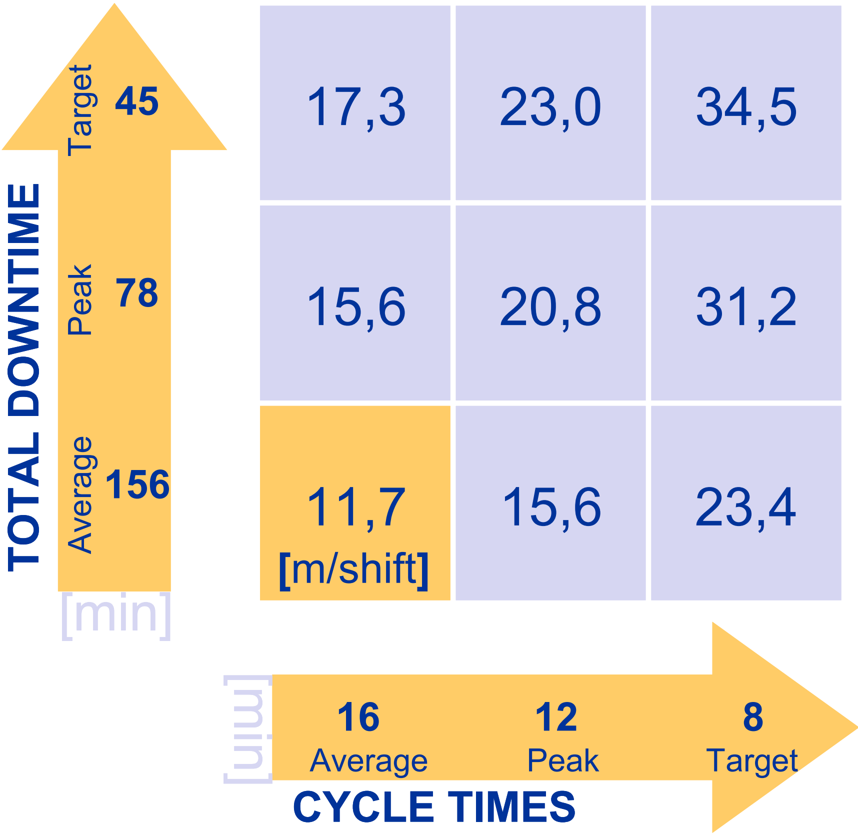


Figure 4-4:
Performance matrix – potential for increasing the advance rate.
Assumption: 390 min/shift.
Source: Colliery reports cp. [M16MEL]

4.4.2 Uptime and Downtime

A continuous miner is everything else but a machine working continuously: The actual cutting time of the CM is about 2-10% of the calendar time.

The definition for downtime used in this study is related to lost and unproductive time. This is the time when the face cycle is delayed or interrupted.

Downtime can be divided due to the causes. These are organizational delays, geotechnical problems, equipment breakdowns, section layout and others [P02NIE].

The focus in this study are the organizational delays. These are:

- Machine tramming
- Move of cables
- Belt extension & services
- Preparation and refitting
- Maintenance
- Cleaning of floor and drainage
- Safety (rockdusting, …)

The other causes require a more detailed and much more mine site specific approach to reduce the related downtime.

4.4.3 Potential for Improvement

In this paragraph a theoretical analysis will be conducted, to identify the power of single parameters in the overall performance. First however, some definitions have to be made. The results are then compared with real data from the industry to set the emphasis for the change management.

Organisational Performance

The organizational productivity based on the face cycle would be 100 % if the next system (haulage) is not waiting (minimum cycle time / actual cycle time). This depends whether the machine is permanently working at a maximized parallel operation or on the job procedure (priority is set on loading the haulage system by using possible bolting interruptions). The minimum cycle time has to be calculated by measuring the times spend on cutting, bolting, ventilation extension, SC waiting, etc. (see figure 7-3 in the case study).

The organisational productivity for flitting, extension services, breakaway, degassing, etc. is too extensively to be included in this analysis.

Machine Performance

The machine performance depends on the cutting and drilling speed of the CM and on wether the machine is capable of simultaneously cutting and bolting.
The face cycle of the CM (cutting, roof bolting, rib bolting, loading, waiting) depends on the wheeling distance and the number of shuttle cars or the machine performance. This causes either waiting time for the CM or for the SC. This partly belongs to the organizational performance.

Operators Time Productivity

The operator's performance simply depends on how much the operator is following job procedures and how much time they are working at the face. The key words are motivation and environment.

Based on the development parameters of the mines, the sensitivity of various variables can be calculated to find the key factors influencing the advance rate.

With an assumption of 50 %[11] uptime and 70 %[12] operators time productivity, in this example

- A 10 % decrease of downtime causes 10 % more advance.
- a 10 % increase in the operators time productivity (from 70 % to 80 %) causes about 6.25 %[13] more advance

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[11] The downtime shown in monthly reports for gateroad development is about 50 % of calendar time at North Goonyella Mine.

[12] The operators time productivity was estimated with about 70 %.

[13] Result of (100 %-(70 % / 80 %)) * 50 %.

- A 10 % increase in machine performance effects only the uptime, so that 5 % more advance can be achieved.
- A 10 % improvement in cycle times by means of organization will improve the advance rate as well by 5 %.

This shows that downtime is the most sensible part; however other parts have much more potential in total.

Most surveys are focusing on the reduction of downtime, as described by Raddatz in [B00RAD]. This results in making single processes in the production chain more independent. Different surge systems like the 14BU loader or the future ACBM may help here. These systems will be dealt with in detail later.

If downtime could be decreased to 0 %, advance could increase by 50 %. However improvements in other parts would allow far higher advances. This systems approach focuses on using uptime more efficiently, by covering a variety of aspects as discussed in this chapter. The following graph shows the spread between actual and possible cycle time. On average, the cycle time is twice as much as the actual possible. Finally it can be recognized, that uptime performance could be doubled on average - without changing any equipment.

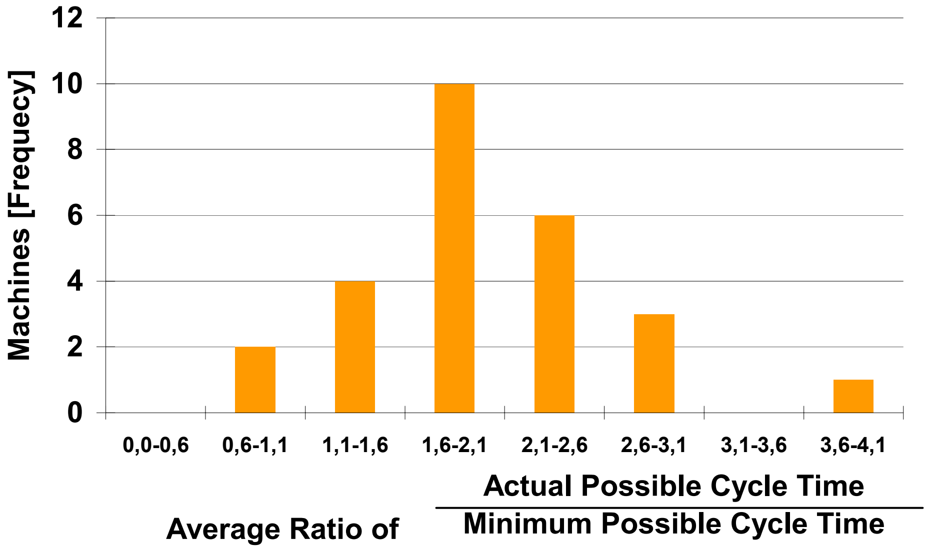

Figure 4-5:
Invert cycle time capacity ratio of ABM20 machines used in Australian mines (n=26)
data: [M16MEL]

4.4.4 Application Examples

Anglo Coal mines utilize process mapping to control and improve development performance. The basic idea is that the same procedures are repeated for every pillar. Example: seven days (about 17±1shift) are scheduled for a pillar of 100 m length and 35 m width which equals 235 m. The first five days are used to mine gateroad, crosscut, and gateroad in three steps. The last two days are used for belt extension and other services. Then single steps are improved and the result on the whole process can be assessed [M07ROB].

In May 2003 Newstan Colliery introduced a data logging system which was installed on a VA ABM20 during an overhaul. The data signal is modulated onto the current in the high tension cable. In the transformer station it is demodulated and transmitted to surface via a multi mode glass fibre cable. There the statuses of all functions of the CM are visualized. Details can be found in appendix 8.

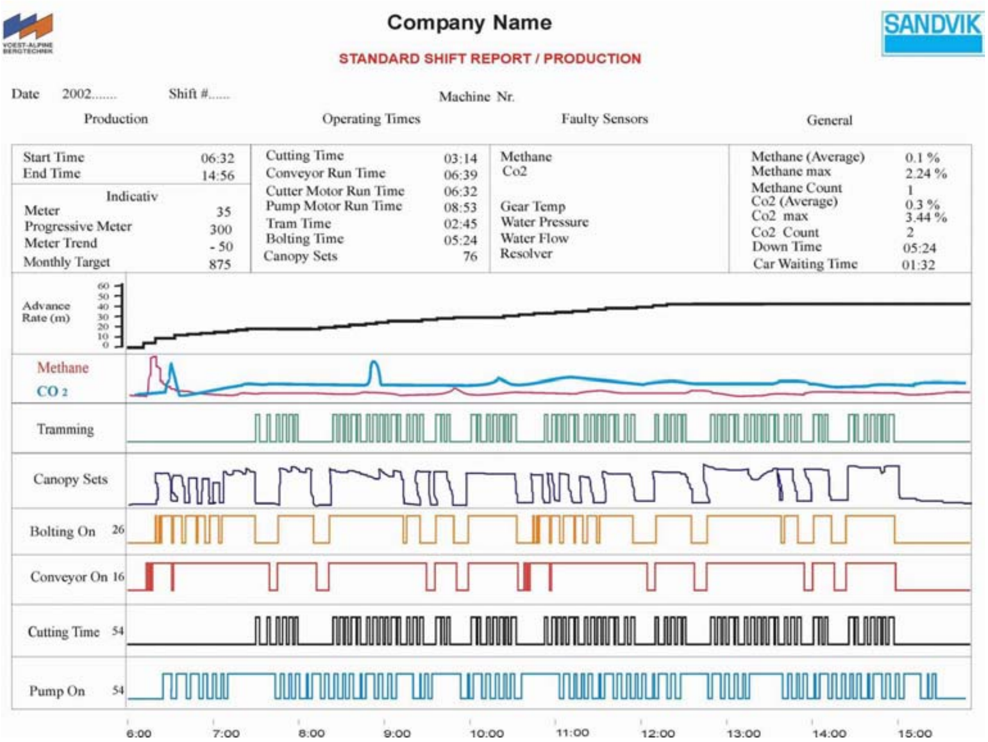

Figure 4-6:
Example of a production shift report compiled out of logging data
[M16MEL]

4.5 Layout

Optimization of the layout is one of the most effective and basic engineering disciplines. A bad layout can cause various problems, for example in ventilation, rock mechanics or safety. A good and not too conservative layout may save material, manpower, minimizes the loss of deposit and therefore improves the economic efficiency of the operation.

4.5.1 Mine Access

Australian underground longwall mines are between 100 - 500 m deep. Some mines are the extension of an opencut mine via the highwall. From there ramps are driven further down into the seam.

Other deeper mines are using ramps to access the seam from surface – especially the deep coking coal mines in central Queensland like North Goonyella or Moranbah North. Shafts are used only for ventilation yet. However such layout aspects have to be chosen very carefully already before opening a mine.

Most Australian mines can be accessed by automobile vehicles from the surface. This makes the supply of the development panels uncomplicated and comparably cheap – even bigger machines like continuous miners can be handled in one piece. However, some of the old mines in NSW like Southlands or Newstan are using dolly cars[14] in the main inclines. The coal is hauled by conveyors out of the mine.

4.5.2 Number of Entries

It is astonishing that development strategies worldwide are split in two wings rather than being equally distributed. To find out why, following decision drivers were determined, to estimate whether the choice of the number of entries is conditional, cultural, legal or of other origin.

Certainly a lot of the applied technologies depend on the mining tradition of the region or country. The only mine in Australia using a three-entry system was opened under US management. In any case, there must be other, sounder, reasons for that.

Legal restrictions are best suited to explain this behavior. In Australia regulations are not as restrictive as in the US. In Australia belt entries may be used for ventilation. Therefore any additional entry can be used for ventilation purposes. In the United States the mining law section § 75.350[15] restricts the use of belt entries for ventilation and thereby the use of two-entry systems.

It is noticeable that mines in the US are changing mostly from a four-entry to a three-entry concept. Attempts to use a three-entry system in Australia were not too successful and the operators are thinking about switching back. This behavior could suggest that the financial optimum is closer to a two-entry rather than a three-entry system. In order to examine this, it is to be tried to determine the added value of a higher number of entries.

4.5.3 Multi-Entry Systems Value Approximation

The benefit of an extra entry is not changing with development costs. The main disadvantage is the additional 10 % layout loss (30 m for the extra pillar on 270 m longwall + 30 m standard pillar).

It is usually applied together with the place change system (cut and flit) to reduce investment costs by operating only one CM.

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[14] Mine wire rope haulage system which transports men and materials in and out of the mine in an incline.

[15] "…the entries used as intake and return air courses shall be separated from the belt haulage entries, and each operator of such mine shall limit the velocity of the air coursed through belt entries to the amount necessary to provide an adequate supply of oxygen in such entries and to insure that the air therein shall contain less than 1 vol% CH4 and such air should not be used to ventilate active working places."

A rough calculation, without looking at synergies which are only fairly possible to calculate, is going to show the additional value of a multi-entry system. Following assumptions are made:

- Cost of a single-entry about 10 000 A$/m
(German hard coal Mine, depth approximately 1 000 m)
- Cost of a two-entry gateroad per linear m: 3 000 A$/m (Australia)
- Development ratio two-entry mine of about 2.3
(example: 30*100 m pillar)
- Development ratio three-entry mine about 3.6
(example: 30*100 m pillar)

The additional gateroad costs by changing from a two-entry system to a three-entry system are about 3 900 A$/m. With a 2 000 m panel this results in additional panel costs of about 8 mio. A$. This expenditure has to be compensated by the amount and quality of the coal mined of about 2 mio. US$[16], higher advance rates, avoiding of a reduced work schedule caused by heat, lower operating costs for the longwall, etc. Only one Australian mine has a three-entry system and it is therefore possible to conclude that the benefits described above do not justify the additional costs.

Greater mining depth will usually result in more difficult ground conditions and thus more support is required. If roof and floor conditions are worse (mudstone, water etc) the additional costs can be vastly higher. This also explains why German mines, which have a depth of between 800-1 600 m, are going for a single-entry. Additionally chain pillars need to have a width of up to 120 m [M01LAU]. In this case the additional cost between a one- and a two-entry system may be 13 000 A$/m instead of 3 900 A$/min between a two- and a three-entry system in Australia. The add-value will remain almost the same. A loss of deposit even faces that.

Finally it can be mentioned, that the three-entry system can show its superiority at lower mining depth, good roof and floor conditions and a high coal quality. The only mine applying this in Australia is Moranbah North - a producer of a high quality coking coal. The added value of a three-entry system vs. a two-entry system is estimated by 2 000 A$/m which faces often additional cost above this value.

4.5.4 Pillar Length

Utilized pillar lengths are widespread in the Australian mining industry (benchmarking survey, figure 6-3). This is possible because the choice of the pillar length depends much more on the subjective decision of the mining engineers. To a lower degree the choice of the pillar width which is driven more analytically by rock mechanics. Enlarging the crosscut

[16] = 2 000 m panel length * 5.2 m width * 4 m height* 1.6 t/m³ * 30 A$/t_coal_ROM.

distances is changing the balance between cutting time, bolting time and wheeling distance.

Larger pillar lengths have several advantages:

- Better ratio of development metres per metres of longwall retreat
- Development is accelerated
- Development costs are reduced
- Frequency of panel advance is reduced
- Geotechnical risks at intersections are avoided

With increasing pillar distance the number of crosscuts are reduced. By this means the ratio of development metres per metres of longwall retreat is improved.

The main geotechnical problems occur at intersections of gateroads with crosscuts when the face of the longwall reaches these positions. Enlarging the pillars reduces the number of intersections and some secondary support.

A panel advance needs in average between three to four shifts. These shifts are a major source of downtime. This can be significantly reduced with longer pillars.

It is evident that also some disadvantages are involved. These are mainly

- Increasing wheeling distance
- Longwall monorail cable length
- Increasing emergency escape way distance
- Supply of sufficient ventilation volume for heat dissipation and gas dilution

An increased wheeling distance will primarily affect mines with a low bolting density. Mines with a high bolting density (for examples six roof bolts and four rib bolts per meter) are more restricted by bolting than by haulage[17]. This effect is modelled in the North Goonyella Case Study in chapter 6.

The longwall cables and hoses on the monorail[18] can only be extended to a certain amount which is less than the length of the monorail cables. This effective length has to be considered when selecting the pillar length and should be a multiple of the pillar length. If not, the monorail has to be relocated more often than necessary. A common effective length of a cable is about 200 - 300 m.

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[17] A detailed analysis for tree-entry systems is done by Lautsch [B03LAU].

[18] The longwall monorail system covers the leapfrog distance from the tailgate to the load centre. It is situated at an intersection where is enough space for a transformer, a hydraulic pump and other installations..

Increased distance of emergency escape ways from the face is an issue, but as most mines are using sucking face auxiliary ventilation any hazardous gases are discharged by the ducting.

A key factor in extending the pillar length is the improvement of the auxiliary ventilation to compensate additional friction and leakage losses. Presently 2 m tubes are in use. Doubling the length of the tubes will reduce the leakage by 50 %. Also friction at the connections is reduced. To keep the distance to the face at a minimum, even with longer tubes, the concept of telescoping ventilation tubes also termed "sliders" should be considered. In fact, this is already state-of-the-art in US mines.

The elevated heat conditions in the summer months in Queensland are already effecting development. In some mines cooling machines may then be necessary (chapter 4.6.5).

Optimization

Paterson simulated a 2 000 m long panel to determine the most suitable pillar length related to the advance rate with different equipment configurations. Further, roadway dimensions of 5.2 m*3.1 m, a pillar width of 30 m, 1 m cutting depth per face cycle and 4 roof bolts/m were chosen. The scenarios were examined using a conventional continuous miner[19] with 2 (CM2) and one with 4 (CM4) bolting rigs as well as a loader/bolter miner[20](LBM) and a cutter/bolter miner[21](CBM). One or two shuttle cars are used. The result is an optimum length of around 125 m for in-place mining, like shown in the following graph [P94PAT].

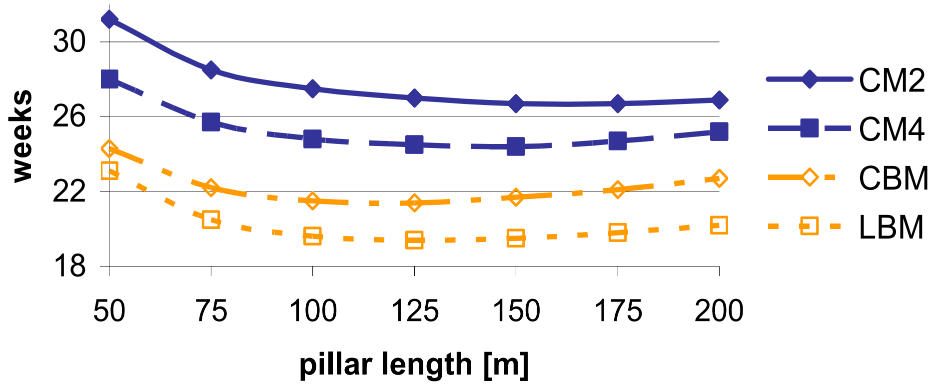

Figure 4-7:
Influence of the pillar length on the advance rate.
[P94PAT]

The optimum pillar length related to costs will be longer than the one optimized on the advance rate, because the development ratio becomes better. Because the decrease in advance rate with longer pillars is not significant, a reasonable value for a cost optimized pillar length will be between 150 -200 m. In appendix 7 the pillar length cost estimation of Misra [P96MIS] can be found. The introduction of continuous haulage

[19] conventional CM: simultaneously cutting and loading (interruption for bolting)

[20] loader/bolter CM: simultaneously loading & bolting or loading & cutting

[21] cutter/bolter CM: simultaneously cutting & bolting

systems as well as other new technologies shown in chapter 4.6.4 will even allow the length exceeding 200 m.

The benchmarking survey (chapter 5) came to the result, that there is already one mine with a pillar length of 155 m. However, because of ventilation problems most mines are developing crosscuts every 100 m at present.

4.6 Equipment & Technology

The choice of the right equipment and the awareness of the different specifications to customize standard products to the special conditions on the mine site is a basic factor for a successful operation.

Another more and more important issue are the ergonomics of the equipment. To get operators to stay on the miner, the environment has to be user-friendly. Keywords are dust, noise and space. Additional cooling systems make climate conditions more bearable.

4.6.1 Simultaneously Cutting and Bolting

In the Australian mining industry, bolting is very dense in comparison to the South African mines. Almost all CM's used in Australia have onboard bolting rigs; the ABM machines are additionally able to simultaneously install roof support while cutting and loading coal. This process eliminates the "stop&go" nature of conventional miners. Besides the advantage to conduct the cutting & bolting simultaneously, additionally for car changing and wheeling cycle time can be saved if the bolting takes longer than the loading. The differences in the operation are shown in the two following figures:

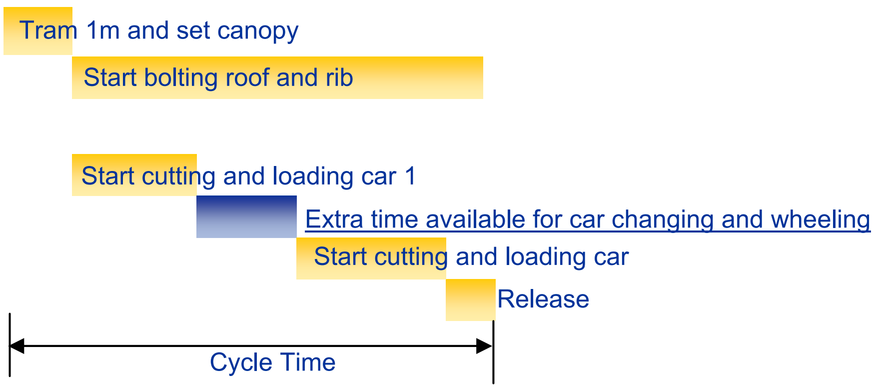

Figure 4-8:
Simultaneous cutting and bolting (VA ABM)
cp. [M16MEL]

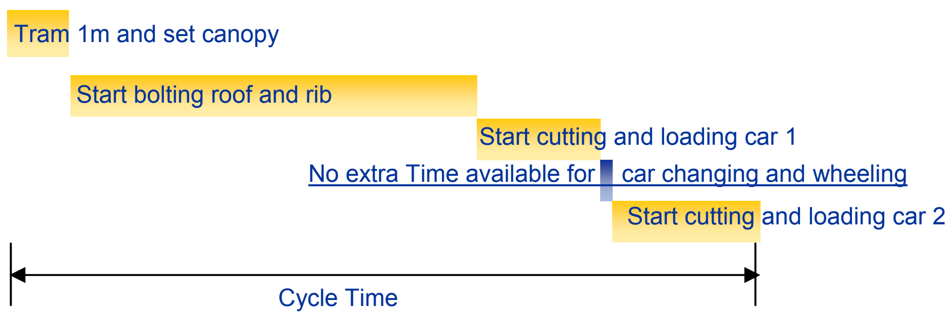

Figure 4-9:
"stop and go" operation
cp. [M16MEL]

4.6.2 Continuous Miner Loading Systems

The various methods of material gathering devices are varied and numerous. The choice of the right system is important to achieve the performance target. The main decision factors are cut-out-distance and rock type.

Standard machines have a front conveyor and loading star drive units, thus the chain is "pushed", which is not advantageous especially if the chain is not properly tensioned. On high performance machines the conveyor is separately driven by a rear drive unit, thus the conveyor chain is "pulled". The advantage of this design is higher performance and lower wear of the system, one disadvantage are the spacey drive gearbox and motor, which are constantly hit by the shuttle car boards. This shows only a few considerations when designing a loading conveyor system.

CLA's - Centrifugal Loading Arms.

This is the most common method of collecting material. There are various designs – JOY offers them in three diameters, two thicknesses, two speeds, three different operating centre distances and two different tip configurations (i.e. three arm vs. six arm CLA's). These variations cover the majority of the mine requirements. They are driven by either a single motor located in the gathering head or the dual motor design (JOY's most popular). These designs also supply power to the conveyor chain through a timing shaft.

The rear conveyor drive adds another motor to the system to run the conveyor chain independently from the gathering device. This is helpful on other more dense material than coal such as salt, potash, trona, gypsum, etc. JOY's HM class machines use a rear conveyor drive (RCD) [C01STE].

The first series of the ABM20 machines is equipped with four centrifugal loading stars/arms (CLA) which have a small diameter and are steeply attached to the frame. It minimized the cut out distance and bolts can be set closer to the face, because the loading part of the machine is much more narrow. On the other side, this design has a limited "stockpiling" capacity of less than a shuttle car load, because the machine was originally planned to load the material directly while cutting. However, the new series is now equipped with two CLA's which prevent material from getting stuck in front of the miner. [C03NEU]

Gathering Arms

(JOY) This is largely an outdated method of a gathering device. The arms are designed to reach out and pull in material while not infringing upon the ripper chain. As advances in drum lacing have improved, the ripper chain is not needed as much because the core is more manageable now than it was in the past with older style solid heads or three-drum machines. Although they are still used in some places, their application is minimal [C01STE].

(VA ABM) Initially the ABM machines were equipped with lobster style gathering arms, whose design allows to cover wide loading aprons with active loading to the conveyor. The disadvantage with this system is high wear rates of the parts & links if highly abrasive material has to be moved. In such cases loading stars offer less wear [C03NEU].

JOY's East- West conveyor

This design came from the Australian entry drivers like the 1SS and some 12CM12 hybrids. This design allowed the bolters to be within a metre or so of the face. The design is more complicated with its complex design of the drive units, has a comparable high wear and is arguably underpowered but has a niche market. It should not be used with clayey material, because it tends to get stuck. VA never offered east-west conveyors.

Plow

This may not be the correct terminology for JOY's IMM method of material gathering but explains how it works. As material is cut and laid onto the floor, the miner advances and the plow acts as a backstop for the material as the drums unique augering lacing, drives the material towards the centre where a ripper chain draws it into the conveyor which is powered by an RCD. A solid head has been tested and doesn't seem to be as effective [C01STE].

4.6.3 Surge Systems

A surge system can be used as an option with SC/RAM Cars, especially when the CM is not able to cut and bolt simultaneously:

- Drop on ground and pick up (e.g. JOY 14 BU Loader)
- Surge (Bunker) car (e.g. CSIRO)

14 BU loaders are used as a surge system when the wheeling distances reach a certain limit. The limit in wheeling distance is decreasing with decreasing bolting density. The loader may become redundant if the CM is able to cut and bolt simultaneously.

These machines can be widely found in the United States. In Pennsylvania 5 % improvement could be achieved [B03LAU]. Also at Gordonstone mine in Australia the advance rate could be increased from 1.5 m to 2 m per operating hour [P94KAT].

The main advantage of the 14BU loader is that it takes out the variation in the haulage system by eliminating the waiting time during bolting. A very welcome side effect is that it automatically keeps the road clean and no spillage is left. This also leads to cycle time reduction. Even when the 14 BU breaks down, it is possible to tow the loader out with an Eimco.

The main disadvantage is that the working area is reduced and thereby the access to the CM is hindered for supply etc. Other disadvantages are the poor water or slurry handling ability, an extra needed man who however can be saved in road construction and the tendency to overuse the surge point [P94KAT].

The disadvantage in supply and man travel is much less affecting systems with three or more entries because the pillar lengths are usually smaller and the loader can be flitted out.

Figure 4-10:
Photo of a JOY 14BU Loader

The bunker car technology is an option coming up in the next years. It is basically replacing the 14BU loader system as a surge system and can be combined with additional secondary bolting. Details about the ACBM system newly developed by CSIRO are given in chapter 3.5.1.

4.6.4 Continuous Haulage Systems

There are various designs of continuous haulage systems on the market. Most of these systems can be found in the United States. In Australia is the application of continuous haulage presently only limited to discussions, no systems are found in the field.

Continuous haulage systems eliminate the bottleneck shuttle car and can outperform them especially under wet and muddy road conditions and long wheeling distances. They also improve the safety by reducing the amount of traffic.

Table 4-9:
Overview of continuous haulage systems

Conveyor Type	Manufacturer
Bridge	Long-Airdox, Fairchild, Jeffrey, Joy, Stamler
Flexible Belt	Joy, DME
Self-Propelled Chain	CONSOL
Temporary Belt Support	CONSOL, JOY

Cascading bridge conveyors consist of several linked bridge segments using chain conveyors. At each transfer point a crawler unit is necessary, where one man each might be required. For example an 80 m pillar block requires a bridge conveyor with about eight segments and an overall length of 180 m.

Flexible belt conveyor trains use a flexible rubber belt. The latest model from JOY is the 4FCT01 and is available in lengths of up to 128 m and requires one operator. The disadvantage is the comparably high investment cost, high maintenance cost and risk of breakdown.

Consol developed a new continuous haulage system called TramVeyor. It is based on a 200 m flexible chain conveyor with a feeder breaker behind the continuous miner. From the chain conveyor the coal is transferred via a belt interface onto the section belt [P02BAK].

Besides there are systems available that facilitates the belt extension during belt operation called temporary belt support systems (TBS). These systems allow inserting new belt structures and idlers parallel to production. JOY's system requires a take-up unit and has a length of 12 m; CONSOL's TBS is 80 m long and has an optional take-up unit [P99MCD].

In the performance and cost model from Nienhaus et. al. the mobile bridge conveyor as well as the mobile belt conveyor scenario as two under six were underperforming in the total rate of advance even by higher specific costs [P02NIE].

The cheap option compared to these expensive systems are standard top or bottom mounted 1 050 mm conveyor belts, as they are already used for coal clearance from the feeder to the belts in the main roads. Most systems already have a take-up unit, so that a continuous miner in a belt road can easily be connected to a conveyor. This is even easier in a super-section operation.

Another interesting option was mentioned in a note of Voest Alpine about their experiences with the ABM30 in the Bosjesspruit Colliery, South Africa. There the belt was connected to the CM (only) when the belt road was driven.

4.6.5 Cooling Systems

In the Australian mining industry mine cooling systems are not yet present. The reason is probably that in the old underground mining districts in NSW the temperatures in the summer were still good to handle. With the development of underground mines in central Qld in the last ten years heat became an issue, but lack of experience and expertise repressed the spread of these systems.

Because the demand in these mines is only seasonal and limited to certain areas within the mine, decentralised cooling systems are the better option. Two different systems are available at the market, distinguished by the medium of heat dissipation.

The less complex version is the direct heat exchanging system also referred to as "air-refrigerating-machine". This system uses heat exchangers or "recoolers" in the return airway. Here a special circuit of refrigerating agent can be saved. The other one is the water-to-air heat exchanging system "water-refrigerating-machine" which uses the dust suppression water before it is used to dissipate the heat to the media.

Air-refrigerating-machines are common with up to 300 kWh refrigerating capacity, water refrigerating-machines range from 600 to 1 000 kWh [B89REU]. Both cooling circuits are sketched in the following figure:

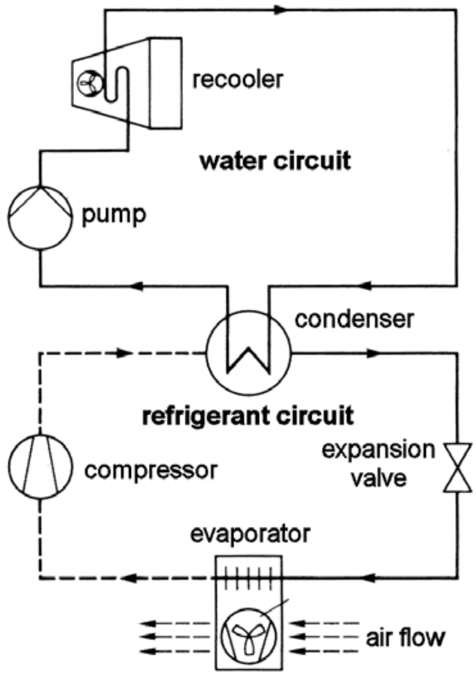

Figure 4-11:
left: Direct heat exchanging system
cp. [B89REU]

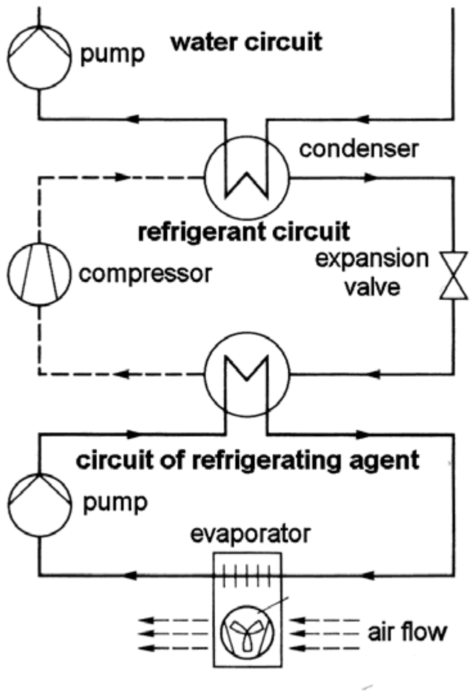

Figure 4-12:
right: Water-to-air heat exchanging system
cp. [B89REU]

4.7 Operation & Organisation

The approach is completed by looking at operation, control and organisation of the development process. Good equipment and a bad organisation are worse than bad equipment and a good organisation. This is the area where the most time should be spend on.

4.7.1 Primary vs. Secondary Support

To counteract differences in roof stability, a couple of support codes are defined. These support codes describe the bolting density, the bolting roster and bolt types as well as the time of installation. The installation of a 5 m resin grouted mega bolt takes about 15 min – if the bolt is cement grouted it takes even longer. To optimize the advance rate and to maximize the performance of the development system, it should be tried to reduce the number of additional support within the cutting cycle to a minimum. In a single section system configuration the secondary bolting can take place after the continuous miner has flitted to the other heading. In a super section this has to be done during the service extension.

4.7.2 Rockdusting

Some mines are using a manual quickduster for rockdusting, like Newstan Mine in NSW: One man holds the dusting tube, another the quickduster which is powered by pressured air. The third man carries the 25 kg limestone-dust bags a few metres from the rib to the quickduster and pours them in. This method leads to a good coverage, but material in the quickduster tends to get stuck. Also there are three men necessary.

Most other mines today use attachments for the Eimco LHD. One man can conduct the work alone and the limestone can be supplied in big bags. The tramming of the machine is sometimes difficult – especially when manoeuvring under ventilation tubes.

4.7.3 Road Construction and Water Drainage

Road Construction and water drainage is an elementary part of keeping the working environment in good condition. A clean environment protects the equipment enhance miners to perform better. Paying attention to the floor profile is important to prevent the creation of water holes that hamper productivity. The effort will pay back in decreased travel time, faster haulage cycles and reduced maintenance on outby diesel equipment [P01SOR].

ACARP funded a twelve months study on the opportunities of a technology transfer from unsealed road technology on the surface to mine roads. It was assessed that better pavements are cost effective, and savings in excess of 1 000 000 A$ per mine could be achieved per year.

The conclusion of the project was that in-mine materials can form suitable pavements if water is controlled. Imported aggregate will not improve pavements on most coal mine floors unless water is controlled. The aggregate used should provide a high permeability that allows water to drain away from the pavement surface [P94LOG].

4.7.4 Traffic

The vehicles used in the mines are usually heavy duty diesel mine cars cooled by water evaporation and a pressured air motor starter for spontaneous combustion protection. The most common vehicle is the PJB Minecruiser. Some mines like Moranbah North use Toyota Landcruisers in the mains, which have lower maintenance costs and require a lower capital expenditure. Vehicles are not only used by the crews but also by maintenance men, surveyors, engineers, and other management staff.

Therefore the focus should be set on reducing the traffic in the mine. This leads besides reduced costs also to less heat and exhaust emission to the mine air. Especially on ramps the combustion emissions are extraordinarily high. A taxi and/or shuttle service driving in certain intervals within the mine reduces traffic significantly. Such a system exists for example at Moranbah North Mine.

4.7.5 Education & Skills

It is important to have a multiskilled team in which a redundant amount of men can proceed with different kinds of work in the panel. Absent miners can be replaced and new people better introduced into the mine. No one would blame something on someone else if the same job another day by oneself. By and by it leads to develop more sensibility for other things. Kelly expressed this idea by the slogan "Leave no Stone unturned"[B99KEL].

In return the demand for training is higher, e.g. it is essential that a sufficient number of people - especially on the maintenance shifts - have made all important tickets.

Formerly, the opposite and conventional objective was to have a lot of demarcation. Then everyone is a specialist in his field and is only responsible for a limited range of tasks.

Another very practical issue is the education of health and safety aspects, which are as well in the interest of the mine management. To prevent reductions in the productivity caused by heat, it is essential to educate people how to handle heat exposure (drinking, scheduling of breaks, …). This lead to a better efficiency of the work.

As well the personal work should be equally distributed over the crew. Often this is better done by involving the work team – keyword empowerment.

4.7.6 Parallel Operations

Many works in the area of roadway development can be done simultaneous. Some concurrence is achieved by organisational means – others by changing technology like in the case of simultaneously cutting and bolting (see chapter 4.6.1).

Newstan Mine introduced the approach to straighten out the different work sequences of driving belt road, travel road and cross cut. The installation of the belt structure can so already be conducted while miners drive the corresponding travel road, but two boot-ends are required. [M15STE]. More details on the panel extension tasks can be found in appendix 3, standard area methods in relation to parallel operations in appendix 9.

Table 4-10: Options for parallel Operations

	Parallel Operations	Means
Face Cycle	Cutting and Support	Technology (Bolter Miner)
Pillar Cycle	Face Cycle and Services	Organisation
Pillar Cycle	Breakdown and Housekeeping	Discipline (& Organisation)

However the synchronization of tasks may be limited in some cases: in case of a breakdown, the tradesmen are usually busy with repairing the machine in question. Therefore they are not able to do other works like running or connecting cables / pipes.

Many maintenance tasks require power supply for the equipment in order to use the diagnostic systems. Consequently during the service extension many maintenance works cannot be conducted, because at the same time changes at the electrical systems are done.

The importance and the sensitivity of this issue require a careful planning. The creation of an uptime & downtime work-list for tradesmen respectively operators with priorities may help to clarify the tasks and may lead to less unproductive time. A draft selecting some tasks is shown in table 4-11. The content of the work-list for tradesmen depends on weather their main purpose is to repair breakdowns or to install and maintain other equipment. In the following table selected tasks are conjugated as uptime or downtime tasks.

Table 4-11:
Uptime / Downtime List.
cp. [B99KEL]

Downtime Work List (Tradesmen)	**Uptime Work List** (Tradesmen)
▪ Repair equipment (CM, SC,…) ▪ Pump line extensions ▪ Water barriers ▪ Recover material ▪ Hang cables ▪ Move equipment (belt, …) ▪ Roadworks	▪ Vehicle Maintenance ▪ other “normal” work ▪ … ▪ Supply pods ▪ Housekeeping
Downtime Work List (Operators)	**Uptime Work List** (Operators)
▪ Cleaning up ▪ Roadworks ▪ Stonedusting ▪ Supply CM (bolts, vent-tubes,...)	▪ Face cycle advance ▪ ./.

5 Benchmarking Survey

In June 2003 a benchmarking survey was conducted in Australia to provide a comprehensive database to mines, equipment manufactures and researchers. The combination of these results can be used to verify strategies, indicate research projects or determine improvement potential. Besides it allow each individual mine to rank its position compared to the rest of the industry.

This benchmarking survey was conducted to determine the industry's best practice and future trends. It includes the following major topics:

- Roadway design
- Technical and organisational procedures and change
- Performance factors

The first section commence with a brief description of the different categories of benchmarking, comparing the potential of such a survey with other methods. Further on, the procedure of collecting and evaluating the data in the survey is summarized, assumptions are listed and potential errors involved in this survey are shown.

In the main part of this chapter the results are discussed by using different statistical methods like histograms, distribution and scatter plots. A comparison of the results of this survey with a survey from 1994 conducted by Robertson [P94ROB] is used to detect trends.

5.1 Types of Benchmarking

Benchmarking is about comparing and measuring performance against others in key business activities. Lessons learned from the best are then used to make targeted improvements. The two main questions can be formulated in the following way:

- Who is better?
- Why are they better?

To get answer to these questions, different types of benchmarking can be used alone or together. The four different types are listed in table 5-1 on the next page.

Table 5-1:
Types of Benchmarking
[P01WIN]

Type	Definition – Procedure - Improvement Potential
Internal Benchmarking	▪ The process of comparing one particular operation within the own organization with another. ▪ This type of benchmarking is by far the easiest because all the information should be available in house. ▪ Productivity improvement is usually about 10%.
Competitive Benchmarking	▪ The process of comparing an operation with the direct competitors. ▪ Because usually the most market players are very reluctant with publishing information, this is the most difficult type of benchmarking to carry out successfully. ▪ Productivity improvement is usually about 20 %.
Functional Benchmarking	▪ Means the process of comparing an operation with that of similar ones within the broad range of the same industry. ▪ This is relatively easy to research and implement. ▪ Productivity improvement may be 35 % or better.
Generic Benchmarking	▪ The process of comparing operations from unrelated industries. ▪ The advantage of this type is that the problems of competition do not apply, increasing the access to information and reducing the possibility of legal problems. ▪ Productivity improvement may be 35 % or better.

In this survey the competitive approach was chosen to be able to assist all the participants by finding the best practice. The comparison of this survey with ones conducted before enabled to detect market trends.

5.2 Procedure

5.2.1 Questionnaire & Database

A questionnaire was developed based on old surveys from a ACARP Workshop and the Joint Coal Board. These questionnaires were distributed by Hookham from the Australian Longwalls magazine via email or fax. In the following figure 5-1 an anonymized questionnaire is shown. The questions asked were quoted correctly.

AUSTRALIAN LONGWALL´S Survey
Questionnaire Gateroad Development

Company:_______________ Name:_ eMail:

General ALL DATA PER SECTION (No of Equipment, etc.)
Name MAINGATE Mine: ______________ Gateroad:______________________

Geometry – for Longwall
no of entries 2
Roadway width * height 5.5 m * 3.5 m Coal left on: Top 0.9 m Floor 0 m
Pillar width * length 35 m * _____ m ☒Centerline dist. OR ❐Solid
x-cut angle 90 °deg
Roadway floor type ❐Coal ☒Shale ❐Sandstone ❐Concrete ❐Other: __________

Organisation 7 Men per shift
manning 7 Men at face 0 Men outbye (Services) 1 Supervisor
working time 4 days per week 3 shifts per day 10 hours per shift
additional roster arrangement:_____________________
maintenance ❐Unplanned ❐Window ____ hours/day ☒Other: 1 SHIFT/WK +
panel extension duration shifts: 1 (5h)

Cutting Linear m required to cut per year: 15/18,000 m/y
CM (Manufacturer; Model) ABM20
system configuration ☒single unit ❐supersection
cut out distance: 3 m (unsupported advance)
average advance 17 m per shift & 200 m per week; _____m needed per year
☒in place ❐place change

Support ☒onboard bolting ❐ separate bolting machine
Roof Bolts installed rows: 4 spacing: 1 m length: 1.8 m material: Steel (H/T)
other support ☒Mesh ☒Plates ❐Spray ☒Wstraps ❐Other:___________
Rib Bolts installed rows: 2 spacing: 1 m length: 1.2 m material: Steel / F'glass
other support ❐Mesh ☒Plates ❐Spray ❐Wstraps ❐Other:___________

Haulage
Coal Hauler / SC (Manuf.; Model) Joy 22 s/c Pieces: 2 ☒Electric ❐Battery ❐Diesel
Feeder Breaker ❐yes ☒no
Belt width: 1200 mm take-up unit: ☒yes ❐no 1.5 m/s dev. 4.5 m/s – L/W.
specify if known:______________________

Main Problems 3 Seam Gas 5 Dust 4 Ventilation
rating in % OR by priority 1,2,3,… 2 Mud/Water 1 Support 8 Stresses (Roof | Rib)
non relevant problem = priority 0 6 Equipment 7 Belts ___Other:________

Comments COAL IS APPROX 25-30% ASH – MAINLY FOR POWERSTATION + SOME EXPORT AS COKING COAL (14% ASH) – V. LOW SULPHUR

FAX to +61 7 33788283 OR eMail to mhookham@corplink.com.au

Figure 5-1:
Anonymized Example of an Questionnaire
[WINKEL]

There are 18 underground longwall mines at present in NSW and 9 in QLD from which 24 mines took part in the survey as listed in table 5-2. The participation rate is thereby about 90 %. Individual mines will not be identified and the results are presented in a random order.

Table 5-2: Participating mines [WINKEL]

New South Wales		Queensland
Angus Place	Metropolitan	Crinum
Appin	Newstan	German Creek Central
Baal Bone	Southland	German Creek Southern
Beltana	Springvale	Kestrel
Cumnock No.1	Ulan	Moranbah North
Dartbrook	United	North Goonyella
Elouera	West Cliff	Oaky Creek No.1
Glennies Creek	West Wallsend	Oaky North
Wylee (missing)	*Tahmoor (missing)*	*Newlands (missing)*

From the data collected an Microsoft Access database was developed as shown in the screenshot.

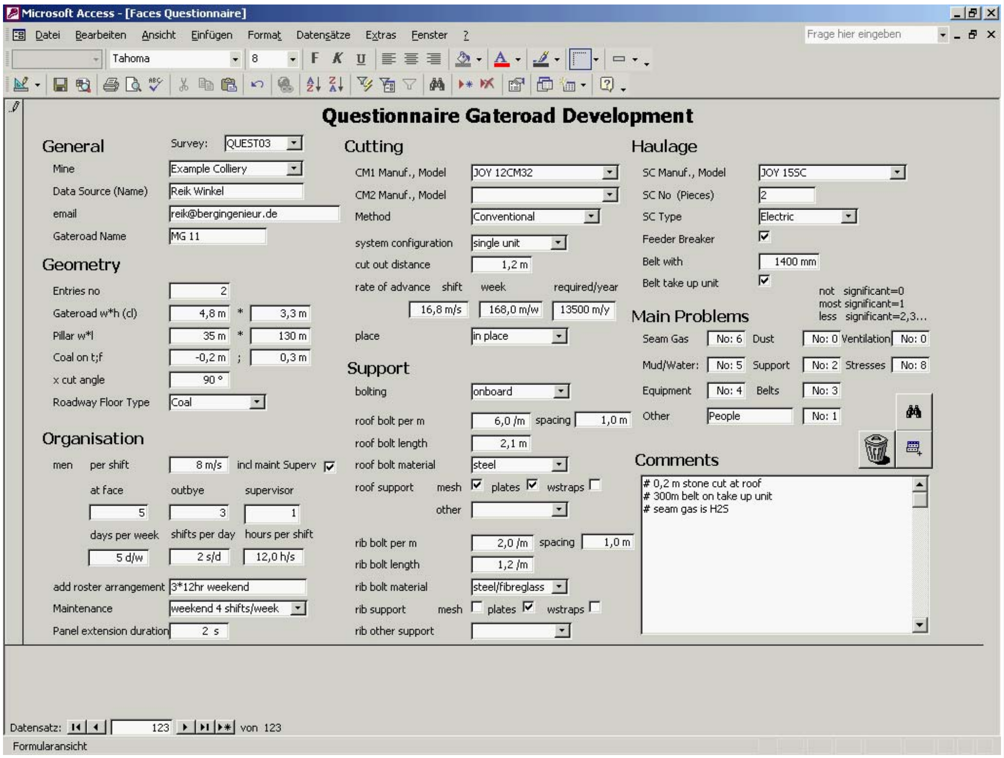

Figure 5-2: Benchmarking database. [WINKEL]

5.2.2 Assumptions & Preconditions

Two mines completed two questionnaires each for gateroads – one for a single section and one a super section. Because of these different system configurations, both questionnaires are used in this benchmarking survey in order to have a broader data base for finding out the best practice – especially because an internal comparison shows the different capabilities from a single to a super section.

Performance values from a single unit are not directly comparable with the values of a super section. A good relation between the single section and a super section advance rate is 50 - 70 %. This ratio appears reasonable because two single sections are performing better than the more complex super section. Therefore at critical statistics these values are differentiated.

To be able to create a good histogram, the pillar width is rounded to 5 m. Where ranges of values were given in the questionnaire these were averaged to make them suited for an statistical analysis.

The road width used in this survey is always the centreline distance.

Specifically performance ratios calculated using the advance rate defining “the higher the better” is not completely true. The planned advance rate is not always the highest which can be achieved. Reasons for such management decisions are explained in chapter 4.4.

5.3 Quality of Results

The quality or validity of the results collected from the questionnaires depended on various aspects. These are:

- the care and understanding of the person in the mine who replied to the questionnaire
- the quality of the data available to the person
- the comparability of the data
- the correctness, accuracy and clarity of the questions asked in the questionnaire.

Due to these aspects the data had to be verified before using it. Further in the benchmarking process. Examples are described as follows:

From one mine two different persons replied to the authors’ questionnaire. However the answers were not identical. For example, in one questionnaire the crosscut angle was given with 70° - in the other one with 90°.

An error related to the care of some persons is that the question for the i) number of roof/rib bolt rows and the ii) spacing has been answered several times with i)1 m, ii)1 m. The right answer would be a unit free value [n] for the number of bolts per length of spacing - like 6 bolts over a spacing of 1 m.

The participants were asked to add all data per section. Surveys for super sections were conducted for the entire section to avoid confusing two crews working on the same super section. When evaluating the data, exceptionally low advance rates were observed but due to the fact that the note was quite explicit on the questionnaire, the correctness of the data was assumed.

One mine quoted 9.5 m/shift and 360 m/week. By using the organisational data from the same questionnaire (4.5 days/week, 3 shifts/day) a maximum weekly advance of 128 m/week could be achieved. The original value of 360 m/shift– which otherwise would be by far the best performer, has been replaced by 128 m/week. The same person quoted the manning for the whole mine and not for the section.

It is evident that most people did not understand the meaning of “coal left on top in metres” respectively “coal left on floor in metres” – probably because most mines are not leaving any coal on the floor/top due to a low seam thickness. Some mines named a higher value of coal left than the coal seam thickness. For that reason this data is not illustrated, however the roadway height is set in a ratio to the seam thickness.

Furthermore, mines are collecting their data on a different basis. Some mines probably include the panel extension time in the average advance rates, others not. Also the differentiation between men outbye (services) and men at the face is done differently.

The questionnaire developed was not clear enough in the formulation of the main problem question. The idea of the question was to rank the listed problems by numbers. The ranking should have been clearer so that every number should be used once. Problems which are not production relevant should be evaluated with “0”. That means that if all eight problems are relevant, the numbers “1,2,3,4,5,6,7,8” should be used. In practice however, some people evaluated the problems with 1,1,1,2,2,3,3,3. This had to be translated in the right scheme so that the differentiation between same values was done randomly.

Concluding can be said, that most of the invalid data could be “repaired” by using other sources. It is therefore valuable and usable for the benchmarking survey.

5.4 Discussion of Results

In this chapter statistics generated by processing the database are shown. The same order like in the questionnaire is used. Ultimately also some scatter plots were created, to find eventual dependencies on the advance rate.

5.4.1 Layout / Geometry

All mines except two are developing the longwall panels with two entries. The entries have a width of 4.8-5.4 m, averaging 5.1 m. The roadway height varies between 2.3 and 4.1 m, its average is 3.0 m.

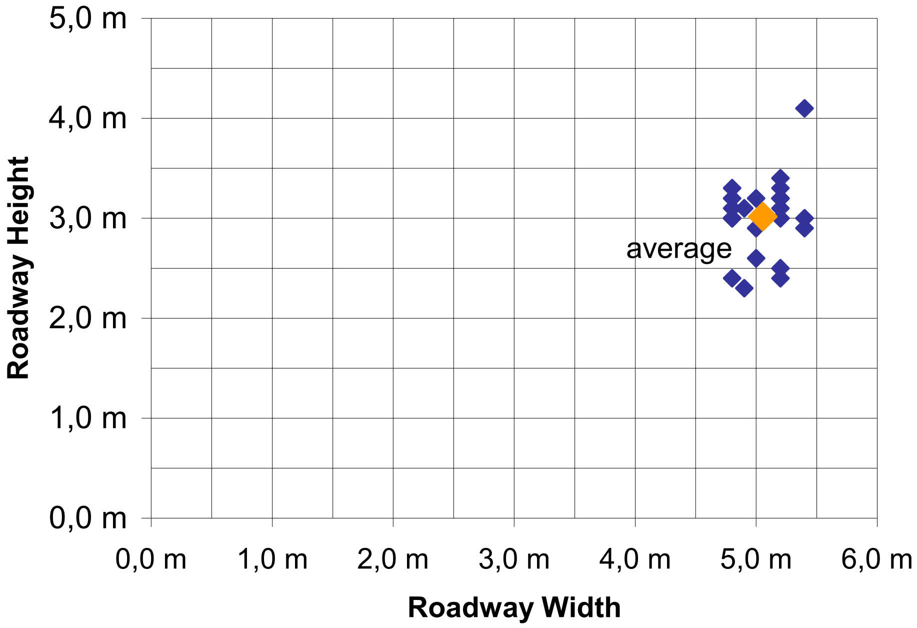

Figure 5-3:
Roadway dimensions

A common chain pillar width is between 30 and 40 m. However, one mine is using a pillar width of 25 m, one with 45 m and one with 50 m. 73 % of the mines are using a pillar length of 90 – 100 m. Five mines create longer pillars with lengths between 115 m and 155 m.

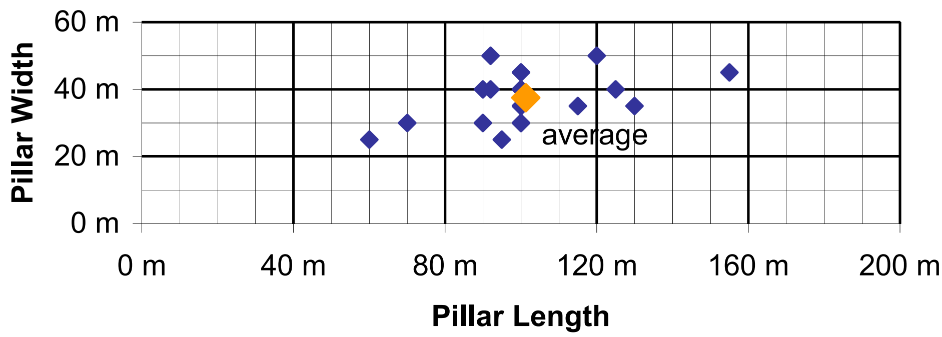

Figure 5-4:
Scatter plot pillar width/pillar length

In the following figure the relation between the ratio (roadway height / av. seam height) vs. roadway height is shown. A clear trend is visible: if the coal seam is less than 3 m mines are accepting to cut rock. Above a 3.5 m seam thickness coal is left in the roof and/or in the floor.

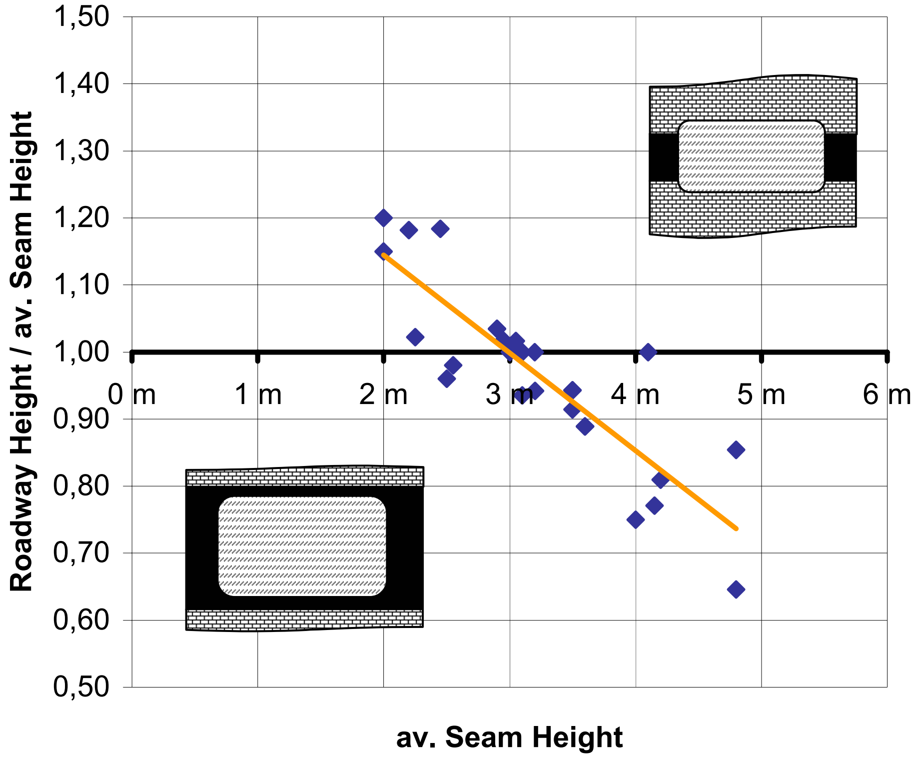

Figure 5-5: (Roadway height / average seam height) vs. roadway height

The development to mining ratio averages 2.4 varying from 2.3 to 2.5. About 80 % of the mines are using a crosscut angle of 90°, the rest are using 70°. By looking only at mines opened after 1994 the result is the same.

The roadway floor type in eight mines is shale, in four mines mudstone and in eight mines coal is left as a pavement. This means that almost all mines are leaving coal in the floor if the seam thickness is substantially higher than the roadway height.

5.4.2 Organisation

For a single section a manning of 7-9 men is standard, from which 5 men are at the face, 2 are tradesmen and 1 is supervisor respective deputy. In one mine only 5 men are working in the panel[22]. In a super section between 13 and 16 men are necessary.

50 % of the mines have a shift time of 8 hours. Roadway development is running 5 days/week in 50 % of the mines. Details are shown in the next

[22] This mine achieves a development rate of 15 m/shift but only 4 bolts are installed each metre.

figure. 70 % of the mines have three shifts/day whereby the rest work on two shifts/day.

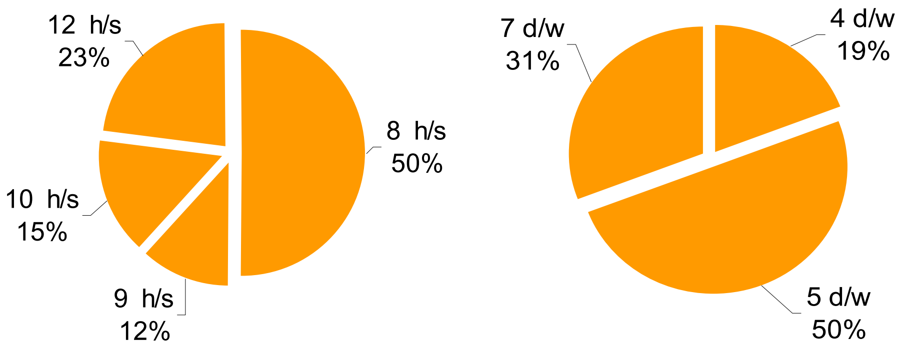

Figure 5-6:
left: Shift length in [hours per shift],

right: Development days in [days per week]

Nine mines are applying a 3 day*12 h weekend roster. One mine mentioned a special and interesting roster. The nightshift and the dayshift as well as the dayshift with the afternoon shift are overlapping, so the shift changeovers are done as a "hot seat" change. Between the afternoon shift and the nightshift a delay of 3 h exists.

Another very important factor is to organize the panel extension in a way to minimize the needed time to get the miners as fast as possible back to the coal. Three mines are very well organized by doing this within one day. The best super section is carrying out the panel advance in three shifts. The distribution is almost Gaussian, as shown in the following figure.

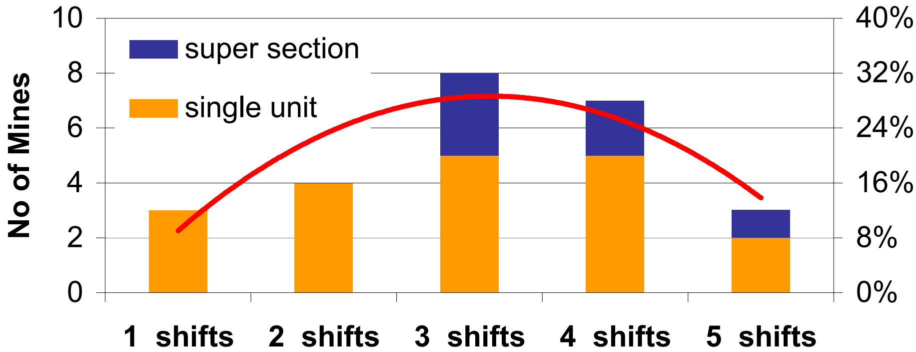

Figure 5-7:
Panel extension duration

For maintenance every mine in Australia has its own strategy. Because of the variety of concepts, a detailed evaluation is needless – rather four groups can be distinguished: About a third of the mines are doing maintenance only when required. Almost half of the industry has defined maintenance windows of a couple of hours every day. Another group of mines mainly use the weekends for maintenance. The last group has maintenance windows of several shifts/week. Combinations are occurring as well.

5.4.3 Cutting

There are only two mines with a place change respectively cut & flit operation. These are as well the only ones using separate bolting rigs. The majority of 65 % are using a single unit rather then a super section.

The average development rate is 13.6 m/shift, with a min of 5 m/shift and a max. of 23 m/shift. Subdividing these development rates on super section and single section configurations, the super section development rate average is below the one from the single section. Due to the fact that a super section is more complicated and cost intensive. The following figure is differentiating between the different system configurations and is shows no correlation. Even the top performer is a single section.

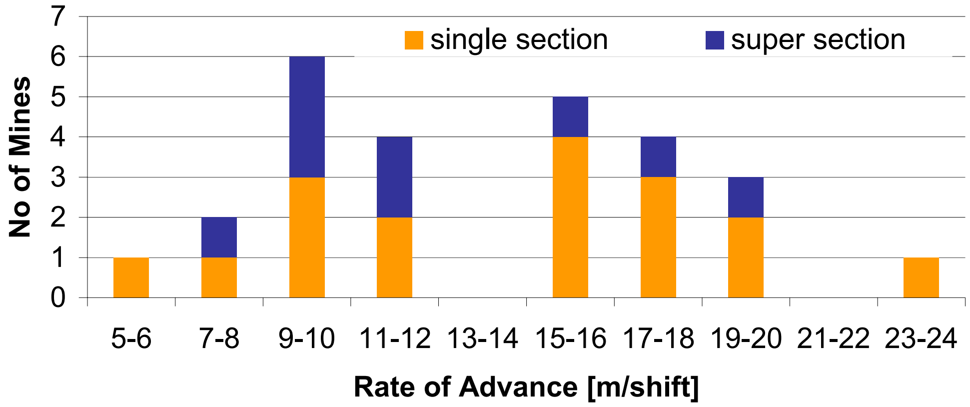

Figure 5-8:
m/shift (singe unit / super section)

By looking on the ratio m/shift vs. m/week it can be observed that between 7 and 20 shifts are productive per week. In average, twelve shifts are productive which equals four of seven days at three shifts per day.

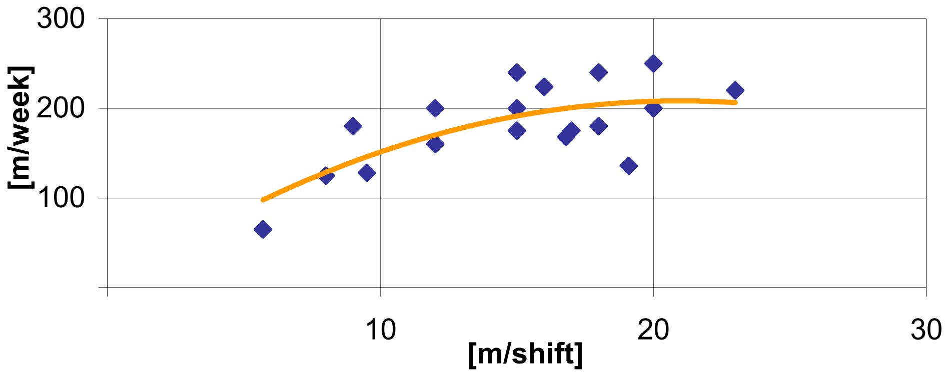

Figure 5-9:
Rate of advance: Relation between m/shift and m/week

5.4.4 Support

All mines are using either four or six roof bolts. On modern continuous miners four bolting rigs are attached. Hence the additional time and work between two and four roof bolts is insignificant and the mines tend to follow the safer approach. Additionally up to six rib bolts are installed. Sixty-seven percent of the mines utilize a spacing of 1 m and only a few up to 1.5 m. The figure following on the next page is adding up all bolts.

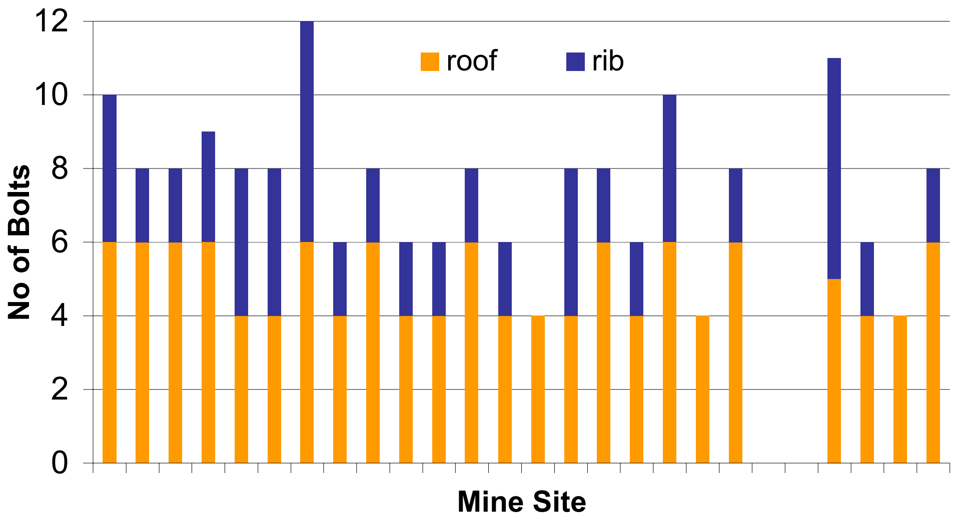

Figure 5-10:
Number of roof and rib bolts

The use of mesh for the roof reinforcement is quite common – the rest is using w-straps. For the ribs mesh is little used. Plates are used by about half of the mines (see figure).

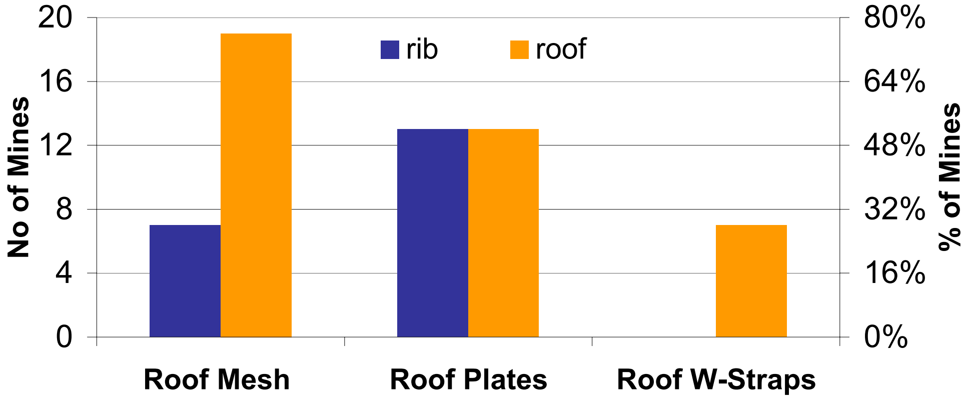

Figure 5-11:
Use of mesh, plates and W-straps

The most common lengths of roof bolts are 1.8 m and 2.0 m. By far the most common rib bolt length is 1.2 m as illustrated in the following figure.

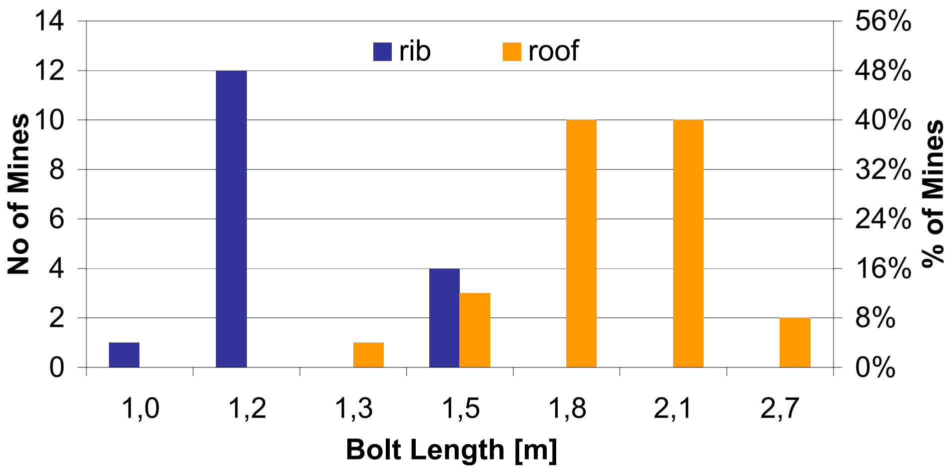

Figure 5-12:
Roof / rib bolt length

Many mines reported additional support like 6 m flexi bolts at intersections and other special circumstances.

5.4.5 Haulage

The standard vehicle for coal haulage is the electric JOY 15SC shuttle car which is used by 20 mines. Two mines are using the JOY 12SC32, one mine a Hydra Car and one mine a diesel RAM Car from DBT.

Approximately half of the mines are installing a 1200 mm development belt. To avoid changing the whole belt for a wider longwall belt, some mines are already installing wider belts during development. The distribution is illustrated in the figure. All mines except one are using a belt take-up unit.

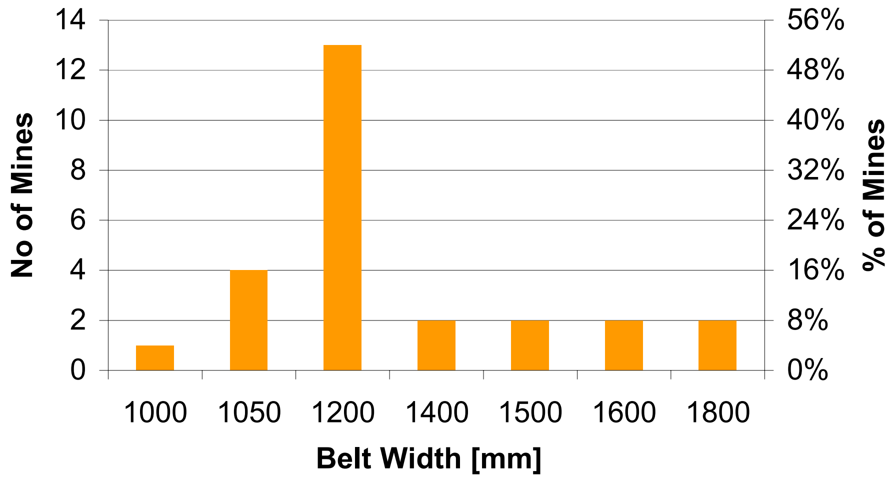

Figure 5-13: Belt width

5.4.6 Major Problems

The evaluation of the different problems is done by weighting the different priority numbers (1 to 9). To find a weighting factor, it is assumed that the 1st 3 problems have the same negative effect on development like the rest of the problems. A weighting factor of 0.85 was found by solving the equation following out of the assumption.

On this basis, the following formula[23] was developed to estimate the ranking of each problem:

$$Ranking = \frac{\sum_{i=1}^{9}\left(factor0.85^{i} * NoVotesInPriority\_i\right)}{factor0,85}$$

Using the formula each vote in priority 1 is weighted with 1, priority 2 with 0.85, priority 3 with 0.72 and so on to priority 9 with 0.28. This formula is used for every of the eight problems. Other problems reported were faults, summer heat, frictional ignition, H_2S gas and people. These are not included in the ranking because each of these problems was reported only once.

[23] The excel model weighting the single votes is part of attachment 7.

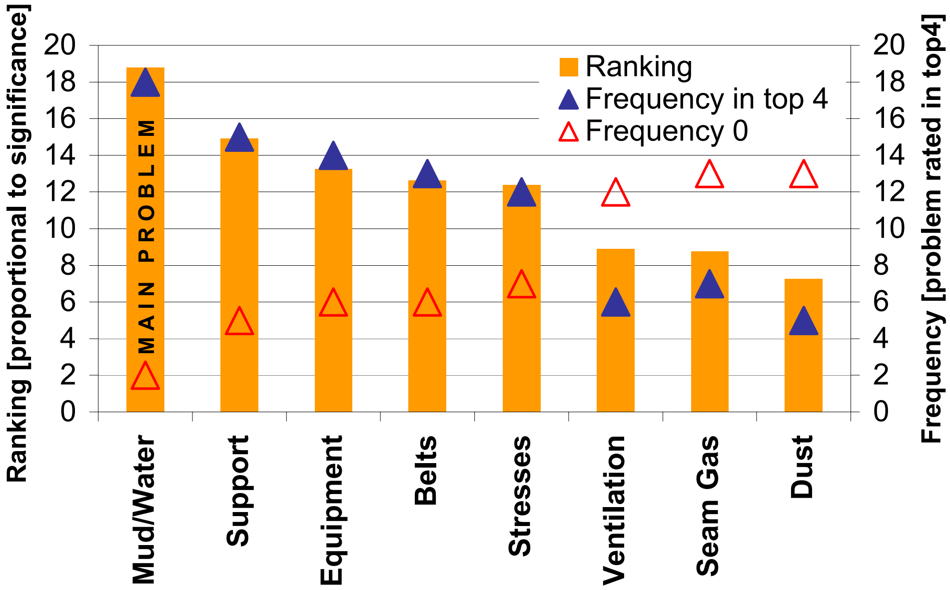

Figure 5-14:
Ranking of major problems

Like shown in the figure 5-14 the distribution of the problems by positive votes comply very clear with the anti proportional distribution of the insignificant problems. Mud respective water was rated by far as the main problem. This suggests the conclusion that even more effort has to be spent on road construction and maintenance. Recommendations are given in chapter 4.7.3.

Additionally, machinery like belts and equipment and geological effects, like faults, stresses are standing side by side in the ranking. Ventilation, including dust and methane gas is comparably the smallest problems in the industry.

5.4.7 Performance Scatter Plots

The idea behind the use of scatter plots is to find correlations with the advance rate.

The next graph shows, that there is a correlation between the depth and the rate of advance. However, the high variation in depths between 100 m-300 m shows that other factors must have a bigger influence.

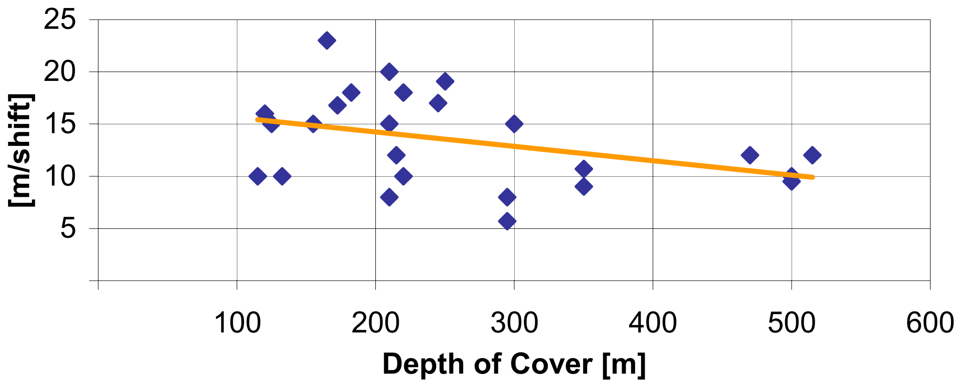

Figure 5-15:
m/shift vs. depth

The clearest correlation is the bolting density. Figure 5-16 shows that doubling the number of bolts per metre from four to eight, leads to a 40 % drop in the advance rate. But still some mines with ten bolts/m are outstanding.

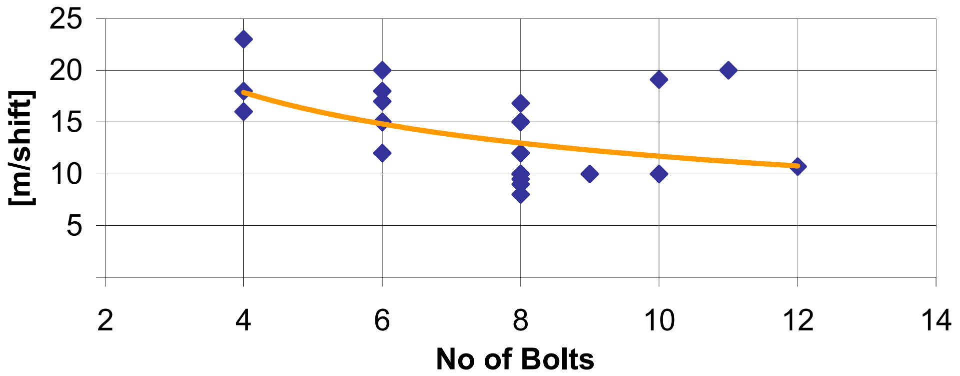

Figure 5-16:
m/shift vs. roof and rib bolts

Figure 5-17 shows clearly, that an increase in the shift length will not result in a increase of meters developed in this shift.

Figure 5-17:
m/shift vs. h/shift

5.5 Comparison of Results

In Australia about 300 km of gateroads are developed with CM each year with an average advance rate of about 13.6 m/shift. US mines are faster in development – also due to much thinner seams. In the Pennsylvanian three-entry place change mines advance rates of 40 m/shift could be achieved [B00RAD] – however the shift length have to be considered. In German hard coal mines with continuous miners average advance rates of 11 m/day (±4 m/shift) are realistic.

In the last ten years in Australia many different roadway development surveys were conducted focusing on different objectives. Some were made for magazines, others like the one from Robertson 1993 for a ACARP research project. The joint coal board started in 1995 with making this kind of surveys on a half year basis, however it was discontinued a shortly after. Because all surveys focus on different aspects they all have different levels of detail. Only a few aspects are compared in the following figure. The list is not complete, because some surveys are not published like the CSIRO rock bolting survey 2002. Even though not all mines replied to all of the surveys, the low variation in results shown in figure 5-18 is quite impressive. Only the development performance, which naturally changes over the time, has a high variation.

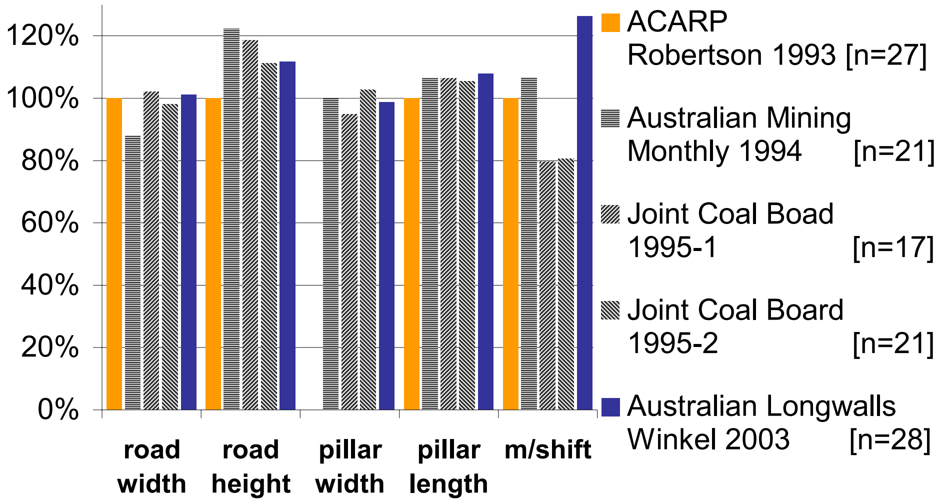

Figure 5-18:
Roadway development Surveys - normalized on Robertson 1993

Because of the detailed information supplied from Robertson, collected in 1993 for a ACARP roadway development workshop, this survey is used further on for a detailed analysis. The most common method is to compare the average values of older surveys with new ones. In this survey the original uncondensed values are taken to compare each with itself. This enables to assess the number of mines, which really changed parameters and performance.

To do so, the 13 mines listed in the table 5-3 were identified which took part in both surveys. Many other mines are already shut or younger than the survey from 1994.

Table 5-3:
Mines participated in the Robertson survey 1993 and in Winkel 2003

Angus Place	North Goonyella
Appin	Oaky Creek No.1
Baal Bone	Southland
Elouera	Ulan
German Creek Central	West Cliff
German Creek Southern	West Wallsend.
Newstan	

By comparing the old results, clear trends were identified:

The number of mines which reduced the shifts per day as well the days of development per week is quite high. None of the mines increased the shifts per day and only a few increased the days per week. In average the decrease was half a shift/day and 0.7 days per week. This has been compensated by an average increase in shift length of 1 hour per shift. Details can be found in the next figure.

The development performance has been increased by 70 % of the mines – in average of all 13 mines by 1.5 m/shift to 12.2 m/shift. During the same time 50 % of the mines reduced the bolting pattern – in average over all mines 0.6 bolts per metre more. However the higher advancement rate appears to be more a result of the increased shift length rather than the result of process optimization (figure 5-19).

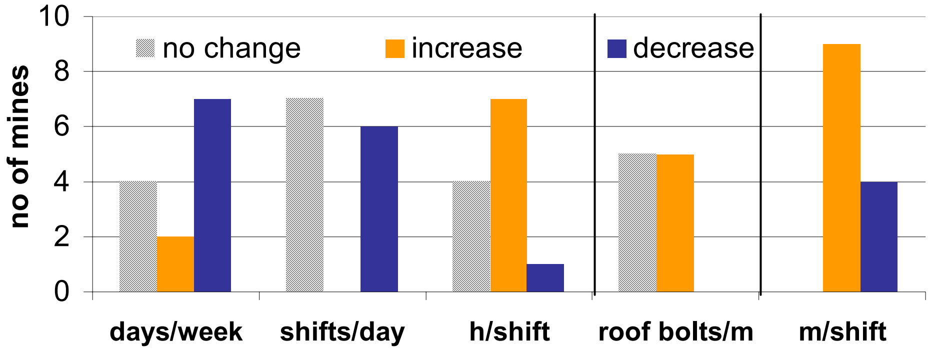

Figure 5-19:
Change of organisation, support and performance

The kind of equipment is mostly still the same than 10 years ago. Then seven mines used mostly JOY continuous miners, three mines mostly an ABM20 and three a DBT (Jeffrey) cut & flit miner. Today in the sum all cut and flit miners were displaced by ABM20 machines, however some mines switched from JOY to ABM20 and vice versa.

The panel layout changed as well. Today the roads are slightly wider and higher, pillars are longer.

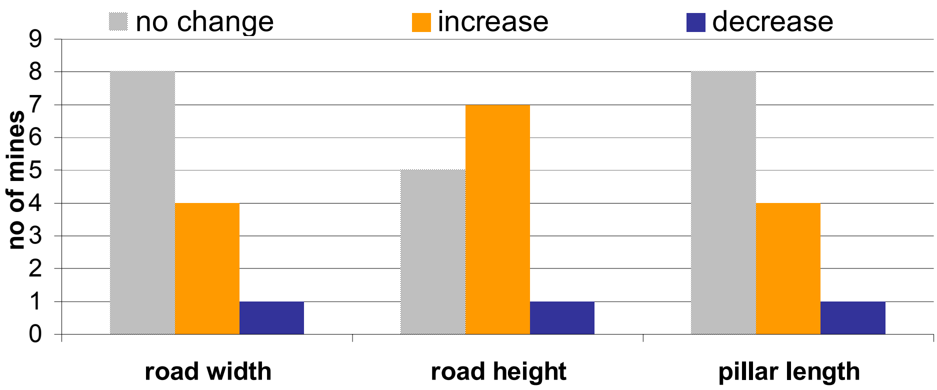

Figure 5-20:
Change of layout

5.6 Conclusions

A very broad evaluation was conducted, showing the status of roadway development in Australian longwall mining industry. This survey is particularly helpful for low performers to get an impression which circumstances accelerate the performance. This method can be referred as best practice which is described here.

It is observed that the spread of performance in m/shift is distributed over a wide range from 6 to 23 m/shift. The standard deviation is 4.5 m/shift showing that there is potential for improvement. It can be noticed that a higher longwall retreat rate is “pushing” the development performance.

A very clear result of this survey is that a super section system configuration is underperforming industry wide. The total cost of a super section are about two times as high as a single section, but have to be divided on less metres developed. Not only the average advance per (productive) shift is much lower than two single units, also none of the mines is doing a panel extension under three shifts. This reflects very well the exposed need of infrastructure. Keep it simple - a super section setup should stay a niche solution if a single section cannot keep up with the longwall retreat rate.

The average pillar length is increasing steadily. Today for the most chain pillars a length of 100 m is chosen, however already one mine introduced a pillar length of 155 m and a cluster of mines are driving a crosscut every 125 m. Pro and cons of longer pillars are discussed in chapter 4.

Even when the shift lengths were increased in the last ten years by most of the mines, longer shifts than the standard eight hour shifts do not correlate with the drivage. Usually at least an effect of relatively low travel-time per shift-time should be visible. Six mines do apply a shift roster with twelve hours per shift – the reason is probably of organisational and union nature rather than a mean of optimizing the performance.

Water and the formation of slurry inbye in the panels is an issue for almost every mine. It is one of the oldest problems in the mining industry, despite innumerable solution strategies it is still a top issue. Certainly cleaning in short time intervals is essential. This problem has been discussed in chapter 4.7.3.

Regarding maintenance no best practice could be detected. The most mines apply a maintenance roster just as it fits in the schedule, showing that maintenance has a quite low priority in the development concepts. If this is right or wrong, is a point of further investigation.

6 Case Study: North Goonyella Mine

The North Goonyella Coal Mine (NGCM) is owned by RAG Australia Coal, a subsidiary of RAG Coal International in Essen, Germany. It is located approximately 150 km south west of Mackay at the Northern margin of the Bowen Basin in Central Queensland. The longwall production of high quality coking coal commenced in 1994.

It mines 4.5 metre of the 6 metre thick Goonyella Middle Seam at a current depth of cover of 180 metres. The mine has been operated in its ten year life-time by about five different management teams. Thus frequent operational changes have been conducted and no steady corporate objective could have been introduced. Recently, the last share was bought from Thiess and, since then, lots of effort is put in change management. Therefore, these ongoing projects will probably overlap with the results and recommendations of this case study. First results are already visible in the daily business.

6.1 Geology

Permian age strata is characteristic for the Moranbah Coal Measures which belongs to the Goonyella Middle (MCM). The stratigraphy of the MCM broadly comprises an alternation of volcanolithic claystone, siltstone, and sandstone units. They are punctuated with regionally extensive coal seams.

Overlayed are a series of thick high-ash coaly units of the Fort Cooper Formation that are capped unconformable by a veneer up to 40 m thick of Tertiary alluvial sediments and basalts in various stages of weathering [B99SMI].

The lower part of the seam has a thickness of about 2.4 m and contains the highest coal quality. It is continuing with a mudstone band of about 10 cm thickness. This band is used for orientation in development as well as in the longwall.

The roof and floor conditions are moderate to weak. The floor consists of over 10 m of cross-laminated fine-grained sandstone and siltstone termed as “mudstone”. During the development 1 m of coal is left on the floor, to prevent deformation of the mudstone floor by shuttle car traffic. This part is mined later in the longwall.

The upward succession of roof strata consist of 30 m of claystone and siltstone, then a thin couplet of coal and tuff (P-tuff), followed by up to 15 m of siltstone and 10 m of sandstone up to a height of 55 m.

High stresses and unfavourable local rock structures (faults, fracture zones etc.) are the major factors affecting the roof and face stability. The upper part is quite stable and therefore a coal beam is left in development to prevent roof control problems of the weak overburden mudstone strata.

6.2 Mining

The longwall face has presently a width of 250 m and is scheduled for extension to a width of 300 m in August 2004. Accordingly, future panels will then be developed in a distance of 300 m. The shields and the shearer used are manufactured by JOY, the face conveyor by DBT. The longwall cables and hoses are hanging on a monorail. They have a effective expansion length of 300 m.

A major thrust faults with a displacement of up to 6 m is crossing the actual longwall panel. As a consequence major roof falls occur at the longwall face. Their probability of occurrence rises if the longwall is pt on halt for a couple of days.

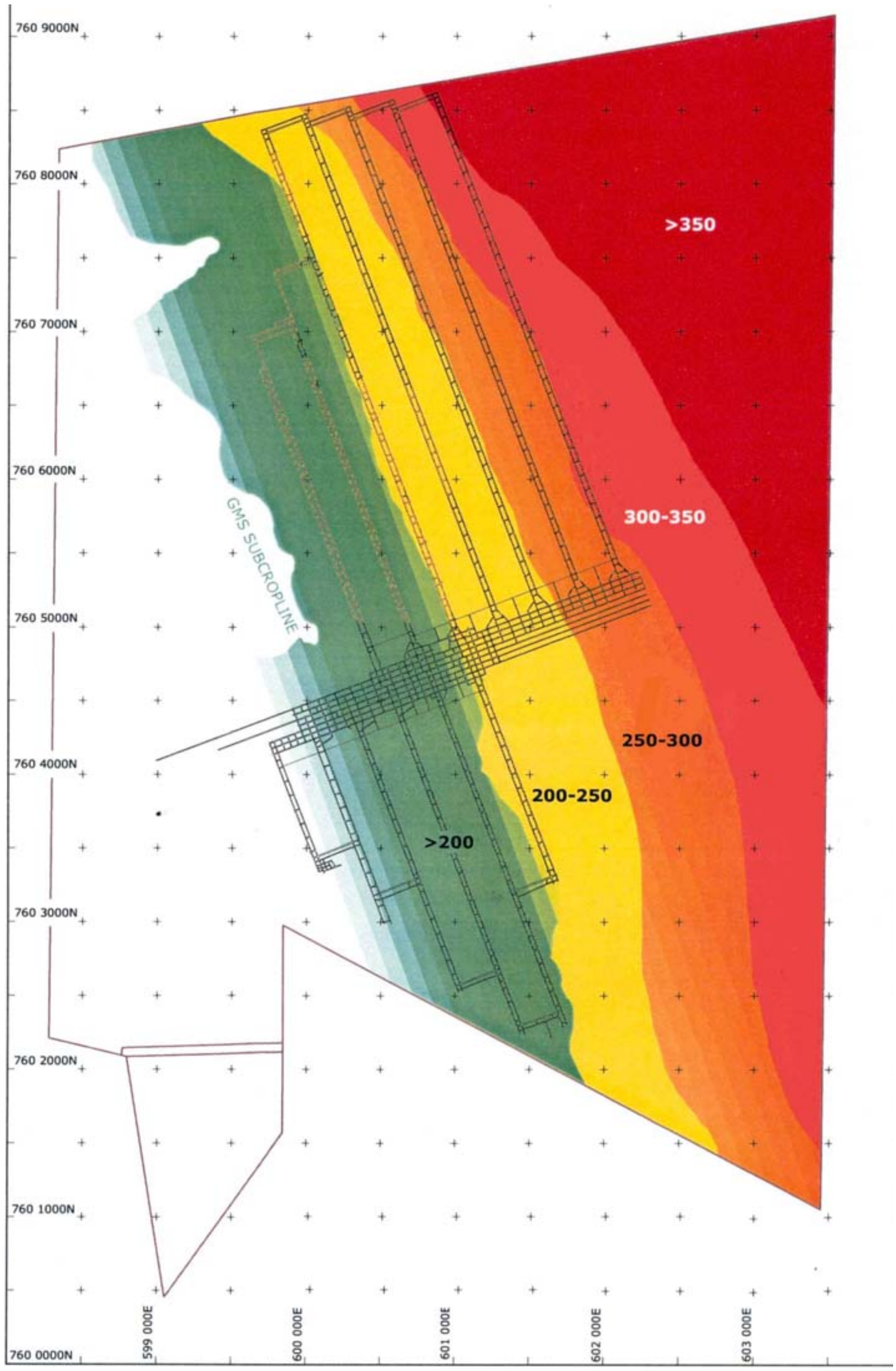

Figure 6-1:
NGCM depth of cover (middle seam)
[M01LAU]

6.3 Development (RESTRICTED)

Not available here, since this chapter contains confidential information.

6.3.1 Pillar Cycle

Not available here, since this chapter contains confidential information.

Secondary Support

Not available here, since this chapter contains confidential information.

Maintenance Crew

Partly available here, since this chapter contains confidential information.

Three tasks are conducted during this window:

- Limestone rockdusting
- Continuous Miner supply
- Cleaning of wheeling road and boot end

Suggestion for the future:

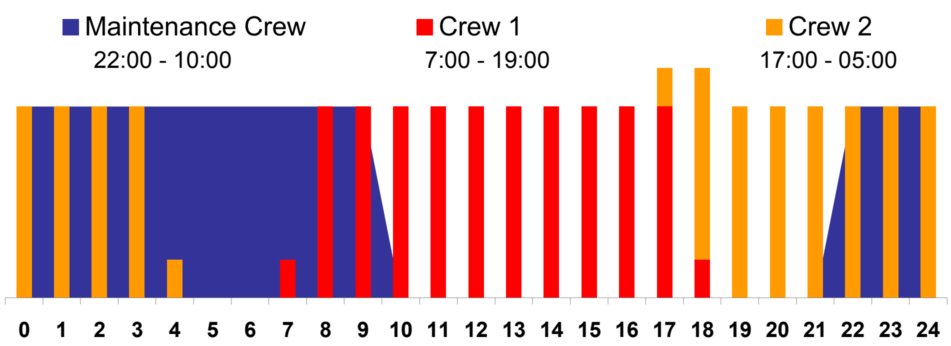

Figure 6-2: Overlapping CM Crew roster with one maintenance window per day.

Organisation

Not available here, since this chapter contains confidential information.

6.3.2 Panel Cycle

Mine Geometry

Partly available here, since this chapter contains confidential information.

Gateroads are driven to a height of 3.4 m and a width of 5.2 m. The centreline distance between the crosscuts is 100 m and the centreline distance between the gateroads is 40 m. To orientate the gateroad within the seam in order to prevent roof failure and mudstone floor, a claystone marker band is used.

A cut out distance in excess of 6 m is possible, but in reality bolting is undertaken at a cut out distance of 2-3 m.

The maintenance of a top coal beam of 1-1.5 m thickness is essential to ensure the roof stability.

Ventilation

Not available here, since this chapter contains confidential information.

Water control

At NGCM the outby water control is very efficient. A drainage trench is constructed and equipped with a pipe to pump the water to the surface like explained in chapter 3.3.2 The water control inbye is limited to sporadically installed pressured air water pumps. Once the coal slurry is formed, it is nearly unpumpable. Under the one meter layer of coal bottom is a very water sensitive mudstone floor. If this protecting layer is destroyed by the SC wheeling, the conditions become worse.

DSK Auguste Victoria Mine in Germany encountered similar problems with water sensitive ground and man made water in development with an ABM20. The total amount of water (270 l/min - 70 % drilling and 30 % dust suppression) was reduced by changing the angle of the nozzles, the use of different drill bits and an optimization of the total water distribution [P02VIE].

First experiences with a new water mist spraying system[24] on a roadheader resulted in a significant reduction in water of about 1 l/min per nozzle. Additionally the escaping methane is diluted [P02BAU].

Shift Time Utilisation

Not available here, since this chapter contains confidential information.

Breakdown & Use of Breakdown Time

Partly available here, since this chapter contains confidential information.

Table 6-1: Readings Lautsch [M01LAU]

Readings	Value
Meters adv. in calendar time (x blocks a y m)	x m
Calendar Time (13.8.02-10.4.03)	240 days
Time CM switched on	x h
Time Cutting switched on	x h
Calculations	**Value**
Percentage CM1 to CM2	42 %

[24] Development of Heitkamp and Deilmann-Haniel by assistance of DMT.

Av Operating Time per shift (2 shifts/day)	x h
Av Cutting Time per day	x min
Av Operating Utilisation (to calendar time)	x %
Av Cutting Utilisation (to calendar time)	x %
Av Cutting Time per m	x min
Av Linear m per shift (to calendar time, 2 shifts/day)	x m/shift

Material Handling

Not available here, since this chapter contains confidential information.

6.4 Simulation (RESTRICTED)

Partly available here, since this chapter contains confidential information.

To evaluate the potential for improvement at NGCM the different cycles have been modelled by a Excel model of Melrose [M16MEL]. The parameters are assumed as follows:

Table 6-2: Simulation Assumptions for NGCM

Description	Value	Unit
Roadway Width	5.2	m
Roadway Height	3.4	m
Number of Roof Bolts	6	
Length of Roof Bolts	2.1	m
Number of Rib Bolts	4	
Length of Rib Bolts	1.8	m
Mesh	yes	m
Avg. Strap Spacing	1.0	m
Avg. Shuttle Car Capacity	14	t
Avg. Shuttle Car Speed	80	m/min
Avg. S/C Discharge time	80	sec
Avg. Cut-out Distance	2	m
Avg. Coal Density	1.42	t/m³
Number of Shuttle Cars	2	

6 Case Study: North Goonyella Mine

The simulation assumes that the machines can be operated at their full potential. In practice, however, people and people management play an integral role in determining machinery performance. This includes individual motivation and skill, but relies also on the work environment.

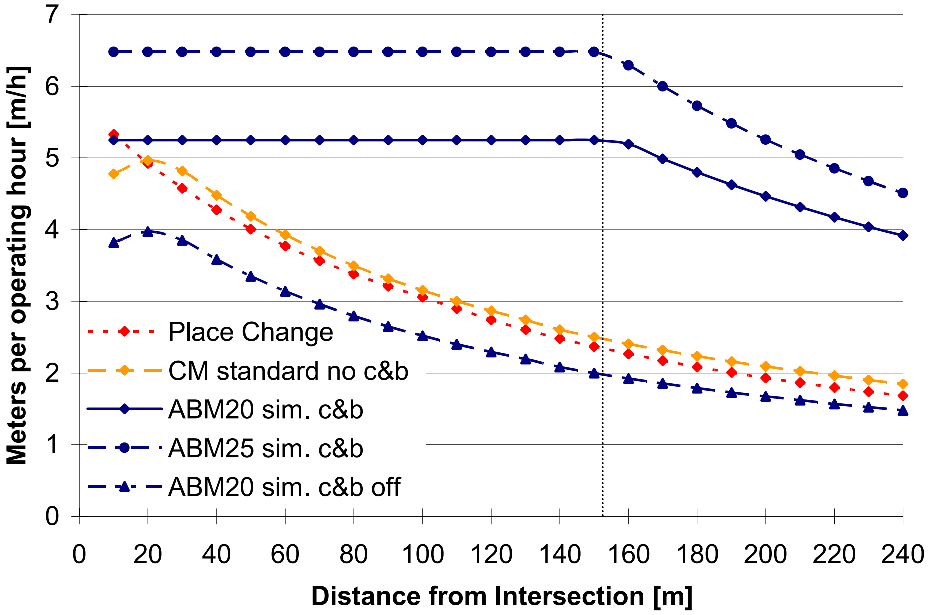

Figure 6-3:
Mining System Performance NGCM Face Cycle Simulation
cp. [M16MEL]

Using the present performance (x % Uptime, x m/shift, x h/day and 2 shifts/day) an advance of about x m per operating hour is achieved. This figure shows that the production is limited neither by the machine performance nor by the wheeling distance.

The maximum distance from the intersection is presently 140 m. Increasing the pillars to 200 m (maximum distance 240 m) will drop the reasonable achievable advance rate per operating hour with an ABM20 only during development of the last third of the roadway. There the advance rate could be increased on average by 10 %. However, the maximum available shuttle car cable lengths have to be considered.

However the supply of sufficient air flow for heat dissipation and gas dilution might become more difficult (chapter 4.5.3). Efforts must be undertaken to reduce friction and leakage losses for example by using longer ventilation tubes.

The graph shows also the capability of the ABM 20 if cutting and bolting are done simultaneously. This function has been switched off and necessary attachments were disassembled from the miner - a clear reason could not be found.

6.5 Conclusions (RESTRICTED)

Partly available here, since this chapter contains confidential information.

The pillar length of 100 m has potential for optimization, like shown in the analysis. The bolting density is quite high and the present advance rate underperforms so that the resulting advance rate would only be slightly restricted by a larger wheeling distance. However, if pillar lengths of more than 133 m are chosen, the longwall monorail cable needs to be extended.

6.6 Recommendations (RESTRICTED)

To improve the overall performance in the area of development, the author recommends a diversified strategy:

Short term

Not available here, since this chapter contains confidential information.

Medium term

Partly available here, since this chapter contains confidential information.

An investigation looking for a suited a water mist system for dust suppression on the ABM 20 as well as for the use of drill bits with a lower water consumption should be conducted.

A container based supply system can reduce handling time of consumables and material wastage. Jennmar as bolt supplier offers the packaging of CM containers and the direct recirculation of unused consumables. Modifications of the CM's are then necessary.

The Eimco rockduster attachment which is presently used is state-of-the-art, but the slinger unit it does not always cover the whole roof and rib. Also lots of time is used for machine tramming. It might be useful to replace the slinger discharge unit with a men controlled pressured air discharge hose.

In the area of organisation the introduction of simple and short standard area methods (SAM) and/or a gantt chart scheduling could be helpful. The tasks may improve in continuity - especially if referring to the panel extension. To implement this, all shifts and all groups should be involved and the team should consist of a diagonal sliced selection of engineers, deputies, tradesmen and operators.

The introduction of a shuttle and/or taxi service can reduce the traffic in the mine and ramp significantly, as well as the maintenance cost (chapter 4.7.4). Eventually the cheaper Toyotas can be used in the mains.

Long Term

Partly available here, since this chapter contains confidential information.

By looking on the results of the Systems Approach (chapter 4.5.4), the results of the NGCM haulage simulation and the special situation at NGCM it appears reasonable to increase the pillar length up to 200 m. This implies changes in the ventilation system, like the introduction of longer or wider ventilation tubes. As well the use of sliders should be considered.

On a longer term the introduction of a continuous haulage system appears reasonable. A top bolt-mounted conveyor[25] using plastic idlers and lightweight idler-stands appears reasonable. Top mounted conveyors are particularly suitable for high roadways, the light weight makes the installation easier. This system would eliminate the restrictions of a monorail.

[25] In appendix 11 a technical drawing from the German Walsum coal mine is showing a possible connection of a belt conveyor belt with the CM.

7 Summary

As a result of the growing disparity between the preference of the longwall production and roadway development, the advancement of improved roadway development practices has become necessary. To assist in relieving this disparity, this study presents key aspects influencing the preferenced Australian roadway development systems. A systems analysis overview and a benchmarking survey are presented.

Various Australian Institutions undertake research activities in the area of coal mining, including The University of Queensland, The University of New South Wales, their associated research institutes and institutions such as CSIRO and JCB. Their funding comes from the Australian Coal Association Research Program (ACARP), as well from the state governments which are interested in the growth of the mining industry, one of the most important business sectors in the eastern Australian states of New South Wales and Queensland.

An overview of the results of several projects undertaken by the aforementioned institutes and the experience of the mines a state-of-the-art roadway development practice is given in this thesis. All important processes within the development systems were divided into cycles, creating a basis for a systematic analysis. Differentiation was made between the face cycle, on the micro scale, between the pillar cycle and panel cycle to the mine cycle concerning global aspects. Consideration of mining law was also made. The law describes mainly safety aspects like fire protection and ventilation requirements, but also defines a minimum for pillar width and limits the roadway width to 5.5 m. It should be noted that for every major change in the development practice, a risk analysis will be necessary.

The development costs in Australia were estimated to be in the range of 2 000 to 3 000 A$ per metre. The major cost share is labour, followed by infrastructure. Machinery and consumables comprise less than a third of the total cost.

The layout of Australian mines differs significantly from layouts in the United States, South Africa or Germany. In Australia the two-entry system is prevalent with only one exception as a three-entry system. It was estimated in this study, that this concept is best suited for the Australian conditions.

Different indicators suggest that the pillar length will increase in the next decade significantly. The benchmarking study showed that few mines have pillars less than 90 m in length. Recently, one mine changed their pillar length to 155 m. In future, with technological improvements, it is possible that 200 m pillars will be contemplated.

Continuous cutting and bolting is becoming the standard in Australian mines. The benefits of this class of machines were theoretically approximated and proven by results from the benchmarking survey: Mines which are using this type of system can achieve a significantly higher advance rate, if properly implemented.

Continuous haulage systems are not yet completely compatible with present development practices. Under current circumstances, the full potential of these systems can not be utilized. Through research more sophisticated and customized solutions which fit in the narrow requirements of a two-entry system should be developed.

As well, by technological means, heat problems in the summer can be overcome. Decentralized cooling systems appear feasible in deep and/or large mines in Central Queensland.

In all cycles improvements can be achieved by organisation and/or technology. Above average performers were identified by superior organisation and management rather than different equipment.

Observations included: The construction of plane and dry roads outby is important for the supply of the panel with different resources. For the face cycle and the pillar cycle the inbye roads where the shuttle car is wheeling are the main concern. Water inflow has to be kept at a minimum, pumps have to be installed close to the water sources to protect the road and mud has to be disposed before its formation. This effort is worth the trouble: It makes most of the other processes faster and easier, protects the equipment, and keeps the safety and worker motivation higher

Within the panel extension there is a large amount of potential improvement. Some mines are able to complete all tasks within less than one shift – others must interrupt production for up to five shifts. Clear concepts of standard area methods (SAM) guarantee the quality of the workings. A good organisation avoids delays caused by lack of material, equipment or other resources. A proper preparation which permits a high level of parallelisation minimizes the panel extension time, which is termed within this study as downtime.

The mapping of tasks and resources with planning tools such as gantt charts assist the development engineer in optimizing the process. The outcomes and procedures have to be translated in concise and clear language for the miners and tradesmen in the panel. Feedback in both directions is essential for successful and sustainable process improvements.

New advances in mining technology promise more efficient roadway development, such as: A automated surge and bolting car designed to accelerate development within the panel; surface to in-seam drilling technology intended to abbreviate the panel cycle by pre-degassing the seam. In the future, auger systems may potentiate a significant reduction of crosscuts. If these technical innovations will materialize remains to be seen.

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Resources

For printed **B**ooks or Reports the syntax
[**B**_*Year of Issue_First 3 Characters of the Surname*] is used.

For Conference **P**apers the syntax
[**P**_*Year of Issue_First 3 Characters of the Surname*] is used.

For **I**nternet Documents the syntax
[**I**_ *Year of Issue _3 describing Characters*] is used.

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Meetings

For **M**eetings the syntax [**M**_*Number_First 3 Characters of the Surname*] is used.

No	Name	Location, Date, Topic
01	**LAUTSCH, THOMAS** General Manager Mining RAG Australia Coal	
02	**BRERETON, DAVID** PhD Professor and Director Centre for Social Responsibility in Mining - University of Queensland	
03	**LEVER, PAUL** Professor and CEO at CMTE Cooperative Research Centre for Mining and Technology & Equipment. The University of Queensland. Experimental Mine	
04	**KELLY, MICHAEL** Group Leader Mine Engineering CSIRO Exploration and Mining	
05	**CUNNINGHAM, JOCK** Group Leader Mining Automation CSIRO Exploration and Mining	
06	**HOOKHAM, MARIAN** Editor Australian Longwalls (Aspermont Limited)	
07	**ROBERTSON, BRUCE** Chief Mining Engineer Underground Anglo Coal Australia Pty Ltd	
08	**MITCHELL, GUY W** Manager Underground Strategy and Development. BMA (BHPBilliton Mitsubishi Alliance)	
09	**BLIGNAUT, JOHN** Vice Mine Manager	

	Southern Colliery of German Creek Mine - Capcoal/Anglo Coal	
10	**ALDERSON, ANDREW** Area Sales Manager JOY Mining Machinery	
11	**BRISBANE, PETER** Underground Mine Planning Manager -Underground Strategy & Development Group BHP Billiton Mitsubishi Alliance	
12	**COLES, CAMERON** Graduate Geologist Moranbah North Mine Anglo Coal	
13	**MONAGHAM, ANDREW** Mining Engineer North Goonyella Mine	
14	**MIFFLIN, ANDY** Underground Operations Manager MIM - Oaky Creek Coal	
15	**DAWES, STEPHEN** Mining Engineer Newstan Colliery	
16	**MELROSE, ROWAN** Managing Director VA Eimco Australia Pty. Limited	
17	**WRIGHT, BARRY** Business Line Manager VA VA Eimco Australia Pty. Limited	
19	**SEEAR, PETER** Director of Cutting Edge	

	Technology Pty. Ltd.	
20	**HOOD, DR. MICHAEL** Head of Department. Chief Executive Officer of CMTE	

Contacts List

For eMail **C**ontacts etc. the syntax [**C**_*Number_First 3 Characters of the Surname*] is used.

No	Name	Topic
01	**STEWARD, CHRISTOHER** Sr. Engineer. CM Development Joy Mining Machinery Co. UK	
02	**CRAM, KEN** Coal Statistics - Coal Services Pty Limited	
03	**NEUPER, REINHARD** Voest Alpine Bergtechnik, Austria	

Figures

Tables