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SIMULATION OF DEVELOPMENT IN LONGWALL COAL MINES

Mehmet S Kizil, Alex McAllister and Robert Pascoe

ABSTRACT: Longwall equipment has been constantly developed and has experienced improvements in cost, efficiency and production. The effect of improvements to overall longwall capacity has put an increasing strain on development operations. Development lag causes issues within mining operations and there are substantial flow-on costs, including higher unit costs, lower production and impacts to market relations. Longwall development processes and the factors that affect productivity are examined. A development program that could be used to simulate the advance of development and production in a longwall coal mine is described. With this tool, it is hoped that mine management can effectively and efficiently respond to changes in mining conditions and combat development lag. Additionally, the simulation package can be used as an educational and demonstration tool.

The main feature of the program is to be able to accommodate differences in advance rates through the development and production panels and hence calculate and simulate a total time for both. The program allows the accommodation of changes in mining conditions as they are experienced.

INTRODUCTION

A significant amount of development is needed before longwall equipment can be moved into the next panel in the sequence and therefore the timing of development to coincide with the end of panel production is vital. In the event that the next panel in the mining-sequence is not ready for the longwall equipment to be relocated, significant amounts of money can be lost as production equipment remains idle. This problem has been exacerbated in recent years with greater developments made to longwall productivity over improvements to the Continuous Miners (CM) used in development and consequently development has become the weakest link in the mining cycle (Misra, 1996). Norwest (2008) expressed the magnitude of the problem with the following statement: *"The number one issue affecting the future of longwall mining is continuous miner development".*

Understanding the progression of roadway development is vital in the planning and management of an active mine. An easy-to-use tool that can simulate, assess and show the impact of changing mining conditions would enable mine management to initiate strategies to deal with projected longwall stand. Also, an easy-to-use simulation package acts as a valuable teaching and demonstration tool within the mining industry. The previous version of the software which was developed within Microsoft Excel (Barker and Kizil, 2009) received interest from industry personnel and hence, further development was the focus of research.

Longwall equipment has been constantly developed and has experienced improvements in cost, efficiency and production. The effect of improvements to overall longwall capacity has put an increasing strain on development operations, with the consequent development lag causing problems for mining operations. There are substantial flow-on costs which result from development lag, including higher unit costs, lower production and impacts to market relations. It has been suggested (Barker and Kizil, 2009) that a development unit can remain well ahead of longwall production as a result of the efficient use of hardware, personnel, supply logistics, planning and scheduling.

The simulation focuses on the key activities that occur in the development sequence in order to help provide an accurate recreation of the pillar cycle process. Several common sequence steps were identified when mining a standard gateroad pillar. Optimal time frames were recorded for completing each task within the sequence plan. With the tool, it is hoped that mine management can effectively and efficiently respond to changes in mining conditions and combat development lag. Additionally, as an easy to use simulation package it can be used as an educational and demonstration tool.

Roadway development at a Northern Queensland mine was monitored to provide primary and secondary data for the project. Comprehensive research of the standard panel and pillar sequence plan was conducted to identify the inherent delays associated with the method. This information provided a basis

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for designing a super panel configuration and sequence plan. Major risks and hazards within roadway development will need to be identified and accounted for to allow for safe cycle design. Development of a basic super panel layout has been performed to provide enough information to design a super panel sequence plan for the Australian mining industry.

ROADWAY DEVELOPMENT

Roadway development in longwall mining involves creating roadways or headings to the longwall panel to provide ventilation, power and services to the longwall operations. The development unit is considered a cost centre. This demands that roadway development occurs as efficiently and effectively as possible. Australian roadway development generally utilises two heading gateroads. These headings are driven using the in place method.

The standard panel method is the most commonly used method for roadway development within the Australian coal mining industry. The standard or conventional method will be defined as the driveage of both headings in a gateroad, using one continuous miner, shuttle car, auxiliary fan and boot end. Current Australian development methods and practices are becoming outdated. The term discontinuous mining refers to the period of planned nil production currently experienced in development pillar cycles. Gibson (2005) suggests that the current mining methods in both standard development and super panel development are discontinuous

Rapid roadway development

The Rapid Roadway Development (RRD) system was formulated to increase gateroad development rates, ensuring longwall continuity, and hence maintain a reliable supply of coal to consumers (Kelly, *et al.,* 2000). Gibson (2005) identified that the cyclic, stop-start nature of current development methods was seen to be a limit to development rates. Especially when haulage distances exceeded 70 m. The following solutions were put forward to counteract this (Kelly, 1999):

- An integrated development system concept;
- Monorail continuous haulage; and
- Monorail mounted services to speed up panel moves and reduce manual handling.

Kelly (1999) found that the solutions mentioned above were not as effective as first expected due to the lack of methodology in project management where these processes were occurring. It was found that partial gains could be made from continuous haulage, but significant gains could be achieved through improving current development processes. Of particular importance was the time constraint recorded when advancing conveyer and panel services whilst employing dual continuous miners in a two heading development, more commonly known as a super panel (Gibson, 2005). A lot of the flexibility of a standard panel unit is removed when running a super panel unit, increasing the duration of panel moves from 27 to 36 hrs. This suggests that there are problems with the super panel method and that improvements can be made.

It has been identified that a benchmarking process is needed across industry to let individual operations pinpoint the time constraints in their operation. One way to achieve this is to incorporate programs such as UCDelay, which categorises an operation's generic delays. This allows mines to standardise their delay categories which will allow for benchmarking across the industry (Porter, Baafi and Boyd, 2010).

CLASSIFYING AND IDENTIFYING DEVELOPMENT TIME CONSTRAINTS

Data was sourced from the selected Northern Queensland operation. Daily, weekly and monthly production reports were compiled using Microsoft Excel. This allowed for the breakdown of work in development units which comprise the total available time of a development panel. It was decided not to collect or analyse outbye panel data as these delays are not recorded as development delays. The data analysed was sourced over 2009. This year was selected because it was the most current data with a full year of production statistics.

Development delay classification

In a mining operation a delay is any event that holds up production or prevents mining equipment operating under standard conditions. These delays are identified and categorised in order to find where major time losses are occurring. It is logical that minimising development delays will generally increase overall output and more specifically reduce development pillar cycle times. Delays can be classified as either planned or unplanned. Planned or 'scheduled' delays are process delays required for the safe function of a mining operation. Unplanned or 'unscheduled' delays are generally random in nature and unpredictable (Porter, Baafi and Boyd, 2010).

Figure 1 illustrates calendar time availability for a typical underground longwall operation. There are several elements that need to be identified when reporting delays. These include, the date and time of delay, duration and type of delay, scheduled or unscheduled delays, and which division is responsible for the delay.

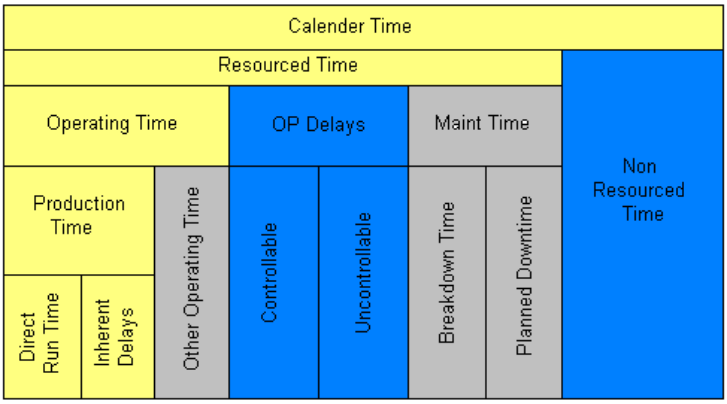

Figure 1 - Breakdown of a development equipment calendar time (Porter, Baafi and Boyd, 2010)

Time breakdown

The overall productivity of a mine is highly influenced by development delays. In order to quantify this it is necessary to identify where and how much an operations resourced time is allocated. Figure 2 provides a breakdown of the production summary for 2009. It is evident that development delays (37%) occupy a significant portion of the production summary, almost as much time as actual production (39%). The major external delay units are the outbye panel and outbye conveyer units. Planned maintenance time also falls under resourced time. The remaining section of the production summary is unscheduled or non-resourced time.

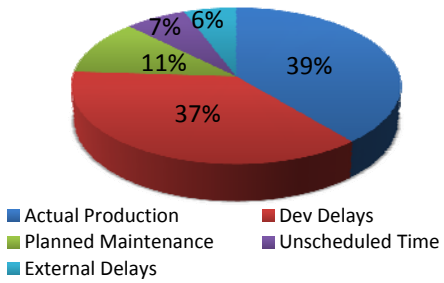

Figure 2 - Production summary breakdown

In order to improve delays associated with development units, a focus on the serial productive units within resourced time is required. A serial productive unit can be defined as one process chain in the development unit that has a potential flow-on effect to another process If a piece of equipment or part of the process stops the development operation, the delay will be recorded against that piece of equipment or part of the process. The remaining affected equipment will be recorded as idle. This method aids in understanding where production losses are occurring in a pillar cycle by pinpointing the equipment or partial processes that are not running efficiently and/or effectively. Six units were recognised as the major

delay causes in roadway development. Each unit is comprised of individual delays, which combine to calculate the total delay time for each unit.

Figure 3 identifies the total delay time for each major unit for 2009. The development unit delays recorded are quite significant. The total delay time of 142 days only leaves 201 days available for productivity under resourced time. One particular delay may take up a large period of scheduled time. This does not particularly suggest that the delay is a common problem to development over a long period of time. Such an example would be delays experienced due to inrush from a 1 in 100 year event. This may take up a substantial amount of time but it is not frequent. Therefore it is important to consider the frequency of delays that are affecting the development panel. Figure 4 provides a breakdown of the frequency of major individual delays affecting the development panel in 2009. These delays are not restricted to one development unit. These types of delays need to be focused on to improve current super panel design. Panel delays occur when performing standard panel activities or processes within roadway development.

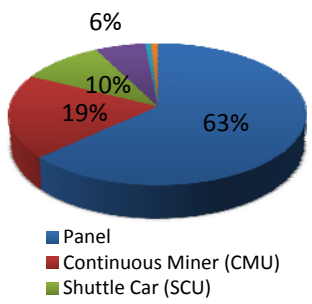

Figure 3 - Total development unit delays for 2009

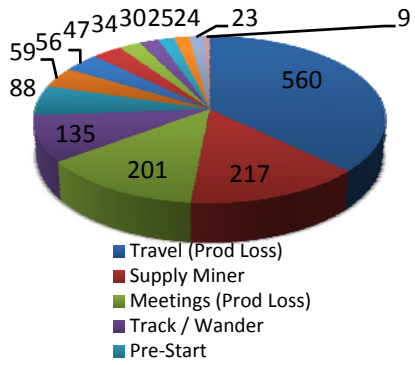

Figure 4 - Total development unit delays for 2009

Super panel delays

What differentiates the super panel method from the single panel method in terms of delay recording is the classification of the super panel as a dual productive unit. A dual productive unit can be defined as a process or piece(s) of equipment where more than one primary productive unit is being used concurrently. It is possible to have more than one primary productive unit in what would normally be considered a single process, such as using two continuous miners in the panel. Each unit is tracked separately in order to classify delays correctly.

The super panel configuration allows for parallel or multiple production paths that enable continued production at a reduced capacity when parts are shut down. For example, if one continuous miner is shut down both shuttle cars are available to transport coal from the other continuous miner. These multiple sub processes have an effect on design and layout of the super panel. Delays that were noted to affect super panel performance were water control, supply miner, flooding, road maintenance, bogged, trip/reset/overload, supply/ trailing cable, transformer move, and process ventilation work. Some of the major delays recorded in a standard panel were omitted when classifying delays for a super panel. This was not because these delays do not occur in a super panel, just that these delays are not particularly relevant in developing the layout and sequence plan of a super panel. As longwall production is improving linearly, development output needs to increase yearly. Sensitivity to time is high and an idle longwall results in the under-utilisation of a very expensive asset. The layout of a super panel was designed to aid in the design of a sequence panel.

Super panel layout

A generic layout of a super panel was designed to improve the super panel method. Fundamentally the super panel layout aimed to:

- Ensure the highest level of personnel safety in the panel;
- Prevent unplanned and process delays;
- Improve the ease of operations by providing a consistent work flow; and
- Minimise equipment damage.

The option with the most significant performance was the premium panel. This method used the same equipment layout as the super panel, with one alternating crew operating both continuous miners as per the sequence plan. Although the cutting rate was lower, the one pillar cycle using the premium panel was completed 43 h faster than the super panel. This method is suited to most operations and has the capacity to be incorporated to any operation over time.

Super panel pillar sequence

Figure 5 illustrates the steps involved in completing a pillar sequence for a super panel. As both continuous miners are running concurrently, the majority of required tasks, needed to complete a pillar sequence, run in parallel. Each step of the sequence drives approximately 20 m of roadway. By breaking the pillar cycle up into smaller steps it is easier to ensure all tasks are completed.

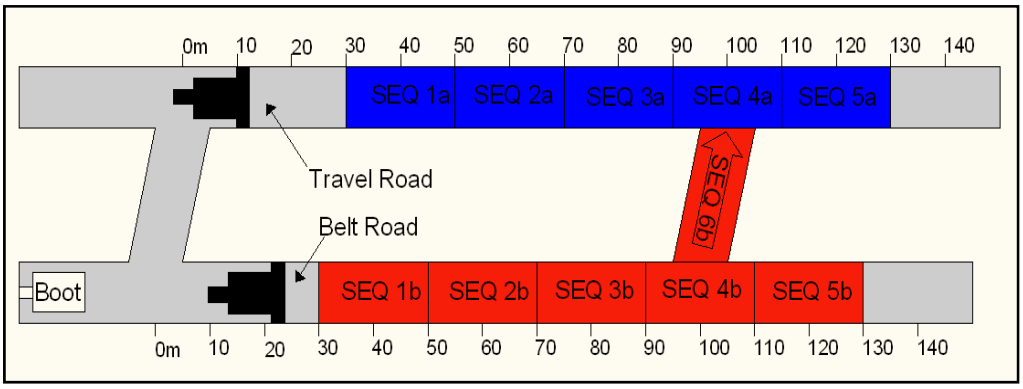

Figure 5 - Super panel sequence plan

Panel options

A study at a mine in the Hunter Basin revealed that there are similar panel methods that yield high metres per cycle and high cutting rates. Table 1 shows the panel performance of each method trialled.

Table 1 - Cycle performances for development methods

Method	100 m Cycle (days)	Metres Per Cycle	Cut Rate (m/h)	Panel Advance (h)
Standard Panel	6.4	230	4	17.6
Super Panel	4.6	236	5.7	25.7
Premium Panel	3.7	236	5.5	18.5

SIMULATION PROGRAM

A relatively *"straight-forward"* simulation program has been developed for non-technical personnel for the front-line analysis of changes in mining conditions. Given that the first version of the package (Barker and Kizil, 2009) was built around a Microsoft Excel framework, it was decided that a stand-alone package built within the VB.Net framework would better withstand the rigors of the mining industry.

The simulation was created to continue the research performed by Barker and Kizil (2009). The objectives of the simulation were to:

- Quickly determine development float/longwall stand time given the appropriate input parameters;
- Assess the impact of changing mining rates or operating time;
- Determine the effects of changing mining parameters such as longwall block length, cut-through length and longwall face length;
- Estimate the financial outputs given input parameters;
- Clearly show/teach the impacts of altering various mining parameters on the mine schedule to crews, students and non-mining personnel;

- Calculate total advance rates as a result of geological input conditions defined by domain; and
- Utilise user-friendly input and operation menus.

The simulation can therefore be used as an effective tool to quantify the impact of changes in advance rates due to either alterations in efficiencies or geotechnical conditions. Additionally, given the fast and efficient nature of the software, the program can help in making decisions regarding the allocation of mining resources, manning requirements and the impact of changes in production/development efficiencies. The main control screen of the simulation can be seen in Figure 6.

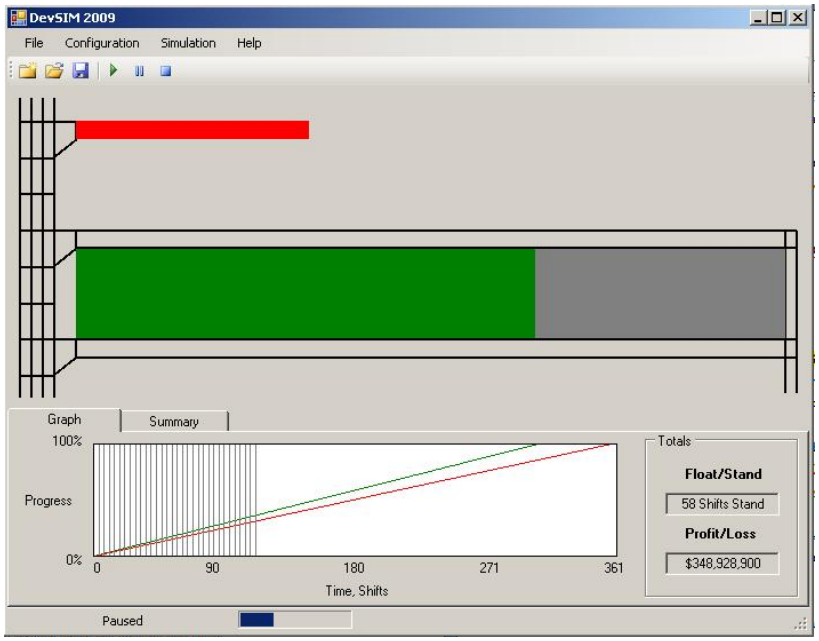

Figure 6 - The main DevSIM control screen showing both simulations in progress

Configuration

The longwall and development configuration shown are broken into three separate tabs: dimensions, performance and financial. The configuration windows were given this arrangement to minimise perceived complexity and to also minimise the amount of screen real-estate used, to account for the use of low resolution monitors.

While the input fields in the 'dimensions' tabs are specific to either the longwall or development input windows, the *'performance'* and *'financial'* tabs for both are exactly the same; the performance and dimension tabs can be seen in Figure 7. Changes to the parameters in each of the tabs have a direct affect on the values in the lower *'summary'* portion of the window, acting as an effective KPI calculator.

The biggest update to the research performed by Baker and Kizil (2009), apart from moving the simulation to the VB.Net framework was the addition of the facility to delineate areas within the longwall or development panels that experience different rates of advance to the default set for the respective panel. The *'advanced performance configuration'* button within the *'performance'* tab of the configuration window for longwall and development will open the *'advanced configuration'* window. The advanced configuration window allows the user to define the metres per operating hour, start and end position of areas within the panel with a non-standard advance rate. When attributing an advance rate to a section of the panel, the program works downward through the recorded section. Given this downward progression of parameters, if the first section in the list delineated an area starting at 100 m and ending at 400 m whilst the second section in the list delineated a section starting at 150 m and ending at 200 m; there would be effectively three delineated sections between the 100 and 400 m marks. If however, the order of these sections were reversed, the advance rate for the 100 to 400 m section would be attributed to the whole area.

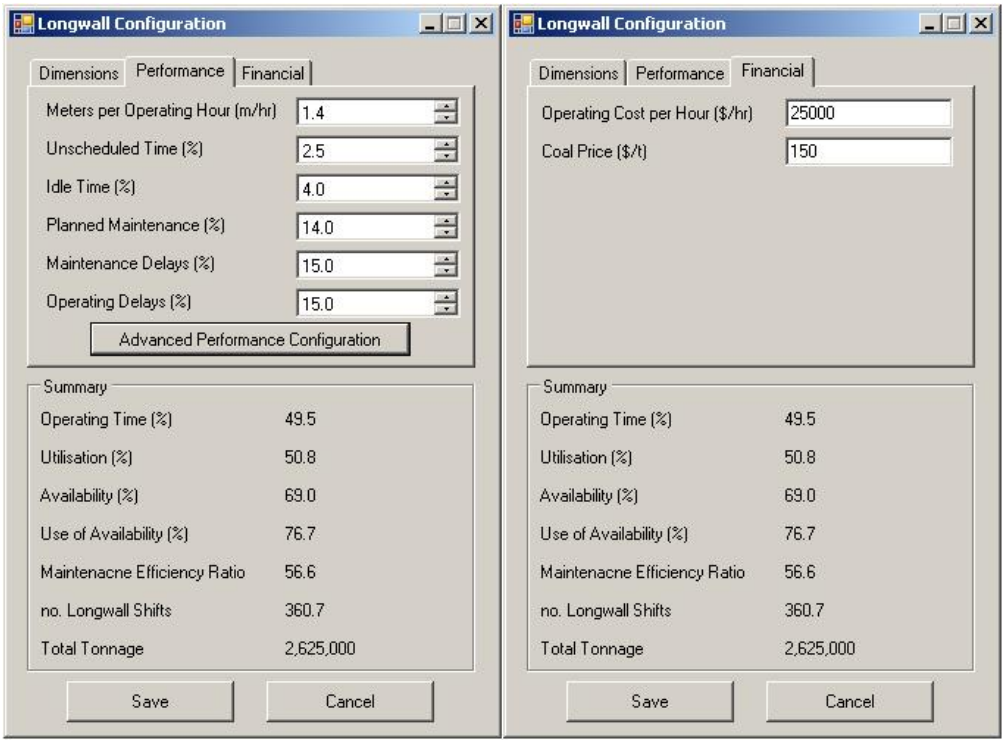

Figure 7 - Longwall performance and configuration tabs

Deficiencies

The simulation program is still in the development and improvement stage and therefore still has a number of deficiencies. The first of these deficiencies is due to the software not taking changes in operating efficiencies into account across different advance domains. The impact of changes in operating efficiencies through harder or more abrasive areas of advance would enable the software to better simulate the behaviour of a development of production panel as a whole. The program needs to deal with variations in mining conditions across two development headings within the same section of development panel. Currently, the latest version of the simulation package does not accommodate this variation.

CONCLUSIONS

It has been established that the biggest factor affecting increases in longwall performance is ensuring that development and preparation of the following panel coincides with the end of panel production. Managing panel development can prove difficult, as there are many factors to consider when estimating development advance and compliance with schedule and budget.

From the case study conducted, it was found that the important delays affecting roadway development were unplanned and process delays associated with travel times, flooding, water control and supplying the continuous miner. These delays were both frequent in occurrence and long in duration. By implementing the defined super panel sequence operations have a basis to work off for future gateroad development when development is struggling to produce an adequate longwall float.

The development of a longwall development simulation program is discussed. It is important to understand all of the factors that affect longwall and development advance. As development cutting rate and support regimes are directly influenced by the geological domain, it makes sense to suggest that development rates could be correlated to *'development domains'* within the coal seam. This idea of course depends on mining and installation of support being the limiting factor in the development process.

The longwall development simulation program with the incorporation of variable advance rates mapped to geological and support domains should provide a useful frontline tool for use in longwall coal operations.

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