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Shuttle car network for roadway development

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Abstract

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One of the major delays assoicated with roadway development is caused by the shuttle car due to its cyclic stop-start nature. Shuttle car travelling paths and machine interactions are normally constraint by the mine's roadway layout and mine safety issues. This paper presents simulations of shuttle car route operations which can be considered at the design stage to minimize the cycle time of a shuttle car as part of a general roadway developemnt simulation model developed using 3D flexsim.

Keywords

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Disciplines

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SHUTTLE CAR NETWORK MODEL FOR ROADWAY DEVELOPMENT

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ABSTRACT

Australian underground coal mines predominately use the longwall method for coal extraction. In longwall mining at least two parallel roadways known as gateroads are mined to delineate the sides of the longwall block, a longwall installation face is then driven connecting the gateroads to enable the longwall mining equipment to be installed. Roadway development should ideally be ahead of the longwall so that the longwall equipment can be installed into the newly developed panel with minimal delay to coal production. A discrete event model of roadway development can help assess how a particular configuration may perform with high levels of variability and uncertainty in operations.

One of the major delays associated with roadway development is caused by the shuttle car due to its cyclic stop-start nature. Shuttle car travelling paths and machine interactions are normally constraint by the mine's roadway layout and mine safety issues. This paper presents simulations of shuttle car route options which can be considered at the design stage to minimize the cycle time of a shuttle car as part of a general roadway development simulation model developed using 3D Flexsim.

INTRODUCTION

Before the extraction of a longwall panel can commence, a series of headings around the longwall panel need to be developed. Commonly known as roadways or gateroads, these headings form the mine ventilation passages and provide access paths for personal, machinery and supplies. The roadways which provide access from the mine entrance to the longwalls are commonly referred to as the main headings. Once the main headings have been established development gateroads are driven on both sides of the longwall panel. When two or more gateroads are driven on one side of the longwall block, they are connected by cut-throughs every 100 m or so. Figure 1 shows a typical longwall panel with the common terminologies.

The roadways are formed by a Continuous Miner (CM) cutting the coal with its cutter drum (Figure 2a). The CM has an internal conveyance system which moves the coal from under its drum to the back of its tail and directly onto a Shuttle Car (SC) (Figure 2b). A shuttle car is generally positioned behind the continuous miner and hauls the coal from the development face onto a breaker/feeder. The breaker/feeder receives the coal from shuttle car, resizes it and evenly loads the coal into the Boot End (BE) (Figure 2c). The BE is basically the in bye end of the main conveyor belt with the last belt roller bolted down to the floor. Bolting rigs on the continuous miner are normally used to provide support to the ribs and roof of the excavated roadway with mesh and roof/rib bolts.

After discharging the coal into a breaker feeder at the BE, the SC and then returns to the CM for the next load. The SC is commonly powered by electricity through a cable linked between the SC and a hook anchored to the side of the roadway. The operating reach of the SC is determined by the maximum amount of cable which can be accommodated on the shuttle cars cable reel drum, usually about 150 m. Where two shuttle cars are used to convey coal from the development face, one SC usually has its cable reel on the left side and the other on the right side. The SCs cannot pass one another in the heading, because of the restricted roadway cross-sectional area and also to avoid the tangling of the cables but have to wait for one and other at a specific location, usually near the intersection of a cut-through. This paper presents a roadway development simulation model with options to evaluate various routes of shuttle cars that can be used to minimize the shuttle car travelling time.

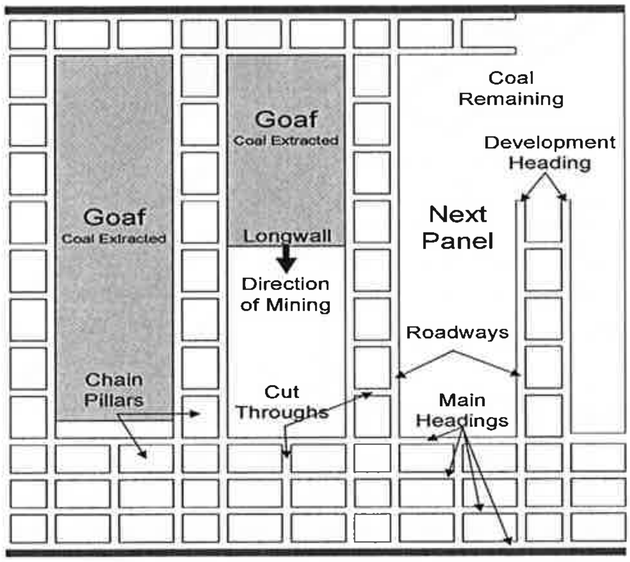
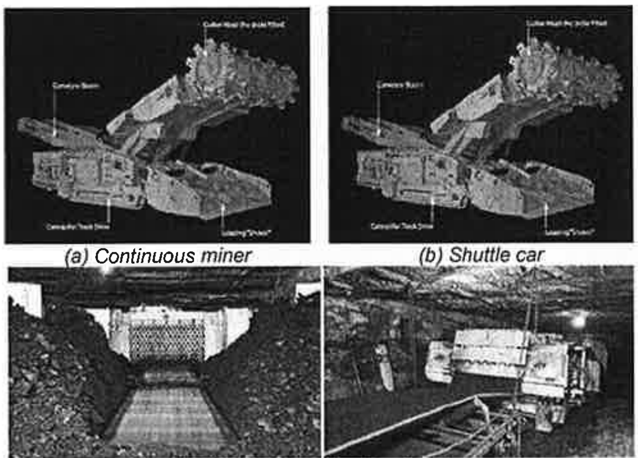


Figure 1. A typical longwall panel with the commonly used terminologies.



(a) Continuous miner *(b) Shuttle car*

(c) Bootend and Breaker Feeder

Figure 2. Main equipment used in roadway development (Joy Mining Machinery).

FLEXSIM SIMULATION MODEL

A general purpose roadway development model has been developed, using 3D Flexsim simulation software, to map the roadway development process including:

- coal cutting and loading by a continuous miner (CM);
- primary roof and rib support with continuous miner mounted rigs;
- coal haulage from the face to the BE by shuttle car (SC);
- conveyor boot end relocations and panel advances;
- operational downtimes and delays:
- multiple headings, figure 3 illustrates a three heading set-up, but two, three or more headings can be configured within the model.

The simulation model is restricted to Australian roadway development practices with options to handle 1 CM with 1 SC, 1 CM with 2 SCs, 2 CMs with 2 SCs and a continuous haulage system instead of shuttle cars.

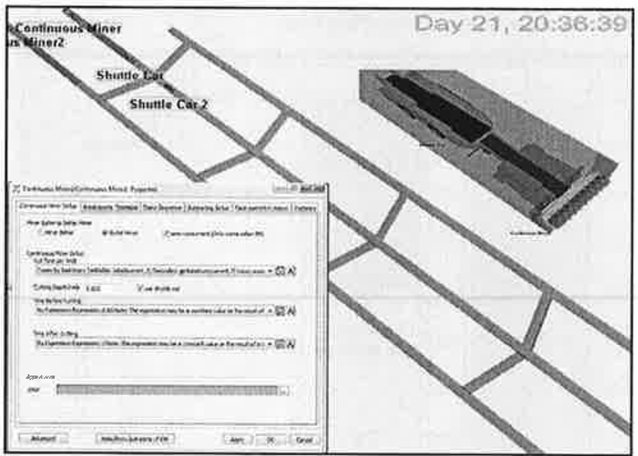


Figure 3. 3D view of the basic Flexsim simulation model.

The SC travelling distance not only changes as the heading advances but also the travelling time along a pillar depends on the pillar size. For modeling purposes, the possible routes for the SC are divided into two main parts as shown in Figure 4 by the dotted line for a two heading development. The "CM part" refers to the SC route is to the right of the dotted line while "BE part" is to the left of the dotted line.

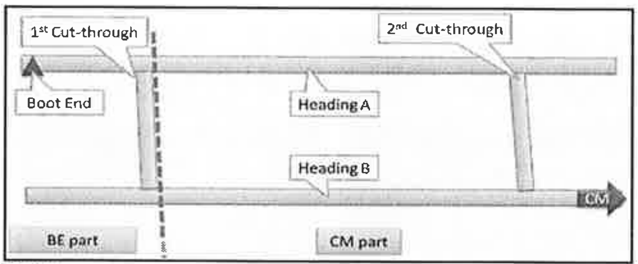


Figure 4. The two parts of SC travelling routes.

The continuous miner can be operating in various locations within the development. For the scenario shown in Figure 5 (a multi-heading development), the CM could be in the heading shown in Figure 5(I), in the right hand side (RHS) cut-through shown in Figure 5(II) or in the left hand side (LHS) cut-through shown in Figure 5(III). When the CM is in a development heading, the SC travels directly to the CM's location. But when it is in the cut-through, the SC travels a full pillar length before travelling to the CM's location.

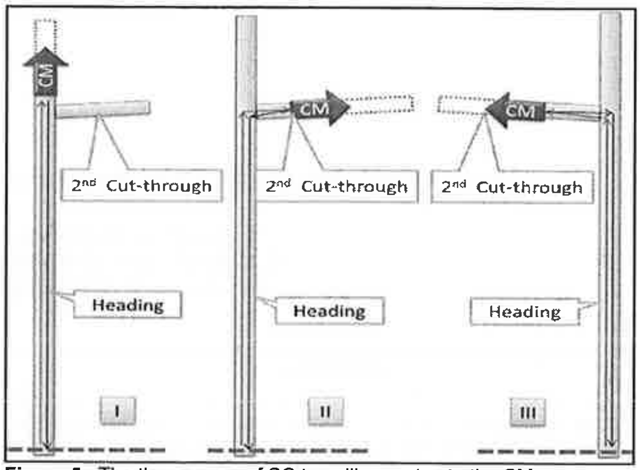
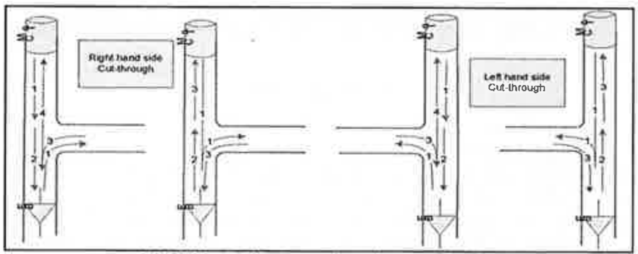


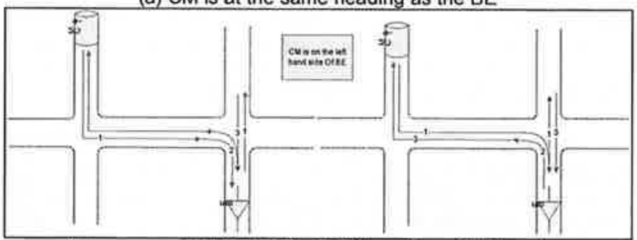
Figure 5. The three cases of SC travelling routes to the CM.

Figure 6 shows the SC tramming routes with a single CM. Where there is a single SC, the SC follows the red routes only; where there are two SCs, the first SC follows the red routes while the second SC follows the blue routes.

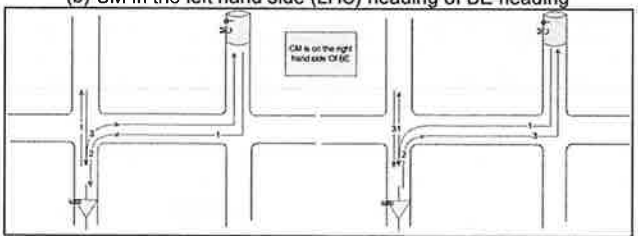
As shown in Figure 6, the routes are divided into several steps. The same number on a route means the two SCs would practically start travelling at the same time. In between steps, the SC either stops for the other SC or communicates with the other SC before moving. For example, SC1 (the red routes) must check whether the BE is occupied before entering the BE area, otherwise it must stop and wait for SC2 to leave the BE.



(a) CM is at the same heading as the BE



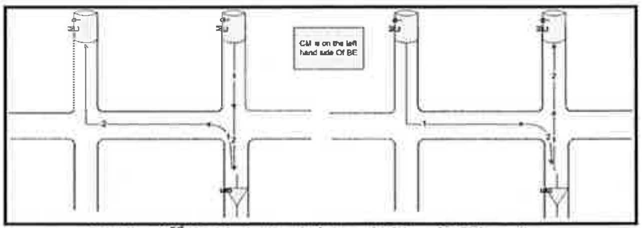
(b) CM in the left hand side (LHS) heading of BE heading



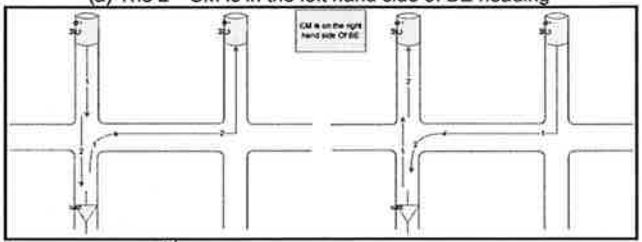
(c) CM in the RHS heading of BE heading

Figure 6. SCs travelling routes with a single CM.

Figure 7 shows similar routes of SCs when using two CMs. Once again, the two SCs must check whether the BE is occupied before entering the BE area.



(a) The 2nd CM is in the left hand side of BE heading



(b) The 2nd CM is in the right hand side of BE heading

Figure 7. SC travelling routes when 2 CMs are operating.

The following five Flexsim task types are used to define the SC tasks using Flexscript:

- TASKTYPE_FRLOAD: This task type loads coal from CM to SC.
- TASKTYPE_FRUNLOAD: This task type unloads coal from SC to BE.
- TASKTYPE_TRAVELTOLOC: This task type initiates SC to travel to a specified location.
- TASKTYPE_SETNODENUM: This task type sets a node value. This is used to change the SC direction when the SC enters a cut-through from a heading or enters a heading from a cut-through.
- TASKTYPE_SENDMESSAGE: This task type sends a message between SCs.

THE FINAL MODEL AND CASE STUDIES

The completed objects including CM, SC, BE and roadway layout with prewritten script, were then added into a user library as a reusable library object by the drag and drop method (Figure 8). To use a SC to service a CM, involves dragging it from the library and dropping it into the 3D view, centre connecting it with the CM, and checking the option "use shuttle car" on the customized GUI of the CM.

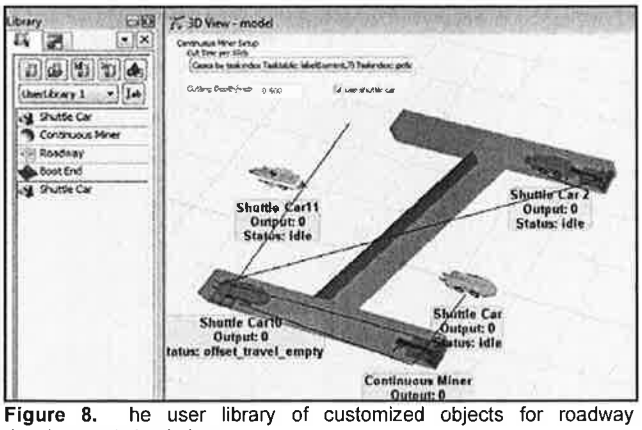


Figure 8. he user library of customized objects for roadway development simulation

Figure 9 shows four scenarios using different haulage strategies.

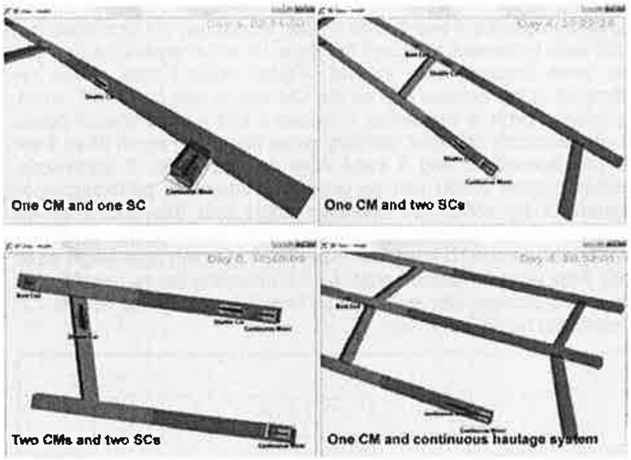


Figure 9. The scenarios of using different haulage strategies.

The developed model was then validated using data collected from two Australian coal mines (Porter, 2010). A typical two heading roadway development using different haulage strategies was studied using the model. The mine parameters were as follows:

- Roadway Dimensions: W=5 m H=3 m
- Pillar Dimensions: L=110 m W=40 m
- Boot End to Cut through = 20 m
- Over drive length = 20 m
- Length of gas drainage stub = 5 m
- Overdrive = 20 m
- Support Density: 6 roof bolts and 4 rib bolts per m advance
- Average time per web = 1.5 minutes
- Average time before cutting = 0.33 minutes
- Average time after cutting = 0.5 minutes
- Average time of double pass bolts = 3 minutes
- Average time of single pass bolts = 1.88 minutes
- Average time to relocate the miner to a different heading = 20 minutes
- Average time of panel advance delay = 22 hours

In order to study the impact of support installation and coal transportation only on the development rate, the face operational delays, breakdown time and shift schedule were removed from the configuration of the model, as they add unnecessary (for this analysis) fluctuation to the results. The simulation time were recorded automatically every 5 meters advance. The total operating hours to complete 5 pillars of the different scenarios are shown in Table 1.

Table 1. The operating hours for 8 different scenarios simulated by the model.

Scenario	Miner Type	Number of Bolting Rigs	Type of Bolts	Haulage Type	Total Operating Hours (5 pillars)
1	Miner Bolter	2	Double pass	1 SC	568
2	Miner Bolter	4	Double pass	1 SC	490
3	Bolter Miner	4	Double pass	1 SC	461
4	Bolter Miner	4	Single pass	1 SC	461
5	Bolter Miner	4	Double pass	2 SCs	410
6	Bolter Miner	4	Single pass	2 SCs	405
7	Bolter Miner	4	Double pass	CHS	366
8	Bolter Miner	4	Single pass	CHS	293

From Table 1, an additional two bolting rigs on the miner bolter (bolting and cutting in series) can improve the development time by 78 operating hours when comparing Scenario 1 and 2. A bolter miner (bolting and cutting are in parallel) can reduce development time by a further 30 operating hours from a miner bolter when other parameters remain the same. However, double pass or single pass bolts make no difference to the overall performance comparing Scenarios 3 and 4, and also Scenarios 5 and 6. The reason is because the coal transport is the main bottleneck as shown in Figure 10, which shows the process rate verse distance from the BE. Faster support time makes no difference to the process rate as the CM has to wait for the SC when the support cycle is completed. Scenario 3 and 4 trend lines in figure 10 are practically identical; similarly when the CM is about 55 m from the BE, Scenario 5 and 6 trend lines are the same. A continuous haulage system (CHS) can be used to improve the performance of Scenario 3 by about 100 operating hours and Scenario 5 by 44 operating hours. However, the support cycle becomes the constraint with a CHS, as can be seen from Scenario 8 in which case single pass bolts help with the performance by 73 operating hours, resulting in about 30% process rate improvement from 5.1 m/operating hour to 7.2 m/operating hour (Figure 10).

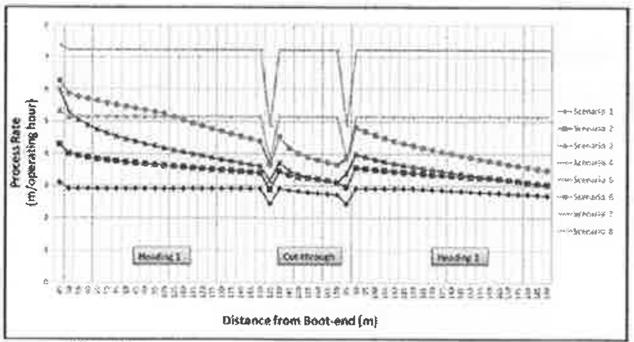


Figure 10. The process rate verse distance from boot-end simulated by the model.

CONCLUDING REMARKS

A roadway development model has been developed using Flexsim, considering the complexity of SC haulage strategies and interactions. The object oriented method offers simple-to-use, standardized roadway development objects for performing particular operations on input data. The model provides a "what if" tool thus allowing a range of equipment configurations, operating practices and mine layouts to be assessed in terms of achievable roadway development as well as equipment utilization. The case studies showed that the model is capable of simulating the haulage options of Australian roadway development practice and helps to highlight the bottlenecks.

REFERENCE

Porter, I., Baafi, E. Y. and Boyd, M. J., Underground Roadway Development Delays, Published in the Proceedings of Third International Symposium Mineral Resources and Mine Development, pp 321-331, 2010.