GPSS COMPUTER SIMULATION OF PROPOSED UNDERGROUND REAR DUMP TRUCK ORE HAULAGE SYSTEM AT ZC MINES, BROKEN HILL

By

John Harrison, Managing Director, Australian Mining Consultants Pty Ltd, and
John R. Sturgul, Professor of Mining Engineering, South Australian Institute of Technology

The investigation was a proposal to replace the present underground train haulage system with rear dump trucks. The number of rear dump trucks required to achieve target output and the required mix of engines and trucks during the changeover was of importance to the designers, and a GPSS computer simulation model of the operation was constructed using GPSS/PC, a recent form of the language for personal computer. Three models were constructed to simulate initial and final configurations of ground haulage systems to transport ore from ore passes to the crusher and then to the skip for transport to the surface. The initial model simulated train operation on two levels and rear dump operation on a third level. The second model simulated rear dump truck operation on two levels and ore being loaded through the crusher to the skip as in the previous case. The third model used rear dump trucks on the lower level with a train to establish the relative merits of methods of transport. The simulations identified equipment numbers, required operating and critical points in the operation which can then be addressed by the mine designers.

The operators of a lead/zinc mine at Broken Hill investigated alternative ground haulage methods to the current rail system. As part of this investigation new simulation models were developed to test in determining the most effective method.

New simulation models have a great number of applications for a mine. They can be used to determine the optimum number of trucks (Bauer, 1969) or to determine the optimum size of inpit crushers (Sturgul, 1987) to suit a few examples. Several computer simulation languages are available but the one used appears best suited for mining operations and was used for these studies is (General Purpose Simulation System). A version of this, known as GPSS/PC is available on personal computers running under MS (or PC) version of the GPSS language

In this study three GPSS models were developed to assist in determining the best methodology for transporting ore from the ore passes to the skip.

The methods were:

- Trains on 19 and 21 levels and trucks on 22 level
- Trucks on 22 and 24 levels, and
- Trucks on 22 level and trains on 24 level

The proposed layouts are shown in figures 1 and 2.

The basic time unit for each simulation was 0.1 minutes and the model simulated 30 days operation or 432,000 time units.

Each model was simulated for 30 days which is approximately 10 percent of a years operation.

DESCRIPTION OF MODELS

The operation of each of the three models is
described with an initial description of parts of the operation common to all models.

Operations common to all simulations

The operation of the skip, crusher and crushed ore storage bin are common to each of the three models.

The crusher operated continuously unless there was no ore in the bin above the crusher or the crushed ore bin was full. No allowance was made for crusher breakdown.

The skip operated continuously and had a 90 percent availability. It would be loaded unless there was less than 15 tonnes of ore in the crushed ore bin. If it was delayed it would wait until there was more than 15 tonnes of ore in the bin then recommence operation.

Shift change and crib

All operations except for the skip and the crusher shut down for 60 minutes at shift change and 30 minutes for crib.

The skip stopped for 30 minutes at shift change and the crusher operated continuously unless there was insufficient ore to crush.

Train operating parameters

The basic parameters for train operation are:
- travel speed 2.5 m/sec
- acceleration and deceleration time 15 sec/cycle
- loading time 2 minutes per truck
- dumping time 1.5 minutes per train
- train load 100 tonnes

The travel times to and from each of the ore passes were determined using these parameters and then a variability factor was introduced into the model so that trains did not operate on a fixed cycle time but one which varied about a mean time.

It should be noted that train operation in these models assumed improved loading and unloading procedures for trains and that truck and train operation were not directly comparable. For example a 100 tonne train loaded in 16 minutes and dumped in 1.5 minutes whereas a 35 tonne truck loaded in 12 minutes and dumped in 1.5 minutes. This gave a distinct operational advantage to the train system which would be overcome by improved truck loading procedures.

Truck operating parameters

The parameters for truck operation are:
- Maximum travel speed 30 km/h
- Loading time 12 minutes per truck
- Dumping time 1.5 minutes per truck
- Truck load varied between 25 tonnes and 40 tonnes (achieved by a distribution in the model)

Truck cycle times were then determined using these parameters and were then varied about a mean by the model to achieve a more realistic simulation of the operation.

MODEL 1

Trains on 19 and 21 levels and trucks on 22 level

The proposed layout is shown in Figure 1.

This configuration was designed as an interim measure prior to rationalising haulage onto 22 and 24 levels.

The objective in this simulation was to limit the output from the trains to approximately 400,000 to 600,000 tonnes per annum, and supply the balance of the required tonnage from trucks on 22 level.

Each train operated one shift in six to obtain the desired production rate of 400,000 to 600,000 tonnes per annum.

The train on 19 level loaded from ore passes at 1550s and 1350s with a similar number of loads being taken from each pass.

After loading, the train travelled to the storage, where the level of ore in the storage was tested to determine if there was sufficient capacity in the storage for the train load.

If there was sufficient capacity the load was dumped, but if the storage was full the train was held until the storage was partially emptied and able to accept the load.

The train on the 21 level loaded from ore passes at 2100s and 1850s and operated in a similar manner to the train on the 19 level.

Operation of storages

There are three storages above the crusher,
- 19 level to 21 level - 2000t
- 21 level to 22 level - 1000t
- 22 level to crusher - 2000t

The crusher was assumed to operate continuously unless the skip storage bin was full or the storage above the crusher was empty.

Ore was moved continuously through the storage above the crusher but was only moved at crib
time and end of shift from the upper storages.

The mode of operation for the upper storages
was to test the level of the 22 level to
the 21 to 22 level storage if there was
sufficient ore, otherwise the balance was
in the lower storage. Filling to a
maximum of 1900 tonnes left dumping space for
skipping truck operation on 22 level.

Movement of ore from the 19 to 21 level storage
to the 21 to 22 level storage did not occur
when the train was operating on 21 level. As
each train only operated one shift in six this
did not impede operation.

At other times the 21 to 22 level storage was
drilled with ore, or received the balance of the
ore from the 19 to 21 level storage if there was
insufficient ore to fill the storage.

Truck operation

Diesel trucks operated on 22 level and loaded
from ore passes at 1150s, 950s, 450s and 250s
on a continuous shift basis. As a truck
preparation to leave the dump area it checked to
determine which ore pass has been used least
and travelled to that ore pass for loading.

It was assumed that there was room for trucks
to pass at each ore pass but once a truck
entered a drive between ore passes no other
truck could enter that drive.

If a loaded truck and an empty truck arrived at
a section simultaneously the loaded truck had
priority.

In the dumping area there is adequate space for
all trucks to queue prior to unloading.

Interruptions in the operation were queuing at
an ore pass if another truck was loading and
waiting in the dump area if another truck was
dumping or if the storage was full.

Model 1 results

Three simulations were run, firstly with 3
trucks on 22 level and then with 4 and 5
trucks, with 5 trucks achieving optimum
production.

The results of the three simulations are as
follows:

<table>
<thead>
<tr>
<th>Trucks</th>
<th>Skip Tonneage</th>
<th>22 Level</th>
<th>Train 1</th>
<th>Train 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>329,170</td>
<td>256,830</td>
<td>281,430c</td>
<td>281,430c</td>
</tr>
<tr>
<td>4</td>
<td>329,170</td>
<td>256,830</td>
<td>281,430c</td>
<td>281,430c</td>
</tr>
<tr>
<td>5</td>
<td>329,170</td>
<td>256,830</td>
<td>281,430c</td>
<td>281,430c</td>
</tr>
</tbody>
</table>

The simulation showed that the introduction of
each truck above the initial three trucks
produced an additional 25,000 to 27,000 tonnes
of ore. Average queue time for the trucks
waiting to be loaded increased from 6.3 minutes
for 3 trucks to 13.4 minutes for 5 trucks.
This is the reason why there was not a greater
increase in output with the introduction of
additional trucks.

The discrepancy between skip tonnage and the
tonneage hauled by train and truck was due to
ore in the storages.

Model 2

Trucks on 22 and 24 levels

The proposed layout is shown in Figure 2.

This model simulated the operation of trucks on
22 and 24 levels.

The objective of this simulation was to produce
approximately 1.0 Mt/annum of ore from 24 level
in one year and the major production of 1.5
Mt/annum from 22 level.

As trucks left the dumping area the ore pass
which had been least used was selected and the
truck travelled to that ore pass.

Trucks were able to pass at each ore pass but
once a truck was in a section of drive between
ore passes no other truck could enter that section.
If a loaded truck and an unloaded truck arrived at
either end of a section simultaneously the loaded truck took priority.

Trucks could be loaded from any one of nine ore
passes on the 22 level. It was assumed that
only three ore passes would be operating at any
one time. The three ore passes were selected
prior to the operation being simulated.

Trucks could be loaded from any one of three
ore passes on 24 level. It was assumed that
all ore passes would be in continuous
operation.

Operation of 24 level bin and 22 level to

As the 24 level bin has only 150 tonnes of
storage the priority was directed toward
keeping this bin empty and only unloading from
the 22 level storage if it was full, or if the
24 level bin was empty.

If the bin or the upper storage were full
trucks were prevented from unloading.

The mix of trucks on each level was varied to
achieve the ore requirements from 24 level of
approximately 1.0 Mt/annum and 1.5 Mt/annum
from 22 level.

The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong, NSW, April 1988

244.
Figure 1
Initial Configuration

Figure 2
Final Configuration
Model 2 results

A number of preliminary simulations were run which showed that too many trucks on 22 level caused excessive queuing and too many trucks on 24 level led to excessive production from that level.

The final selection was for 3 trucks on 22 level and 2 trucks on 24 level.

With two trucks on 24 level and varying the trucks from 3 to 4 on 22 level the results are as follows:

<table>
<thead>
<tr>
<th>Level</th>
<th>Trucks</th>
<th>Skip tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>4</td>
<td>305,535t</td>
</tr>
<tr>
<td>22</td>
<td>3</td>
<td>178,077t</td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>126,867t</td>
</tr>
</tbody>
</table>

The simulation showed that the system was operating at approximately 2.8 Mt per annum, however, as there are no truck or crusher breakdowns in the model actual results would be less than achieved from this model. The balance between the two levels appears to be correct based on the initial criteria and allowing for production losses, and the fact that a truck could be swapped from 24 level to 22 level to balance production.

There were no major holdups caused by priority on emptying the lower bin as this bin was empty for 12.5 percent of the time.

Model 3

Trucks on 22 level and train on 24 level

The objective of this simulation was to replace the trucks on 24 level with a 100t train to determine the effect of this on the operation.

Operation of trucks on 22 level is the same as in the previous model. Trucks on 24 level have been replaced by a train. Initial simulations were run operating the train on a 2 and 3 shift basis with final runs on a 2 shift operation.

The train loaded from each of the three ore passes selecting the ore pass with the least usage at the next loading point.

As there had to be room in the loading bin for a train load the bin was lowered to 50 tonnes capacity or less before any ore was taken from the 22 level storage. However, if the upper level storage was full it took priority over 24 level in unloading.

Model 3 results

The train was operated on 2 shifts as initial simulations indicated that 3 shift operation produced too much ore from the lower level.

A 150t capacity train was also simulated but the output did not differ greatly from a 100t train, so it was not further pursued.

The results are as follows:

<table>
<thead>
<tr>
<th>Skip tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>305,900t</td>
</tr>
<tr>
<td>22 level (trucks)</td>
</tr>
<tr>
<td>24 level (train)</td>
</tr>
</tbody>
</table>

The output of the train on 24 level is still too high and the operating time would have to be further reduced to achieve the required 110,000 Mt/annum from 24 level, as it is operating at a 1.5 Mt/annum rate on 2 shifts. Any further reduction may make a train system on this level uneconomical due to its low utilisation.

Conclusions

The three models highlight the critical areas in the operation.

Common to each model is the operation of the ore passes. If there is not an efficient management system for the flow of ore through the passes production will be significantly impaired.

Production from the train systems is significantly higher than that from the trucks as it has been assumed that an efficient loading and unloading system would be installed for the trains. To obtain a direct comparison between the two, truck loading time would have to be reduced from 12 minutes to 6 minutes which would give a significant increase in output from the trucks, and result in lower truck numbers for the same output. This would have to be balanced against the increased cost of installing and operating an improved truck loading system.

The results show that trucks appear to be a better alternative than trains as they require a lower capital outlay and are more flexible.

These models fulfill the objective of the present study in that they identify appropriate equipment numbers and operating time. They can now be easily extended to include loading into ore passes from stopes and scheduling quantities from each ore pass, whilst including equipment breakdowns.

This would enable any system which is selected to be fully evaluated before commitment to capital expenditure and enables "what if" questions to be answered and fine tuning to be carried out to optimise the system.

If any questions arise as to the impact of changing certain parameters on production it is
a simple matter to modify the GPSS program to
determine the impact the changes will have on
production. Most changes to a GPSS program can
be achieved by changing a few lines. Often
this can be achieved in a matter of seconds.

The use of computer simulation models can be of
great assistance to the mining engineer in many
ways as has been shown in this case study.

Although GPSS has not been widely used by the
mining engineer, with the availability of
versions for personal computers, hopefully this
will soon change.

Acknowledgements

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