AN EASY TO USE SIMULATION PROGRAM
FOR GOLD MINE TRANSPORT PROBLEMS

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ABSTRACT

Efficient transportation of ore bearing rock is an important aspect of the gold mining industry. Simulations of these networks provide management with one of the cheapest ways of dealing with transportation problems. One such simulation model, namely GOLDTRAM, is used extensively by Anglo American Corporation. The scope of problem that can be tackled by the non-specialist user is indicated by the input required and output available.

1.    INTRODUCTION

GOLDTRAM is a simulation program intended primarily for the evaluation of underground tramming networks in gold mines, but it can also be used for evaluating the performance of surface rail networks such as are used on gold mines. The original model was developed in 1977 by John Benest [3].

This paper provides some background to underground tramming and deals primarily with how the model functions, the input required and the output produced. It is hoped that the paper will convey an impression of the scope of a simulation model of a rail network which can be constructed and run by a user who is not a simulation expert and who does not need to be skilled in the use of a proprietary

simulation language.  Needless to say, the "user friendly" front end
and standardized output instructions have to be created in the first
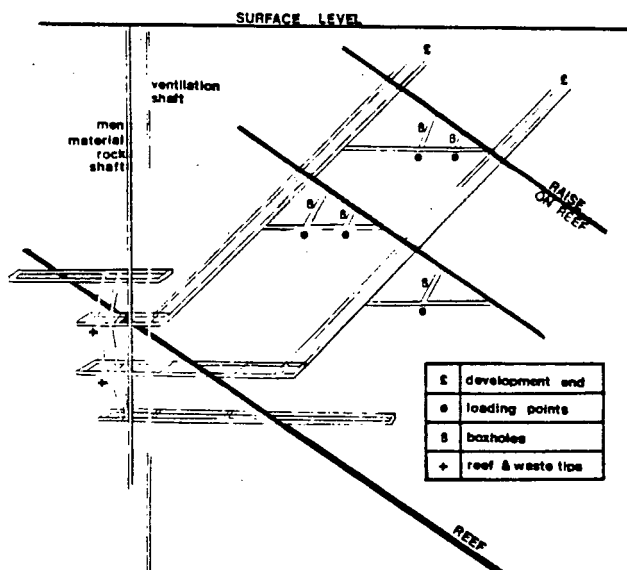place by such an expert.

2.    UNDERGROUND TRAMMING IN GOLD MINES

One very important aspect of gold mining is the efficient
transportation of gold bearing rock and waste rock from working places
underground to the shaft for hoisting.  The conventional method of ore
transportation is a network of railway tracks on which locos with open
trucks called hoppers operate.

Each shaft has many levels and each level may have a complicated
tramming network with several spans of locos and hoppers.

Figure 1 shows a typical layout of one part of a shaft indicating
the important aspects of the network.

FIGURE 1 : LAYOUT OF A PART OF A TYPICAL GOLD MINE

Various problems occur in tramming networks some of which are listed below:

- a drop in tonnage transported
- bottlenecks at intersections, tips and loading points
- the effect of proposed changes to the network
- boxholes always full
- tips always full

The following is a list of possible causes:

- too few loco and hopper spans
- too many loco and hopper spans
- too few tips
- track sections at tips too short
- track in poor condition
- loading times too long
- tipping times too long
- locos travelling too slowly
- layout has too many sharp corners and junctions

The following is a list of some solutions that could assist in making the network more efficient:

- add further loco and hopper spans
- remove some loco and hopper spans
- build a new tip
- extend the track section at the tip
- maintain track sections more often
- test the effect of changes in the layout, including sections of double track, by-passes or loops.

3.    GOLDTRAM - A SIMULATION MODEL

3.1 GOLDTRAM is a simulation model written in GPSS and is specifically designed for underground tramming networks, although it can also be used for certain surface networks.

GPSS (General Purpose Simulation System) is a simulation programming language used to build computer models for discrete event simulations. Users of GOLDTRAM require no knowledge of GPSS to use the model successfully [2].

The program calculates production achieved (i.e. tons transported) in a specified time (i.e. single or double shift) by simulating the journeys of trains over the rail network. To obtain a realistic production figure, the movements of the trains are affected by other trains in the system, the condition of the tracks and delays incurred at loading and tipping points. The delays occur randomly giving different results for successive simulations runs, each for a given elapsed time, allowing the user to express the mean of those runs as estimated average production figures. Results from either different track layouts or loco combinations can then be compared to evaluate proposed changes to the system. The model can perform up to ten simulations each time it is run.

The model simulates the transporting of ore from the stopes and development ends to the main shaft ore pass for all or part of a shaft. The simulation of the main shaft ore pass system is not performed.

The model simulates the scraping of reef or waste into boxholes and will accumulate delays should these be allowed to reach capacity.

This is done until the total amount blasted has been removed or the simulation time limit reached. Development ends are assumed to have the total tonnage blasted available for tramming at the beginning of the simulation.

Any interaction between levels is assumed to occur at a transfer pass where a tip on one level feeds a loading point on a lower one.

GOLDTRAM caters for 3 types of tramming:

a)   Straight through – locos travelling between loading points and tips

b)   Feeder services – locos travelling between loading points and shuttle points

c)   Shuttle services – locos travelling between shuttle points and tips.

At the start of any simulation, the locos may be positioned anywhere in the network. They are assumed to be empty and therefore their first activity will be to select a loading or shuttle point.

After loading, a straight-through loco travels to an appropriate tip. There it will either queue or try an alternative tip if one has been specified. A feeder loco proceeds to its assigned shuttle point, unloads its full hoppers and collects an empty span at the same point.

Shuttle locos may only collect full hoppers from one shuttle point and may deliver them either to a tip or another shuttle point. Hopper spans may vary in size between specified maximum and minimum span lengths for each hopper size. A span consists of hoppers of one size only.

Each loco continues tramming until either all its loading or shuttle points have been cleared or the specified run time has elapsed.

Travelling times are determined from the basic mean loco speed, modified according to the condition of the track sections. The actual speed used is sampled from a normal distribution with a standard deviation of 5% of the modified mean.

Loading and tipping times are sampled from normal distributions with parameters specified by the user. After the loading or tipping time has been determined, a delay time for the whole operation is added. The probability of a delay and the mean duration are input quantities. The actual delay time ic sampled from a normal distribution with a standard deviation equal to 5% of the mean. Shunting times at a shuttle point are not specified by the user. The actual time is calculated as a function of the number of locos and hoppers currently at the shuttle point.

Statistics relating to delay times at each section of track, utilisation of track, waiting times at loading points and tips, tonnage trammed etc, are automatically collected during each run and then summarised by the report writer for the final output.

Current program constraints:

          50 locos
          75 loading points
          10 reef tips
          10 waste tips
           5 shuttle points
          14 loading points per loco
         150 track sections
          10 number of simulations per run

## 3.2 INPUT REQUIRED [5]

### CONTROL DATA

- number of runs
- option of printing all reports or main reports
- random number sequence selector
    - same sequence for each run
    - different sequence for each run
- option of listing input data or not
- duration of each run (in hours)

### LOCO DATA

- number of locos
- loading point selection criterion
    - maximum tonnage as percent of capacity
    - maximum tonnage
- loco type - straight through or feeder
- starting position of loco (track section number)
- for straight through locos:
    - reef tip number
    - waste tip number
    - loco speed (m/min)
    - number of hoppers
    - nominal capacity/hopper (tons)
    - loading points to which loco is allocated

Feeder Locos:
- shuttle point number
- loco speed (m/min)
- number of hoppers
- nominal capacity/hopper (tons)
- loading points to which loco is allocated

Shuttle Locos

- reef tip number or next shuttle point
- waste tip number or next shuttle point
- loco speed (m/min)
- initial number of hoppers
- shuttle point number
- nominal size of hopper
- maximum load (number of hoppers)
- minimum load (number of hoppers)

The loco speed is specified as the maximum speed attainable by the loco anywhere in the network. This can be adjusted for specific areas by specifying the condition of the track as a percentage of the maximum speed.

HOPPER DATA

- number of hopper sizes
- nominal hopper size (tons) (designed size)
- hopper factor (%) (utilisation of the nominal hopper size)
- filling times for boxholes (loading points)
  - average time/hopper (secs)
  - standard deviation of the mean (secs)
  - probability of delay %
  - average duration of delay/train (secs)
- tipping times for boxholes (loading points)
  - average times/hopper (secs)
  - standard deviation of mean (secs)
  - probability of delay %
  - average duration of delay/train (secs)

- filling time
    - average times/hopper (secs)
    - standard deviation of mean (secs)
    - probability of delay %
    - average duration of delay/train (secs)

## LOADING POINT DATA

- number of loading points
- for each loading point
    - initial tons in stope
    - boxhole or transfer pass capacity (tons)
    - scraping rate from stope to boxhole (tons/hour)
    - initial tons available at loading point
    - loading point type                     .
    - track section number where loading point located
    - type of tip – reef or waste

## SHUTTLE POINT DATA

- number of shuttle points
- track section where shuttle point located
- nominal size of hopper
- number of empty hoppers available at start

## TIP DATA

- number of reef and waste tips
- corresponding track section number
- tip type (reef or waste)
- corresponding loading point number if tip feeds a transfer pass

TRACK SECTION DATA

- number of track sections
- for each track section
    - length of track section (metres)
    - track section type
        - track only
        - reef loading point
        - waste loading point
        - reef tip
        - waste tip
        - shuttle point
    - loading point, tip or shuttle point number
    - capacity of track section (Maximum number locos)
    - condition of track (%)
    - adjacent track sections

ROUTE TABLE

The user develops a matrix with destinations as columns and current position as rows. The body of the matrix then contains in the appropriate space the number of the next track section the loco must pass over to reach the specified destination.

EXAMPLE

Destinations (Track sections
containing tips, boxes etc)

| Dest. / Current Position | 3 | 4 | 7 | 12 | ........ |
|---|---|---|---|---|---|
| 1 | 2 | 2 | 3 | 3 | ........ |
| 2 | 3 | 3 | 3 | 4 | ........ |
| 3 | 3 | 4 | 4 | 5 | ........ |
| . | . | . | . | . | ........ |

If current position is track section 2 and required destination is track section 7, the loco must proceed onto track section 3, and so on.

## 3.3 ASSUMPTIONS

Development ends are assumed to have the total tonnage blasted available for tramming at the beginning of the simulation.

Interactions between levels are assumed to occur at a transfer pass where a tip on one level feeds a loading point on a lower one.

At the start of the simulation, the hoppers are assumed empty, and the first activity is therefore to select a loading point.

Straight-through and feeder locos travel with full spans of hoppers of one size only.

The number of shuttle points is assumed to be less than or equal to the number of shuttle locos.

## 3.4 OUTPUT

The following output is produced for each run:

- a list of the loco data used, as this may change from one run to another
- the time simulated
- track section results (for each track section)
    - track section number
    - capacity
    - maximum number of locos

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- average number of locos
- number of entries
- average transit time
- maximum queue length
- average queuing time/loco
- % zero queuing times

- loading point results (for each loading point)
  - loading point number
  - track section number
  - reef or waste
  - capacity (tons)
  - input rate (tons/hour)
  - amount at loading point (tons)
  - tons trammed
  - % time empty
  - % time full
  - tons/hour trammed
  - average loco waiting time

tip results (for each tip)
- tip number
- track section number
- reef or waste
- corresponding loading point number
- capacity (tons)
- tons tipped
- average time at tip
- average queuing time
- maximum queue at tip
- average queue at tip
- tons/hour tipped
- average loco waiting time

- loco results (for each loco)
    - loco number
    - number of journeys
    - tons trammed
    - journey times - average and standard deviation
    - tramming time (hours)
    - tons/hour trammed

- summary of journeys
    - this is a matrix of rows representing loading point numbers and columns representing tip numbers. The matrix contains the number of tipping operations and total tons delivered from each loading point to each tip.

- tipping operations (one table for each tip)
    - operation number
    - loco number
    - time
    - from loading point number
    - tons tipped

If requested, a listing of input data will be printed.

4. CONCLUSION

GOLDTRAM has been used in 35 exercises on AAC Gold Mines for the past 10 years. Its ease of use is its greatest asset and some mine personnel are able to simulate simple networks with minimal assistance.

GOLDTRAM utilises an IBM Mainframe with typically short run times commensurate with high cost efficiency. An average study may take approximately one week to complete once the mine has gathered the relevant data.

Successful applications of GOLDTRAM include:

- a study to determine the best position of a loop on a section of track

- a study to determine at what point further loco and hopper spans would be required if extensive development occurred on a particular level

- the effect the introduction of shuttle points would have on a network.

GOLDTRAM allows mine management to experiment with models of existing and proposed networks without the cost, risk and expenditure of time involved in modifying the real system [1].

## 5. AUTHOR'S NOTE

This paper deals only with the simulation model GOLDTRAM. It is however, not the only model used by AAC. A FORTRAN program, called TRANSIM II written by J Ryder of Chamber of Mines has also been used. The model requires a lot more detailed data but allows a more detailed analysis of any particular system. The question of which to use depends on the problem as GOLDTRAM and TRANSIM II each have their areas of applicability in the study of underground tramming networks [4].

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