Model: Cut and fill productivity
Level: Micro

Operating procedures

Introduction

The goal of the model is to calculate realistic productivity from data collected on site and to estimate the effect when changing certain parameters.   The physical factors (stope configurations, ground support pattern, drilled length, etc.) and the time factors (length of work shift, number of miners, time inside the stope, etc.) constitute the basic parameters of the model. Many cells in the spreadsheet were left empty to allow users to personalize the model according to their needs.

This document will help users by:

- describing the approach used to effect the productivity calculations;
- giving a description of the worksheets in the "Excel" file and their functions;
- identifying the types of required data and indicating where to insert them; and
- describing the different sections of the model.

1.   Approach of the model

The global approach of the model is based on the normal working cycle inside the stopes. Each mining step is separated into activities or tasks which miners must carry out daily.   Certain activities, such as drilling, are repeated each advance and others, such as the construction of manways, are done once per lift. This method of proceeding allows users to be rapidly situated in the mining cycle in order to ensure that all elements are included.
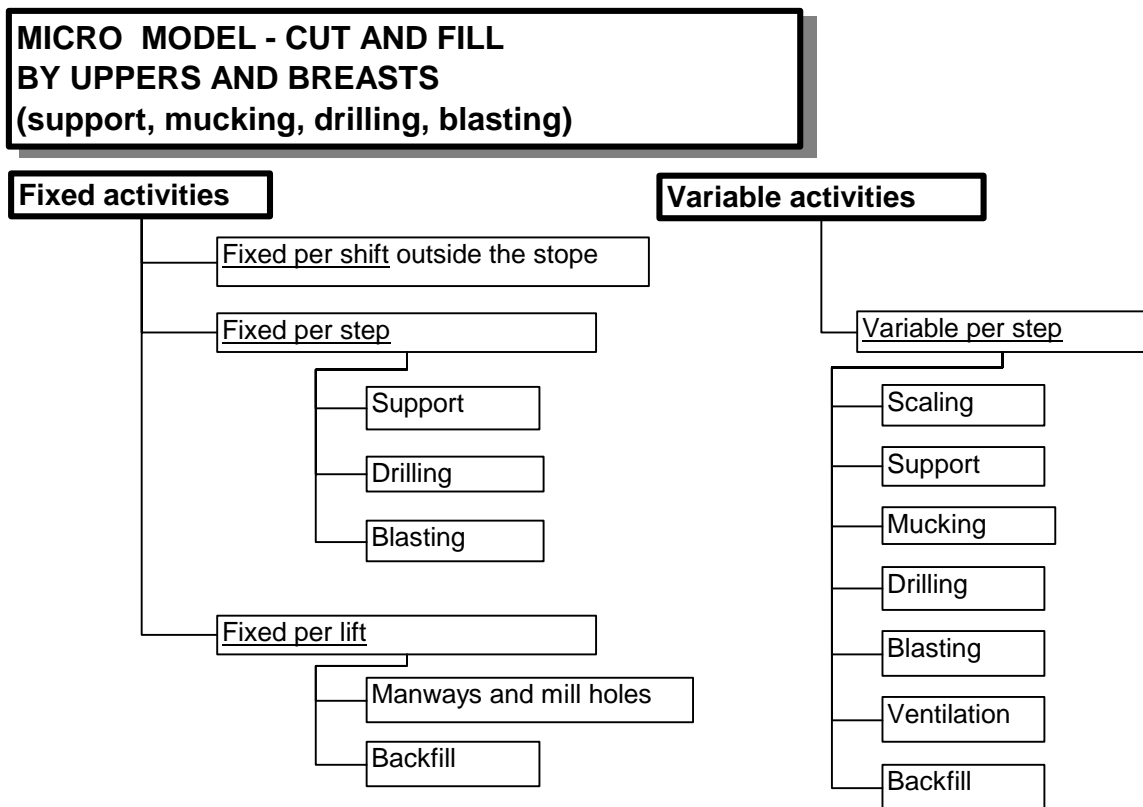
In addition, because most mining activities are comprised of both variable and fixed aspects, the model deals with these separately. In order to clearly appreciate the difference between the two types, an example is given for each aspect.

The variable aspect of each task in the model is considered as being directly proportional to the number of miners; this means that the time required to perform a task will be twice as short if there are two miners as opposed to one. For example, the time required to drill the holes for one round will be 120 minutes with two miners and 240 minutes with one miner.

On the other hand, the fixed aspect of a task in the model is the part which is not directly proportional. For example, the time required for the construction of a manway by two or three

miners is not directly proportional to their number. With two miners, it takes approximately 400 minutes, but with three miners, it takes 300 minutes. The ratio 400/300 minutes is 1.33 while the ratio 3/2 miners is 1.5. It is possible to notice a relationship between the number of miners and the time required to perform a task, but it is often very difficult to determine. It is for this reason that all tasks having this characteristic are classified as being fixed in the model.

In order to better understand the relationship between the information dealt with in the model and the work cycle, the following flow chart summarizes the different aspects in schematic form.

MICRO MODEL - CUT AND FILL
BY UPPERS AND BREASTS
(support, mucking, drilling, blasting)

Fixed activities

- Fixed per shift outside the stope
- Fixed per step
  - Support
  - Drilling
  - Blasting
- Fixed per lift
  - Manways and mill holes
  - Backfill

Variable activities

- Variable per step
  - Scaling
  - Support
  - Mucking
  - Drilling
  - Blasting
  - Ventilation
  - Backfill

2.   Notification

The present model does not perform any automatic verification to notify users when they enter incorrect data. Consequently, it is very important to take the time to verify the entered data.

The results obtained from this model cannot replace a detailed study required for a feasibility study. Natural Resources Canada does not assume any liability for any direct or indirect consequence deemed to have occurred due to the use of the results obtained from this model.

3.   Worksheets

The file contains five worksheets: Uppers, Breasts, Mucking, Backfill and Drawings. Here are their main functions and a brief description of each worksheet:

Uppers: In-stope productivity calculation according to different parameters and stope configurations for mining by uppers.

Breasts: In-stope productivity calculation according to different parameters and stope configurations for mining by breasts.

Mucking: Mucking productivity calculation for different equipment.

Backfill: Calculation of the time required to prepare and backfill a lift depending on different parameters.

Drawings: Illustrations of the common mining steps by breasts and uppers.

Please note that all worksheets are independent and are not connected to one another by formulas.

4.   Sections of the model

Considering that mining by uppers is comprised of different elements than mining by breasts, two separate models were developed. Both models have the same approach and follow the same basic steps; however, mining by breasts requires one additional step. Here is the list of steps for each of these two types of mining:

Uppers
- Direct fixed activities per shift (outside the stope)
- Direct fixed activities per step (inside the stope)
    - Ground Support
    - Drilling
    - Blasting
- Direct fixed activities per lift (inside the stope)
    - Backfill, mill holes and manways
    - Other activities per lift

- Direct variable activities per step (inside the stope)
    - Lift Dimensions
    - Scaling
    - Ground Support
    - Mucking or Scraping
    - Drilling
    - Loading and Blasting
    - Ventilation
    - Backfill
- Lift compilation

Breasts
- Direct fixed activities per shift (outside the stope)
- Direct fixed activities per step (inside the stope)
    - Ground Support
    - Drilling
    - Blasting
- Direct fixed activities per lift (inside the stope)
    - Backfill, mill holes and manways
    - Other activities per lift
- Direct variable activities per step (inside the stope)
    - Lift Dimensions
    - Scaling
    - Ground Support
    - Mucking or Scraping
    - Drilling
    - Loading and Blasting
    - Ventilation
    - Backfill
- Breast compilation
    - Calculation of the possible number of advances per shift
- Lift compilation.

4.1   Description of the sections of the model

4.1.1   Direct fixed activities per shift (outside the stope)

This section takes into consideration all the time required for activities outside the stope which is attributed to each miner for the calculation of productivity. This total time has an important effect on the possible number of advances per shift in the breast-mining environment.

4.1.2 Direct fixed activities per step (inside the stope)

Direct fixed activities per step allow users to verify the required work according to the mining cycle.

- Ground Support:

In the conventional mining cycle, ground support represents the first mining step which is performed at the beginning of the shift. Fixed activities are normally related to material mobilization and demobilization in order to carry out the work during this step. Users must therefore evaluate the time required to bring the material, build the drilling platform (if necessary) and store the material.

In view of the fact that a platform is normally required for drilling and loading holes, its dismantlement is therefore included in the blasting section. It is to be noted that, when mining by uppers, the use of a platform is not standard.

- Drilling:

Fixed drilling activities are also related to the handling of material. The activities during drilling (displacements of the drill, as well as changing drilling steel and bits) are included under drilling productivity in the "Direct variable activities – Drilling" section.

- Blasting:

This section deals with fixed activities before and after blasting.

Before blasting, the main activities are related to material handling during the installation and storage of equipment for the loading of explosives. The platform is normally removed just before blasting.

In view of the fact that it is necessary to muck the ore before blasting, in breast mining, the time to verify the mucking equipment is included in this section.

After blasting, it is necessary to verify access to the stope and, in certain cases, extra scaling is required and ventilation pipes must often be repaired.

4.1.3 Direct fixed activities per lift (inside the stope)

The activities per lift are generally carried out once per lift. They have a major effect on average productivity. It is therefore important to estimate them properly.

- Backfill, mill holes and manways:

In this section, users must estimate the time required for site preparation, moving equipment and material inside the stope, as well as construction (barricades, drainage system, mill holes, manways, spill fences and backfill pipes). The estimated time must take into consideration the number of miners. If the number of workers in the "Lift compilation" section is changed, it is important to verify if the estimates are still valid.

- Other activities per lift:

In this section, users must include factors which may cause occasional delays in production. Visits from the technical and maintenance services, as well as repairs in the main access at the beginning of each lift form part of the most common factors.

4.1.4   Direct variable activities per step (inside the stope)

In the upper model, there are two columns: slot raise parameters and lift parameters. In the breast model, there are also two columns: breast parameters and lift parameters. The calculations of the required time are done per column, thus allowing users to follow the calculation method.

- Lift Dimensions:

This section is used to define the length, width and height of the lift, as well as the slot raise parameters (mining by uppers) and the number of advances, as well as the breast parameters (mining by breasts) and the ore density.

When trying to optimize the length of advances in breast mining, users must change the drilled and broken lengths in this section.

- Scaling:

In this section, the scaling productivity is defined as the time required to wash and scale one (1) meter of stope (the roof and both walls). It is possible to determine this average productivity by dividing the total time required for one advance by its length. This parameter remains unchanged when the length of advances is changed.

- Ground Support:

In this section, the length of the holes to be drilled for the type of support and the number of bolts per 1.2 meter advanced, for the roof and each wall, must be entered in the right-hand columns.

In the left-hand column of this section, the average installation time per bolt must also be entered. When the support specifications require wire mesh or metallic bands, the average time per bolt should include these types of support.

The time required to perform drilling is calculated in accordance with the data in the "Drilling" section.

- Mucking or Scraping:

In this section, the model calculates the time required to muck the ore. The mucking productivity must be entered in the left-hand column for slot raises (uppers) or for one advance (breasts). The same information must be entered in the right-hand column for lift parameters.

Moreover, in this section, it is possible to enter different productivities for the final floor clean-up before backfilling. In order to calculate the required time, the thickness of the ore, which is recuperated, must be entered in the "average thickness" cell in the right-hand column. If the ore grade left on the floor does not justify this additional step in the mining cycle of the lift, users must enter "0" in the "average thickness" cell.

In the "Mucking" worksheet, it is possible to verify the mucking productivity with different equipment in relation to the distance from the face to the dumping point. Section 4.2 "Mucking or Scraping" of this document will give users the necessary information for these different calculations.

- Drilling:

In the right-hand column, the model calculates the average drilling productivity based on a 2.4-meter hole. The required data includes: firstly, the time required to drill a 1.2-meter hole to calibrate the model in relation to the type of rock or drill, and secondly, the average time for repositioning and changing drilling steel and bits for a 2.4-meter hole. Then, the model calculates the average time to drill a 2.4-meter hole and converts it into a productivity of drilled meters per hour. In order to arrive at an average productivity, the total drilled length for a 2.4-meter

advance should be divided by the drilling time. It should be noted that this productivity is also used to calculate the drilling time for ground support.

In the right-hand column of the "Drilling pattern" section, the number of holes per breast, with respect to breast mining, must be entered. For uppers, the burden and the number of hole per row must be entered.

Always in the right-hand column of the "Drilling pattern" section, the model calculates tonnage factors per drilled meter and tonnes per hole. These factors are interesting to compare different mining approaches.

- Loading and Blasting:

The blasting section calculates the time required to clean the holes and load the explosives. The productivity per hole must be entered in the left-hand column.

In the right-hand column, users can calculate the average powder factor by entering the diameter of the drilled holes and the explosive density. In each column, the model calculates the required quantity of explosives according to the entered parameters.

In the model for uppers, the number of "holes per blast" must also be entered in the "Lift parameters" column. This number of holes must be a multiple of the number of holes per row appearing in the "Drilling pattern" section.

- Ventilation:

The "Ventilation" section must be completed when delays are caused by a lack of ventilation inside the stopes. If the available time between work shifts is sufficient to ventilate the stopes, it is not necessary to enter the time per blast. The model calculates the total time from the time entered per blast multiplied by the calculated number of blasts. The total number of blasts takes into account slot raises and blasts in mining by uppers or advances in mining by breasts.

- Backfill:

In this section, the backfill density and backfilling capacity in dry tonnes per hour must be entered. All other activities related to backfill preparation can be found in the "Direct fixed activities related to backfill, mill holes and manways" section.

It is possible to evaluate more precisely the time required for backfilling a lift in the "Backfill" worksheet. This section of the model is explained under section 4.3 "Backfill" of this document.

4.1.5   Breast compilation

This section of the model applies only to breast mining. Its goal is to verify the possible number of advances per shift according to the entered parameters. The model gathers all the data except those per lift (section 4.1.3) and summarizes them in table format.

In this section, the number of people working inside the stope and the length of the work shifts must be entered. However, for the upper model, this information is incorporated in the "Lift compilation" section.

The "contingency" cell represents the uncertainty level and data variation. The smaller the data variation, the more the percentage will decrease. However, if the variation is high, it is suggested that a contingency percentage superior to 15% be preserved. It should be noted that the model calculates the allocated time for contingency in minutes. This period of time helps users to visualize the impact of a small percentage rate for contingency purposes.

- Calculation of the possible number of advances per shift:

This section indicates the number of advances which could be completed according to the particular situation. This number is not automatically used in productivity calculations. In the next section, the average number deemed the most appropriate for the entire lift must be entered.

4.1.6   Lift compilation

In this section, a summary of all the data is presented in table format. As mentioned in the previous section dealing with breast mining, the number of workers inside the stope, the length of the shift and the contingency percentage must be entered (see explanation in section 4.1.5).

The model produces a detailed summary per direct fixed and variable activity and then calculates the required manhours. It should be noted that the row for direct variable activities appears twice. The top one transcribes the calculated hours in the different sections of the model, whereas the figures in the bottom one correspond with the top row figures divided by the number of workers.

The summary per manshift allows users to visualize the distribution of work inside and outside the stope.

The complete list of required data towards the use of the cut and fill productivity model can be found in section 6 of this document.

4.2   Mucking

This worksheet is used to compare the productivity of different mucking equipment in order to select the most appropriate equipment and performance in relation to the maximum distance between mill holes which influences the mining cycle. The greater the distance between mill holes, the more important it will be to use performing equipment for mucking in order to maintain the cycle. The model performs basic productivity calculations allowing users to support their economical calculations to justify their choice.

The model compares four different equipment, allowing users to change the last one. Each has its performance curve in relation to distance. In the last section, users may change the equipment for an equipment of their choice with the corresponding performance. It is important to note that the graphic line will be drawn automatically, however, the mathematical expression of the curve is not automatically updated in the "m³/hour" cell. There is a note to that effect in the model. If the cell formula is not changed, the result in the table for that equipment will be false.

In the upper right-hand section entitled "Table (entries, results)", the following data must be entered for each equipment:
- average operating distance; and
- average availability.

The model calculates the productivity for each equipment from the mathematical expression of the curve. Users may then choose the equipment and the desired performance. This result must be entered in the appropriate cell in the "Mucking or Scraping" section of the "Uppers" or "Breasts" worksheets as described in section 4.1.5 of this document.

4.3   Backfill

This worksheet calculates the required manshifts for backfill preparation and backfilling a lift. The model is composed of four sections: Backfill preparation, Continuous backfilling, Backfilling per shift and Summary of total manshifts required.

The "Backfill preparation" section includes all the required activities to prepare and build the mill holes, manways and fences. Each activity can be carried out by a different number of workers. This allows users to calculate the effect of adding or subtracting one worker in terms of execution

time in an optimization process. The model calculates the required work in manshifts with and without a fence because some operations backfill the lift in a single step.

In the "Continuous backfilling" section, the model calculates the required work in manshifts according to the required volume, the solid rate of backfill and the number of workers per step. The same calculations are done in the "Backfilling per shift" section, but take into consideration the direct fixed time outside the stope in section 1.0 of the model in the "Uppers" or "Breasts" worksheets. In addition, a summary showing the required manshifts for each case is presented in table format.

5. Using the model

The cut and fill productivity model allows users to:
- simulate productivity according to the data collected on-site
    - for active stopes; and
    - when there is a change in the mining method
- validate new mining approaches; and
- validate the interest in importing a new concept and/or new technologies.

The main factors used in the model are:
- stope configuration;
- support pattern;
- drilling pattern and length of advances;
- number of workers inside the stope;
- length of work shifts;
- mucking productivity;
- delays related to ventilation; and
- backfilling productivity.

5.1 Changes in the mining method or stope configuration

In order to simulate the effect of a change in operation, it is important to first simulate the actual situation in order to calibrate the model. The required information in using the model is normally available for most mining operations. When the data is not recorded, a few measures can be taken underground.

It is also important to keep track of the changes made and their effect on productivity. The importance of certain factors on the productivity level can then be quantified. It will therefore be possible to target the critical factors to improve average productivity.

5.2   Validation of new mining approaches

The model allows for the simulation of new approaches or ideas. Users can quantify the effect of changing technologies on stope productivity and, in addition, changes in the type of drill, as well as drilling and support patterns give instant results.

However, it is important of not underestimating the effect of fixed time of a new technology. This fixed time, sometimes difficult to evaluate, may easily augment or diminish the interest in this new method.

In order to evaluate the effect on productivity when a new mining method is imported from one mine to another, it is important to gather as much information as possible on the other operation. The list of required data towards the use of the model (refer to the following section) identifies important data for users to collect during investigation visits.

6.   Required data

For an easier comprehension of the model, a colour code helps users to find the cells where data must be entered.

- The yellow cells indicate where data, specific to the situation, must be entered. All the other cells are locked to prevent formula modifications which could produce false results.
- The green cells identify the results obtained from the entered data.

The following sections of this document list the required data towards the use of the model. As previously explained, the data is divided into two sections, fixed and variable.

6.1   Fixed data

Users are recommended to read over again section 1 "Approach of the model" for a clear definition of the term "fixed data". That section explains the distinction between fixed and variable data. The variable items of the model are listed in the next section.

Here is a list of fixed activities most commonly carried out. If some activities are not included in this list, users can simply add them in the cells provided for that purpose in the model.

Schedule (section 5.0 of the model)

Required number of men		men
Number of hours per shift		hours

Fixed time outside the stope (section 1.0 of the model)

Cage (at beginning and end of shift)		minutes
Travelling (shaft - refuge station - shaft)		minutes
Other travelling delays		minutes
Back and forth to stope		minutes
Supervision		minutes
Work planning		minutes
Complete daily reports		minutes
Lunch		minutes
		minutes

Activities related to ground support (section 2.0 of the model)

Bring equipment and material		minutes
Install setup platform		minutes
Store equipment		minutes
		minutes

Activities related to drilling (section 2.0 of the model)

Prepare material		minutes
Store equipment and material		minutes
		minutes

Activities related to blasting (section 2.0 of the model)

Bring explosives		minutes
Bring and prepare material		minutes
Store equipment and explosives		minutes
Remove setup platform		minutes
Equipment checks		minutes
Connect the blast		minutes
Access verification (to working areas)		minutes
Extra scaling (elsewhere than in working areas)		minutes
Repair and install ventilation		minutes
		minutes
		minutes

Activities related to backfill, mill holes and manways (section 3.0 of the model)

Drainage system		minutes
Mill holes		minutes
Manways		minutes
Barricades inside the stope		minutes
Move equipment prior to backfill		minutes
Install backfill line inside the stope		minutes
Connect to the main line		minutes

Wash the line before backfilling		minutes
Wash the line after backfilling		minutes
Spill fences (outside the stope)		minutes
		minutes
		minutes

Other activities per lift (section 3.0 of the model)

Geologists		minutes
Surveyors		minutes
Mechanics and electricians		minutes
Repairs in main access		minutes
		minutes

6.2   Variable data

Here is the variable data which users will have to estimate or measure in their operation:

Lift Dimensions (section 4.1 of the model)

Length of the lift		meters
Average width of the lift		meters
Height of the lift		meters

Slot raise parameters (uppers) and breast parameters (section 4.1 of the model)

Drilled length		meters
Broken length		meters

Drilling pattern (uppers and breasts) (section 4.5 of the model)

Burden between the rows (uppers)		meters
Spacing between the holes (uppers)		meters
Number of holes/breast (breasts)		holes

Scaling (section 4.2 of the model)

Scaling time per longitudinal meter		minutes/meter

Ground Support (section 4.3 of the model)

Installation time/bolt		minutes
Roof pattern		number of bolts per 1.2 longitudinal meter
		drilled length/bolt
Hanging wall pattern		number of bolts per 1.2 longitudinal meter
		drilled length/bolt
Footwall pattern		number of bolts per 1.2 longitudinal meter
		drilled length/bolt

Mucking or Scraping (section 4.4 of the model)

Mucking of slot raises		tonnes/hour
Average mucking for the lift		tonnes/hour
Mucking of slot raises (cleaning)		m²/hour
Average mucking for the lift (cleaning)		m²/hour
Thickness of the ore (cleaning)		meters

Drilling rate (section 4.5 of the model)

Drilling time for 1.2 meter		minutes
Repositioning time per 2.4-meter hole		minutes

Loading of explosives (section 4.6 of the model)

Clean and load holes		minutes/hole
Number of holes/blast (uppers)		holes/blast

Ventilation (section 4.7 of the model)

Time delay for the evacuation of fumes during the shift		minutes/blast

Backfill (section 4.8 of the model)

Backfill density		tonnes/m³
Backfilling capacity		dry tonnes/hour