Optimization of Extraction Sequence in a Bench and Fill Mine Considering the Impact of Exposure Rate on Dilution: A Case Study

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ABSTRACT

Mine planning is an iterative process, expensive in terms of time and requiring specialized engineering team. Usually, the mine planning process is sequential, that is, a production plan is completed first and then it is adapted to the mine requirements. This often results in not achieving the production goals and the lower NPV than estimated in the original plan.

The main goal of this work is to compare and quantify the impact of dilution and exposure rate of the hanging wall on the optimal mining scheduling. For this purpose, production plans have been prepared for a Bench & Fill operation using, firstly, the traditional approach of mine planning and, secondly, the integrated approach (integrating dilution and extraction rate simultaneously in the mine planning process) using real mine site data.

The operational constraints (fill movement and production rate) and the benefit of each activity was used in determining the order of the extraction sequence. The sequencing of the activities was made using the software UDESS (a software tool developed by Delphos Mine Planning Laboratory), which provided the optimal extraction sequence and a production plan for all scenarios.

While comparing the results, it was observed that incorporating dilution into the process impacts directly into the extraction sequence, which means that the order of stope extractions is different from in the original plan, the NPV is lower, and therefore the plan is different. In addition, it was shown that dilution decreases while applying the incremental exposure rate of the hanging wall.

It can be concluded that the variations in the exposure rate imply a variation in dilution, the production plan, and the extraction sequence.

INTRODUCTION

Within small and medium sized mining, selective underground methods are the most common, and unlike large scale mining, engineering levels are limited mainly by available economic resources, the complexity of tasks and execution time. It is here where we can find an opportunity to improve processes and to add value to the mining business through development and implementation of new methodologies to optimize the stages of mining value chain, like the mine planning process (Luxford, 2000).

The mine planning process is iterative and done in several stages, where production plans are being modified according to operational requirements, which implicates differences between the actual plan and what is really achieved. For example, unplanned dilution is one of the variables that modifies the production plan, adding unplanned waste to the production tonnage and modifying the mean grade (Luxford, 2000).

The main goal of this work is to compare and quantify the impact of dilution and exposure rate of the hanging wall on production plan and extraction sequence. For this purpose, production plans have been prepared for a Bench & Fill operation using, firstly, the traditional approach of mine planning and, secondly, the integrated approach including two dilution models.

The rest of the paper is organized as follows. First, the methodology applied in this work is explained. Next, in section Case Study, we present the background of the studied mine and the economic and operational parameters that were considered. Then, in section Results and Discussion, we show the main results obtained and we discuss the effect of both dilution models in the mine planning process. Finally, we present the main conclusions extracted from this study.

METHODOLOGY

The methodology applied in this work consists in the modelling of a Bench & Fill mine to obtain an optimal extraction sequence and its corresponding production plan through the software UDESS. Figure 1 shows a diagram of the methodology applied, where three models of the mine are generated and given to UDESS to find the optimal extraction sequence and production plan for each model, maximizing the objective function, that is the Net Present Value (NPV) of the mine.

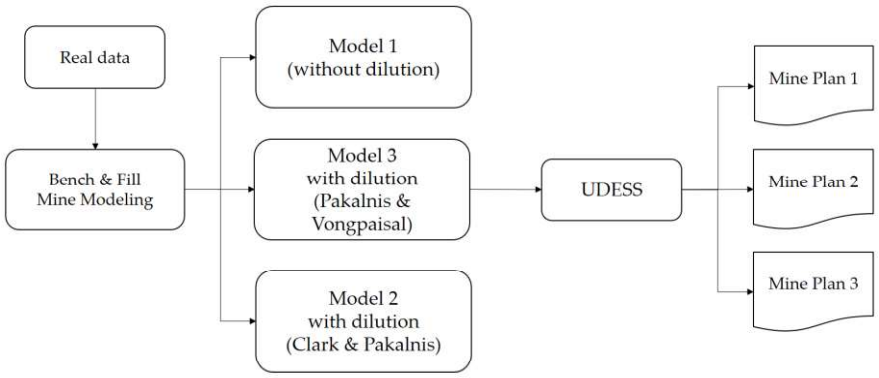

Figure 1 Methodology scheme.

UDESS (Universal Delphos Sequencer and Scheduler)

UDESS (Universal Delphos Sequencer and Scheduler) is an activity scheduler developed in Delphos Mine Planning Laboratory at Universidad de Chile. Unlike other mine planning tools, UDESS finds the optimal sequence for a several number of tasks maximizing the objective function, for instance, the Net Present Value (NPV) (Rocher, W., Rubio, E., Morales, N., 2011).

UDESS optimization is based on the concept of activities or tasks, that relates to each other through precedence constraints. Each activity has different attributes, like economic benefit and cost, and they consume operational resources to be executed. Under these considerations, UDESS generates and solves an optimization model that schedules the activities maximizing the economic benefit or minimizing the cost (Rocher, W., Rubio, E., Morales, N., 2011).

To make this possible, the software uses two text files as input: the activities file and the precedence file. These two files must be constructed by the user. The output given by UDESS is a file that contains the Gantt Chart of each activity for every period evaluated and the NPV of the model (Moreno, 2015).

Construction of the Production Plan

UDESS uses as input the activities and its precedence constraints that results from the mine model. Thus, based on a mathematical optimization model, a scheduling is generated, subject to precedence and operational constraints (Rocher, W., Rubio, E., Morales, N., 2011).

For the construction of the model, activities like horizontal development, extraction and backfill were considered. In general terms, horizontal developments must be completed so extraction may begin, while backfill act as floor for extraction of upper levels. Therefore, the number of total activities in the model is 4,105.

On the other hand, and given the extraction method conditions, five precedence groups were defined. Horizontal main developments activities correspond to all the infrastructure needed to begin the extraction, such as ramps, main drift, crosscut galleries and extraction drift. These activities must be