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THE IMPACT OF AN ERROR IN SELECTION THE PUSHBACKS IN THE LONG-TERM PLANNING OF THE OPEN PIT PRODUCTION ON PROJECT QUALITY, CASE STUDY: OPEN PIT VELIKI KRIVELJ, BOR, SERBIA[**]

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Abstract

Today, there is a large number of software in which various mathematical algorithms for optimization the open pits are implemented. However, the importance of experience of the mining engineers in planning is still crucial for the quality of mining projects. Proper selection of the pushbacks is one of the most important planning steps in a long-term planning of production at the open pit. Therefore, the mistakes that occur in this planning step have a great impact on the project quality. Using the example of the Veliki Krivelj project, this paper presents the importance of correct selection the Pushbacks from an aspect of satisfying the practical geometric mining constraints.

Keywords: *pushbacks, mining constraints, error, project quality, open pit Veliki Krivelj*

1 INTRODUCTION

Long-term planning of the open pit production plays a key role in evaluation the mining projects, with the main objective to maximize the value realized by the excavation and processing of the mineral resources. Usually, due to the complexity of problem, the planning process is divided into phases, generating three related problems that are solved sequentially to obtain a rough production plan, namely:

1) determination of the final pit, which consists of delimiting the subregion of the mine where the excavation will be carried out,
2) selection of pushbacks, that allows to guide the sequence of excavation and to control the design,
3) excavation dynamics, which defines in every pushback when different zones will be excavated.

The main drivers in the strategic mine planning are:

1) to improve income as much as possible, and
2) postpone the excavation of unnecessary mining waste while respecting the technical limitations such as the minimum width of the working

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floor, safe angles of working and final slopes, and planned ore mining capacity.

In addition to identify the optimum pit limit, the pit limit analysis is also used to identify a series of nested pits within the final pit limit. The purpose of these nested pits is to establish a transition from the most profitable material (highest value per unit mined) in the pit to the least profitable or break-even material, which occurs at the pit limit. This understanding will aid the planner in selecting where to begin mining, and in what sequence to mine the pit out in order to produce the highest NPV from the material within the final pit limit.

Pushbacks are nothing more than a sequence of the pit limits on the basis of the alternative economic scenarios. Simply pushbacks describe how a pit will expand as the value of recovered mineral increases. The progression of pushbacks or nested pit shells roughly corresponds to the optimal evolution of the mine over time, Figures 1 and 2.

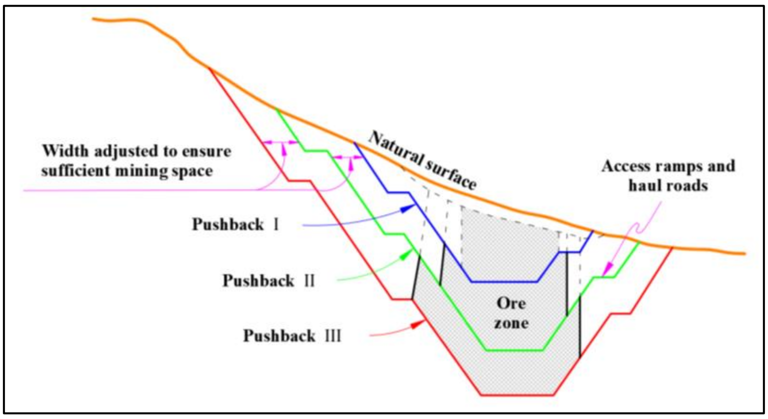

Figure 1 *Phased development of mining works at the open pit [1]*

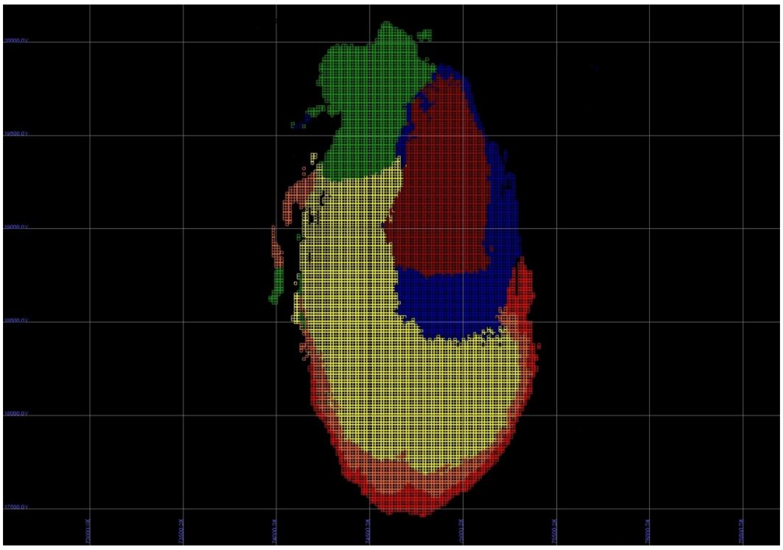

Figure 2 *Pushbacks generated in the Gemcom Gems software [2]*

2 SELECTION OF PUSHBACKS

Pushbacks (Figure 1) are essentially a series of manageable exploitation phases for an open pit mine. A pushback is ideally composed of a unique, spatially contiguous volume that can be mined with the available mining equipment and meets the practical geometric mining constraints.

Selection of a pushback is a key component to the long-term planning process of the open pit as it is critical to the final mine design and realized profit.

Pushbacks are designed to have a quick access to the high-grade ore zones of the deposit to maximize revenue in the early years. Since it is the main purpose of designing the Pushbacks, it also helps to reduce the investment risk. Another importance of using Pushbacks is that they can provide a safety zone for projects so that when the metal price on the market is not favorable, the exploitation of the ore can be temporarily stopped with the minimum losses for the mining company.

Practical considerations result in three categories of constraints on pushback design:

i. **Geotechnical constraints** – refers to the need to respect the general slope angle of an inclination in order to achieve the necessary safety for the work of people and equipment. In certain cases, when the lifetime of Pushback is shorter, it is possible to plan a steeper angle of the Pushback slope inclination, with the aim of reducing the amount of waste, i.e., the overburden coefficient.

ii. **Quality constraints** – quality and overall size constraints on the content of each pushback to meet production targets

iii. **Geometric constraints** - size and type of mining equipment - which ultimately determines the minimum working width of the stages in Pushback. Space is required for the haul road design and machine access.

Geometric constraints have a great impact on the design of Pushbacks, and if the mine planning engineers do not take these constraints into account, the mistakes occur that significantly impair the project quality. Therefore, the correct approach to this problem is to establish a compromise between the stated limiting conditions and desire to achieve the maximum NPV.

This paper is focused on the problem that exists in the selection of Pushbacks and mistakes that engineers can make in the design process when they do not take geometric constraints into account.

3 CASE STUDY

The authors of the paper have used a real example to show the impact of wrong selection of the Pushbacks by designers on the quality of the Veliki Krivelj project.

Two cases were analyzed. The Case 1, which represents the wrong selection of Pushbacks, from an aspect of not respecting the geometric constraints, and the Case 2, which correctly approaches the selection of pushbacks, taking into account the geometric constraints.

As a rule, the planning engineers are not specially trained for this type of work, but it is necessary to have a large amount of professional experience, as well as a significant knowledge of specialized software tools necessary for performing the precise and efficient analysis of design solutions.

The importance of experience in planning in mining projects comes to the fore especially when the quality of input parameters or, as in this case, geometric constraints, should be considered.

The mining plan of the deposit, which includes the optimization of the mine boundary, selection of pushbacks and optimization of mining dynamics, was carried out in the Whittle software by the mine planning engineers.

The pushback selection was carried out using a number of empirical rules on the nested pits, obtained using the methodology developed by Lerchs and Grossmann [3].

The mistake made by the mine planning engineers during the project design is related to the selection of Pushbacks. The mine planning engineers chose the Pushbacks that enable the maximum NPV, not taking into account the necessary width between Pushbacks, which enables smooth and safe operation of the mining machinery (Case 1). Figure 3 shows the contours of he selected pushbacks and final contours of the pit for the characteristic level k+245 m. The figure shows that the mining width between Pushback 1 and Oushback 2 is one block width (15 m). For the applied loading and transport machinery, the minimum safe working width of the floor is 30 m.

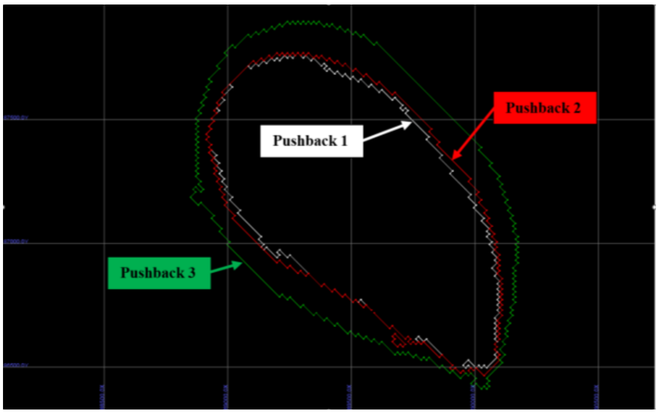

Figure 3 *Wrong selection of Pushbacks in relation to the geometric constraints, Case 1*

The correct selection of pushbacks, which also implies respect for geometric constraints, is shown in Figure 4.

In this case, the mining width between pushbacks is at least 35 m (Case 2).

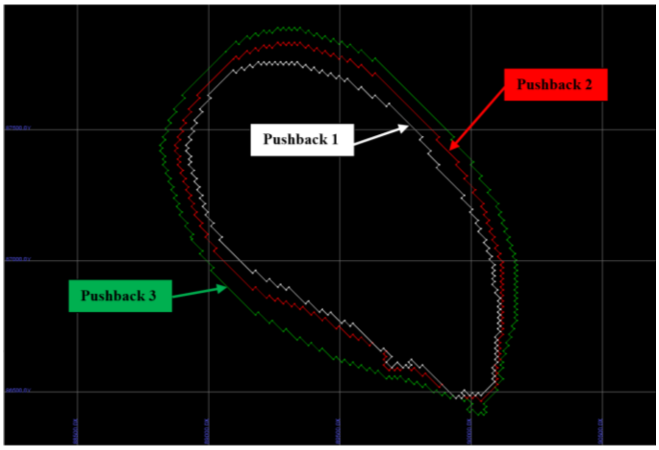

Figure 4 *Proper selection of Pushbacks in relation to the geometric constraints, Case 2*

In the optimization process of excavation dynamics, the simulation and Discounted Cash Flow Analysis (DCF) are performed in order to obtain the maximization of the net present value in a long-term planning of the open pit. The analysis is based on the Milawa algorithm, which is specifically designed to optimize the excavation dynamics of the long-term exploitation planning strategy.

Table 1 shows the obtained NPVs for the Case 1 and Case 2.

Table 1 *Maximum NPV values for the analyzed Cases*

	Case 1	**Case 2**
NPV, $	548,946,621	560,529,960

Graph in Figure 5 shows the cash flow for the Case 1 and Case 2.

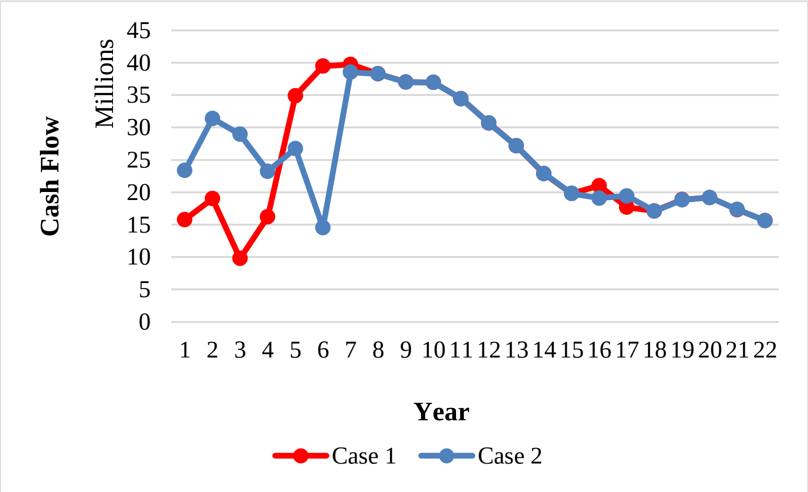

Figure 5 *View of the Cash Flow for the Case 1 and Case 2*

Thus, for Case 1, a higher NPV was obtained, but it is unrealistic considering that it is not possible to realize the planned mining activities due to the insufficient width between the pushbacks, which is necessary for the operation of the equipment.

4 CONCLUSION

In an effort to achieve the main goal in planning the mining activities, which is the maximization of Net Present Value, the mining engineers can make mistakes that affect the quality of mining projects, and therefore the impossibility of implementing such solutions in the mining processes. One such situation occurs when the mine planning engineers in selection the Pushbacks, do not respect the geometric constraints related to the minimum mining width between the Pushbacks.

Based on the analysis of two cases for the Veliki Krivelj project, Case 1, which represents the wrong selection of Pushbacks, from an aspect of non-compliance with the geometric constraints, and Case 2, which approaches the selection of Pushbacks in a correct way, taking into account the geometric constraints, it is shown that the selection of Pushbacks is one of the most important steps in the planning process of open pits and has a huge impact on the mining project quality.

The following NPV values were obtained using the DCF analysis:

- Case 1 560,529,960 $
- Case 2 548,946,621 $

Thus, for the Case 1, a higher NPV in the amount of $11,583,339 was obtained, but it is unrealistic considering that it is not possible to realize the planned mining activities due to the insufficient width between the Pushbacks, necessary for equipment operation.

In the end, it can be concluded that despite advances in the available algorithms, procedures, and software in the open pit planning, a human planner role is still necessary.

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