ABSTRACT

Finsch Diamond Mine (FDM) is a sublevel caving (SLC) operation in the Northern Cape province of South Africa and is owned by Petra Diamonds Limited. The mine was experiencing challenges in achieving its planned production throughput of 280 000 tonnes per month. In addition, it was also facing an increase in unit operating costs and low diamond prices. Consequently, the mine carried out two analytical and optimisation studies in 2018 and 2019, and managed to optimise some operational facets. However, the two studies have fallen short in optimising the production cycle of FDM and reaching the planned production throughput. This research study was therefore undertaken to identify and rank the production cycle input parameters that are the most influential constraints prohibiting FDM from reaching its optimal production efficiency. The Theory of Constraints (TOC) was the main approach used during the study to identify, rank and ultimately make suggestions to eliminate the most influential production cycle constraints. The TOC was chosen as it has a five-step systematic approach to identify constraints and improve the efficiency of a system. It was very important to identify the correct constraints successfully, as it helped to focus and prioritise optimisation projects. Optimisation projects can either be extremely expensive or turn out unsuccessful if focus is placed on the wrong constraints.

To solve the problem, the study's objectives included the preparation of data for the use in, and calibration of, a reliable simulation model of the mine. The data was then used in a software programme called Simio where discrete-event simulation experiments on the production cycle input parameters were run, and compared to a baseline simulation value. The TOC was applied by assuming each time that a parameter might be a constraint. This was followed by testing if it is by incrementally decreasing and increasing its utilisation or influence, and measuring the production output during the second and third steps of the evaluation. Some parameters had to be taken to the fourth step where it was elevated by increasing the number of machines for example. The last step of the TOC was to repeat the process and find a new constraint, as was done in the first step. By exploiting, synchronizing or elevating an assumed constrained, it was not only possible to determine if an input parameter can be listed as an identified constraint, but it could also be ranked on the basis of its magnitude of influence on the production output tonnage. The use of simulation was chosen because it is highly representative of reality and the most cost effective way to experiment with a system that consists of multiple objects, actions and parameters. Furthermore, qualitative discussions and an analysis of historical data were also used in the study to identify other constraints that could not be identified through simulation. A preliminary constraint ranking was created from the simulation runs which created an ideal framework to evaluate parameters in more detail by means of adding historical data to support analyses and arguments.

After presenting and discussing the results from the simulation runs, historical data analysis, and qualitative discussions, the following constraint ranking was established (most influential to less):

- Scheduled production time.
- Number of Load, Haul and Dump (LHD) equipment in use.
- Tunnels available for loading.
- LHD load capacity in tonnes.
- LHD tramming speed.
- Number of production days scheduled.
- Number of drill rigs in use.
- Drilling quality.
- Charging and blasting quality.
- Tip availability.

It was apparent after the ranking that the available production time, the number and performance of LHD equipment in use, and the availability of ore are core to a successful SLC production cycle. The ranking may seem relatively obvious; however, a more detailed discussion about each listed constraint is presented in the research project.

The final constraint ranking was followed by concluding remarks and recommendations to improve the simulation model and possible solutions to reduce or eliminate the ranked constraints. The main recommendations were that the approach presented in this study should be used as the precursor for any optimisation study at FDM in the future, and that the constraint ranking should also be core to any optimisation projects to focus and prioritise effort. Other recommendations were focused on improving the simulation model by adding for example, more qualitative logic, including precursory activities and adding the ability to change the time horizon of the model. More focus was placed on recommendations and solutions to reduce or eliminate the ranked constraints and included some of the following:

- Introduction of a 12-hour shift and a 4-day compressed workweek, with a second blasting opportunity.
- Reduction of pre- and post-production delays with the assistance of digital technology.
- Introduction of remote operation capabilities to increase loading and drilling time.
- Utilising tablets and task management/scheduling software to assist in short-term interval control.

- Maintaining the operation of nine LHDs in each shift, and always have swing units and tunnels available on each production level.
- Upgrading the quality of the roadways and introduce mobile rail-mats in each draw point.
- Review the drilling and blasting practice to achieve better blasts.

Some constraints are complex enough that major studies can solely be conducted on them in the future. The ranked constraints and recommendations remain a guideline to improve the production cycle at FDM and assist in future optimisation studies or projects.