

Strategy optimisation for underground mines

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Open pit optimisation has been readily available as a commercial solution since the mid-1980s, and, more recently, techniques to optimise nested pit shells, pit phases, cut-off grades, stockpiling and schedule sequences have been added.

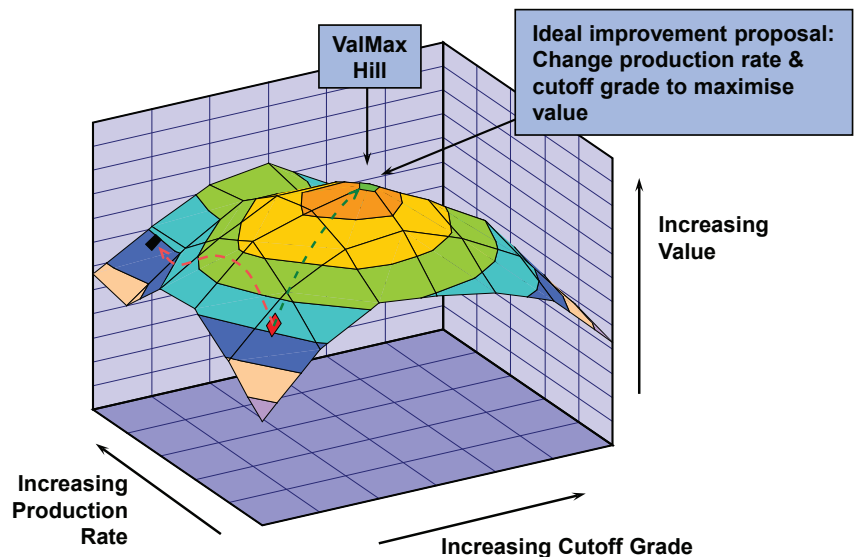
Jeff Whittle pioneered these developments, but today, many software suppliers have similar tools. For underground mine design (using stoping methods), no equivalent tool has been available, and in that sense, it is difficult to claim that designs are optimal. Underground mining is different, as mining is selective, and while mining method and geotechnical ground conditions may impose constraints on the stope sequencing options, there is greater flexibility to optimise stope selection. AMIRA International coordinated the first large-scale research project to identify an integrated and optimal approach to

underground mine design. While open pit optimisation follows a well-defined template, the variety of deposits, mining methods and mine access methods make underground optimisation a far more complex problem. The catchphrase was to produce a 'Whittle for underground'.

Various researchers around the world had developed solutions for individual tasks in the design process, and mining software suppliers had tools for automating the manual design of stopes, development layouts and stope sequencing with resource levelling.

An opportunity existed to develop a methodology and research software that would form the basis for an integrated suite of optimisation tools.

The focus was optimisation for strategic and life-of-mine studies, typically at pre-feasibility stage. This would then be a precursor to more detailed design at a tactical or final feasibility level. The methodology was not to generate a single best or optimal mine design, but to facilitate a Hill of Value study so that the sensitivity of the optimal result to changes in key value drivers could be explored, including



mining method, cut-off grade, and production and development rates, among others.

The first three-year AMIRA research project (2007–2010) was P884 'Planning and Rapid Integrated Mine Optimisation' (PRIMO). This was followed by two additional AMIRA projects, where the research team was reduced to two providers, Alford Mining Systems (AMS) and AMC Consultants Ltd. The two projects were P1037 'Optimisation of Stope Design and Stope Layouts' and P1043 'Rapid Automated Underground Mine Optimisation Framework'. These projects were complementary and built on the methodology identified in PRIMO, but with the goal of an integrated tool chain built on a common software architecture. Sponsors agreed that the acronym SIRUS (Latin for an 'underground granary') be applied to the new project.

The projects have a somewhat unique structure, as the goal of the research projects is to deliver the research as a commercially supported product. Too many research projects produce a piece of research software on a CD, and the value is lost as the industry software providers are unable to deploy the results.

The P1037/P1043 projects have developed optimisation engines for each stage of the strategy optimisation tool chain:

- ▶ stope shapes – producing the optimal set of stope shapes, given a cut-off, stope geometry and geotechnical constraints
- ▶ stope layout – aggregating shapes into larger mining blocks and panels, removing outliers, and, in some cases, choosing different stoping methods depending on ore width
- ▶ development layouts – generating level layouts that 'make the mining method work', based on engineering design rules
- ▶ access – adding ore passes, declines, shafts, et cetera, for access and ore transport to 'make the mine work'
- ▶ stope, development and access sequence optimisation for the life of the mine

- ▶ automated scenario generation and computing execution controllers
- ▶ Hill of Value analysis: to visualise the overall response of value to changes in various decisions and external scenarios in order to facilitate informed decision-making, rather than simply identifying a single optimum strategy.

The goal in each stage is to produce designs in a rapid, automated and comparable format, with calibration factors where the automated designs do not exactly match what might be produced with a fully engineered design.

A research user interface has been developed so that the research deliverable can be accessed by the sponsors. This would be replaced by a commercial user interface after the research deliverable goes through a product development phase where additional functionality can be added, and extensive testing and validation completed.

One of the key objectives for the P1043 project was to explore new mathematical optimisation techniques for sequence optimisation. Methods like mixed integer programming (MIP) and genetic algorithms (GA) have been available for decades and were tested in the PRIMO project, but newer hybrid optimisation techniques have been applied in the SIRUS project. Preliminary results indicate that stope-

by-stope scheduling optimisation down to a time increment of one day can be optimised, with constraints on development, production and treatment, and with the objective to maximise net present value.

The tool chain developed is being applied to sponsor supplied case studies, and an extension to the current research project is anticipated to widen the capability of the framework for different case studies. A third commercial release of the stope optimisation engine with all the latest research developments is planned for 12–18 months, and the remaining research is expected to be of sufficient generality for a product release of the whole tool chain to be considered in the next two to three years. In the meantime, the sponsors will be able to use the research deliverable with the research interface. [LAME](#)

The projects are sponsored by key mining software companies CAE Datamine, Maptek, GijimaAST/MineRP and Deswik and mining companies Newmont, BHPB, MMG, Barrick, Vale, Xstrata/Glencore and Boliden.

Further information can be obtained from Chris du Plessis, Program Manager, AMIRA International.

