Mine Schedule Optimization

Point of View

MineRP

Glossary of Terms

***Decision variables*:** A decision variable is a quantity the decision-maker controls. For example, the number of trucks to use to deliver rock to the crusher may be an equipment scheduling decision variable.

***Mathematical model*:** A mathematical model is a description of a system, using mathematical concepts and language. The model reduces a problem to its essential features, to clarify assumptions, variables, and parameters.

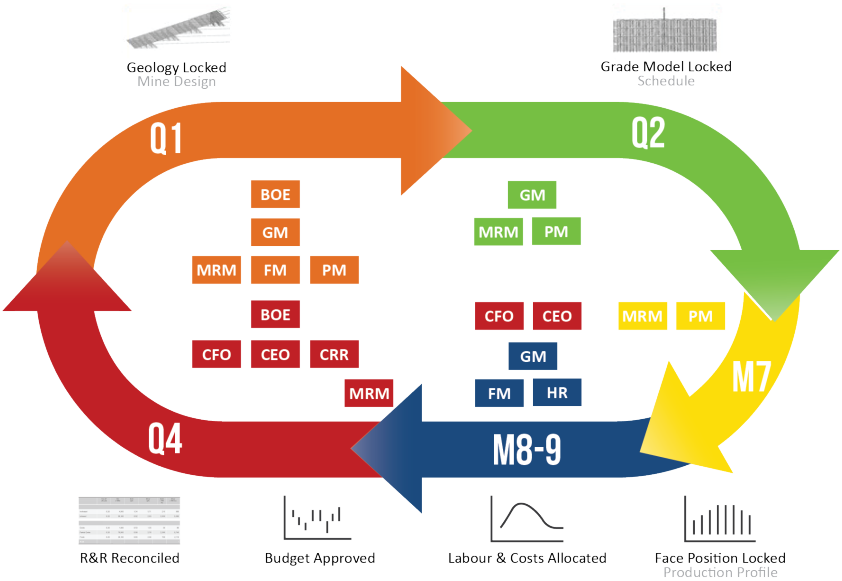
***Optimisation solver*:** A solver is mathematical software that can easily be applied to other problems of similar type. Generally, solvers decouple the definition of a problem from the approach used to solve it. Thus, the solver itself doesn't depend on the details of a particular problem.

***Solver interface*:** A solver interface is a software layer between the mathematical model and the solver. It translates information in the mathematical model into a suitable data format to be used as input to the solver. This layer of software also translates the solution from the solver back to the mathematical model. This is then turned into business actions.

Industry Setting and Problem

Business Optimisation aims to maximise shareholder value. When it validates corporate strategy it is a success. But it needs a complex, prescriptive analytical approach to offer the most effective capital spend and the most efficient operating plans.

Separated technical and financial domains slow down the creation of planning options. This results in sub optimal decision making and forecasting. Many planning cycles simply have no room for the consideration of business options. So there is a limited ability to respond to demand signals and interruptions to operations.



Audience Roles and Objectives

CEO

A **CEO** must craft the most robust strategy and optimised budget. Then, he or she needs to deploy the crucial resources for Sustainable Shareholder Value. The starting point is data for a snapshot of how well people, machinery and infrastructure are used. Effective management and control then needs to know in real time, how well the business complies to Strategic Direction and Financial & Funding Strategies.

CFO

The **CFO** works in a setting of distinct, unaudited technical & financial data domains. Together with planning lag, this makes it difficult to create realistic CAPEX scenarios and dynamic business plans.

COO

At the same time, the **COO** wants best productivity with routine on-target production. The lack of dynamic planning alternatives is made worse by silo perspectives. They create decision making lag and non-aligned execution.

Head of R&R

The **Head of R&R** puts strategic thrusts in context with optimised CAPEX to maintain a fit-for-purpose reserve availability.

General Manager

The **General Manager** drives for safe, effective mine designs and efficient mining schedules. A slow mine design process and delayed and partial operational feedback impede progress.

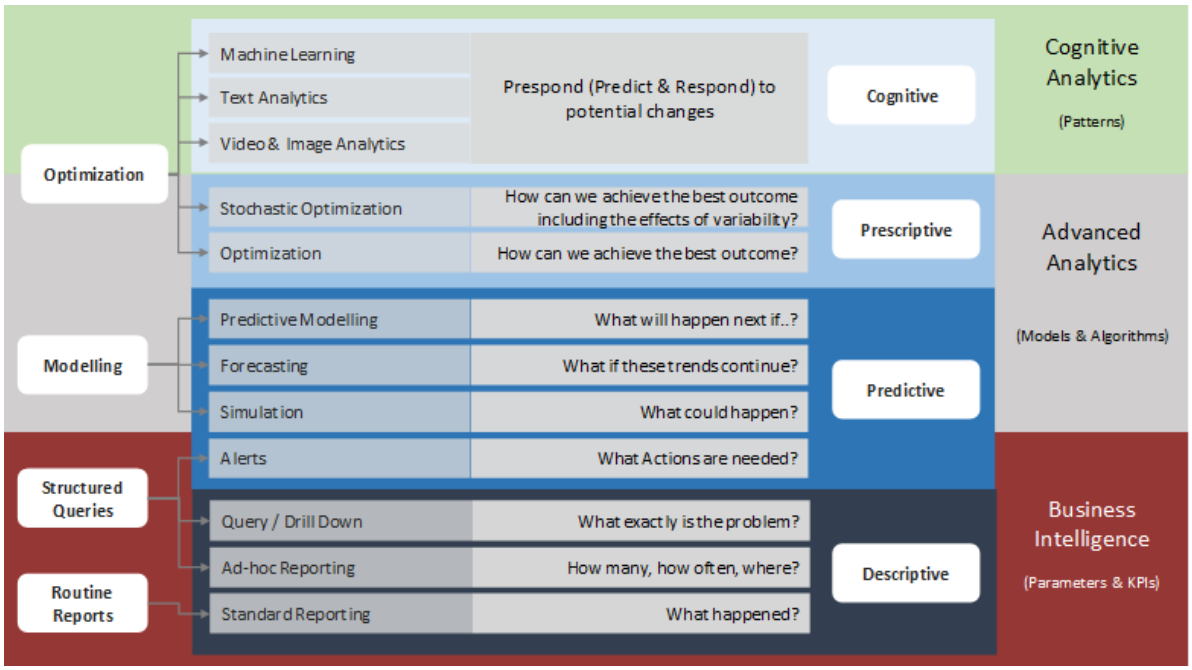
Operations Manager

The **Operations Manager, Mining** would like in-shift (re)-scheduling to respond to disruptive events. Ideally, this means an optimised schedule built on priorities for the use of available resources.

> All these objectives can be accommodated at the same time in MineRP's functionality landscape

Shortcomings of Current Approaches

Advances in IT and mathematics boost the potential for boardroom analytics. Whilst there is a lot of hype around Artificial Intelligence (AI) and Machine Learning (ML), they have over promised and under delivered.



Adapted from: Competing on Analytics, Davenport and Harris, 2007

The main reason for failure of AI and ML in MSO is they were designed for predictive and not prescriptive purposes. They have a specific use for MSO, but don't provide optimal business plans when used in isolation.

A provable measure of quality is vital to avoid having to compete with sub optimal business plans. Other prescriptive approaches e.g. Genetic Algorithms still fall short on this provable measure of quality.

Consensus based approaches are the last class of failed methods e.g. Analytical Hierarchy Process. These are more qualitative in nature and do not support high dimensional, data driven optimisation problems.

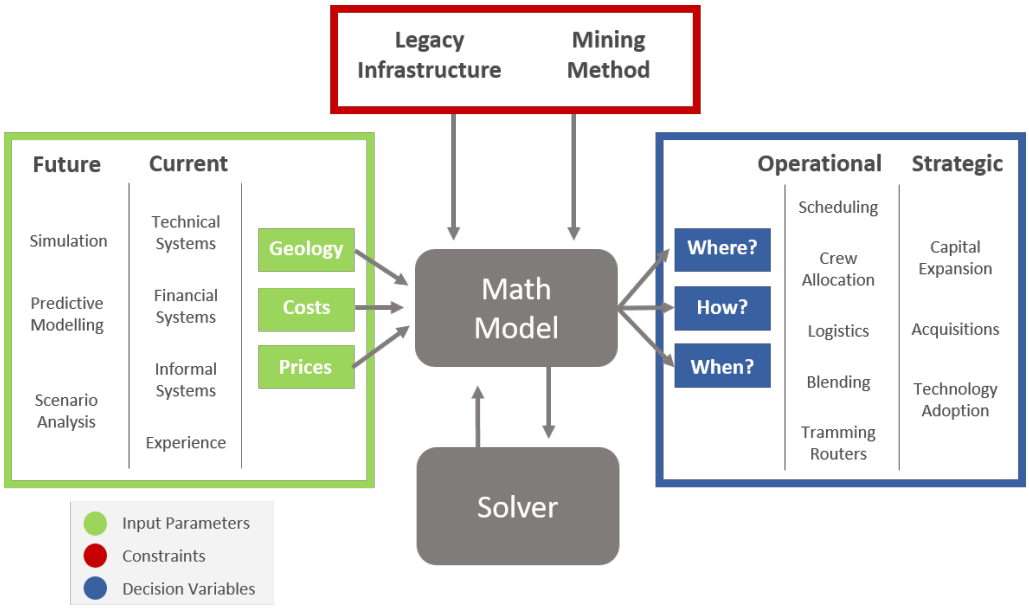
"Whilst there is a lot of hype around Artificial Intelligence (AI) and Machine Learning (ML), they have over promised and under delivered."

The New Approach

CHARACTERISTICS OF MINERP AND ELYTICA APPROACH

Firstly, the Business Question and then the relevant data. Business conversations start with strategy to state a clear Business Objective. This will identify the relevant data. It will also identify its use to the business and the required level of detail. Many business questions can then be answered with quite small adjustments to input data.

Answers generate more questions. Answering difficult questions needs a formal approach such as a Decision Tracking Register and Version Control. Difficult questions could be knowing which capital expansion project to start and when to start it. It might also be for example, the assessment of corporate acquisitions or impact of technology adoption.



To formulate an optimisation problem, the following inputs are needed to construct the mathematical model:

- Decision variables
- Constraints and
- Model parameters

To obtain any useful "answers" from the model a solver is applied. A clear separation of the model and solver with a solver interface allows the use of multiple solvers (proprietary or open source) in a distributed cloud environment. A modular approach to the IT architecture also gives the system more flexibility. This allows for more business and strategy constraints and objective functions (e.g. maximum NPV or cash flow) to be considered.

The New Approach (continued)

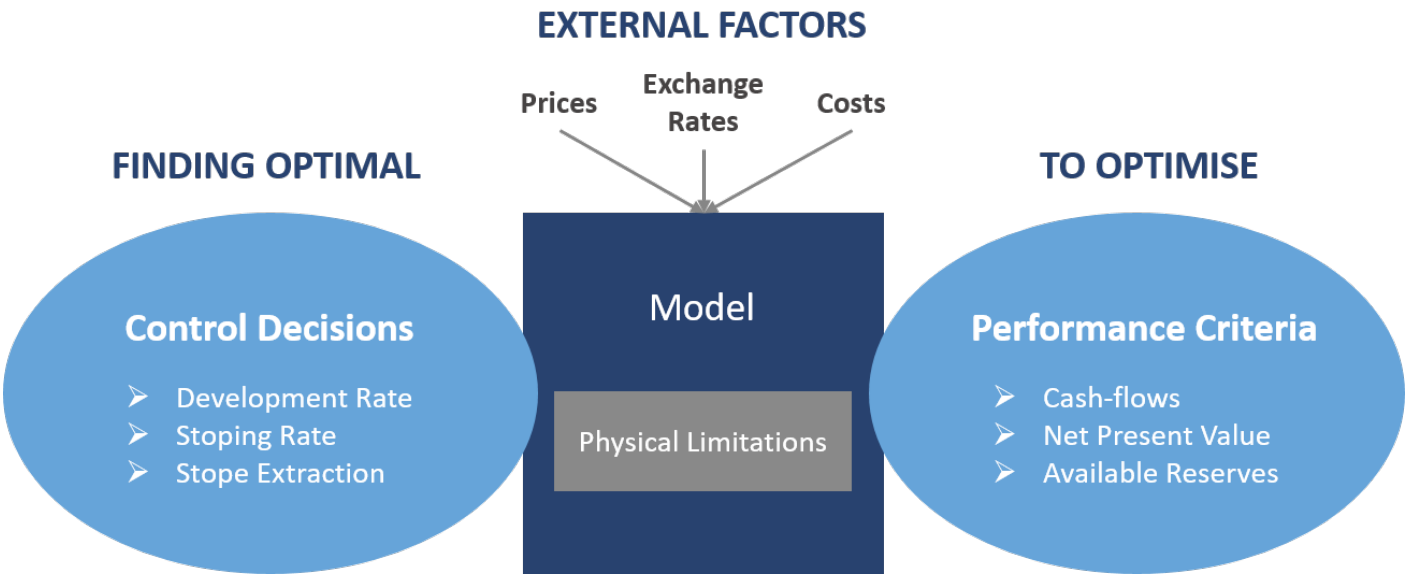
MineRP's partner, Elytica, sets up and maintains the models with concise and efficient work flow. Standard models for the mining domain leave the solver's efficiency to handle the complexities. Here, 'efficient' means finding good solutions in a reasonable amount of time.

Decision variables cover a wide range of items e.g. resource allocations, production rates, blending targets, tramming routes. These items are prescribed to the decision maker to achieve the business objective. Any business constraints at any level of detail, may be expressed as decision variables and added to the model.

Benefits and Proof Points

This approach to optimisation can provide a variety of Business results e.g.

- Recognising what causes profitability
- Uncovering the relationship between the commodity price and mine life
- Exposing long term impact of short term decisions e.g. saving costs now but reducing profitability later
- Understanding how small changes to a schedule impact business targets
- Deciding on timing of development to meet business objectives
- Having all the data available for post-optimisation analysis



Benefits and Proof Points (continued)

Corporate strategy may be aimed at e.g. optimising NPV, Life of Mine or cash flow. MineRP's approach removes the lag from developing mine plans in support of business objectives. This means production, financial and logistical plans can all be driven by available ore reserves. They are also informed by the latest operational results and downstream market demands.

Other datasets can also be used e.g. contractor development costs, different mining efficiencies and costs. For example, we can examine early production build-up, impact on future production levels or look at informed long term decisions.

Critical Success Factors

Mining Schedule Optimisation (MSO) drives results based on the potential of the mineral asset and aligns with integration of the Mine Technical Systems (MTS) and Enterprise Resource Planning (ERP) domains. Turnaround time of planning cycles is imperative for all levels of planning and is achieved through efficient data flow from MTS and ERP systems to MSO systems. Thereafter, innovative modelling and problem solving methods make good use of computing power.

Elytica novelty lies in the way problems are abstracted and how solutions are computed. For example, knowing the % from the true optimum value gives mathematical confidence. Mining confidence comes from MineRP tools to see the mining logic in 3D with animated schedule results.

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