A reliable guide

Sufficient and reliable supply of mineral commodities is an indispensable basis for the development and performance of any industrialised economy. For example, every German citizen consumes more than 950 t of mineral raw materials, including fossil fuels, metallic ores, industrial minerals and aggregates during an average 78 year lifetime.

The economic growth of developing countries and a rapidly growing global population cause demand for mineral commodities to increase year by year, accelerating in the last decade to new records. More than 12 billion tpa of solid mineral commodities are currently mined.

As internal mass transport in the mine is estimated to cover about 25% of total energy consumption of mining projects, it is an important issue regarding costs and greenhouse gas emissions. Haulage is an interesting field for optimisation.

The basis for any optimisation is predominantly a technical and economical evaluation of the employed or planned system and the final comparison of results for different possible solutions.

Apart from technology and costs, environmental aspects are increasingly focused on by society, politicians and authorities and therefore also focused on by decision makers within the mining industry.

Dr David Buttgereit, XGraphic, and Prof. Hussein Tudeski and Thomas Hardebusch, TU Clausthal, Germany, discuss the use of economic and ecological analysis software and its use in mining, engineering and material handling operations.
The Mining-Calculator software offers opencast mining and earthmoving projects, a technical, economic and environmental evaluation, integrating various machine types and both discontinuous and continuous haulage systems. One project can be simulated with different loaders and haulage systems, leading to a user-defined comparison of variants and providing a solid base for strategy and investment decisions.

**Data input**

To start, basic project data, such as material type and characteristics, as well as annual production, is requested.

The program database offers a large variety of different mineral commodities with specific properties, e.g., solid and bulk densities. Those values can be edited by the user to adjust the values individually to practice.

The most important basic value for dimensioning of equipment is the requested total annual or hourly production, usually composed of production at several loading points. The calculation methodology of the program is based on the individual performance calculation for each loading point and the following combination of those individual results.

For the purpose of material loading, hydraulic shovels, electric rope shovels and wheel loaders are available. As the software works independently from equipment manufacturers, no brand or model names are displayed. Machine classes are used instead, orientated at the product portfolio of the actual market. The name of each type consists of the abbreviation of the loader type, the machine weight and the standard shovel volume. Performance data, such as bucket fill factor or availability of loaders can be adjusted to meet the user’s individual requirements.

The program integrates discontinuous and continuous haulage systems, off-highway and articulated trucks, as well as belt conveyors.

In principle, two different project types can be developed:

- Truck: discontinuous haulage only.
- Belt: a combination of discontinuous and continuous haulage.

As for loaders, the software works with machine classes for haulage systems as well. The name of each hauler type consists of the abbreviation of the truck type and the regular payload. The name of a belt conveying system provides information about belt width, speed and type.

The given number of loading points results in a corresponding number of haul roads, which must be defined by entering different sections or uploading a predefined track. The track profiles are interactively visualised for a better control of the data input (Figure 1). The procedure for the definition of the belt sections is identical.

**Equipment selection and filtering**

Based on the input values, the performance data of the different systems and internal calculations, all adequate equipment combinations are computed and displayed in tables. To avoid excessive data in further calculation steps and the final visualisation of results, the user may preselect, and thereby reduce, the number of equipment combinations considered (Figure 2).

Furthermore, an initial analysis of the calculation results for the selected equipment combinations is offered by charts and tables. Each preselected combination of loaders and trucks can be displayed at all loading points.
showing, for example, speed profiles of trucks and haulage cycle times.

**Costs and environment**

Taking into account costs and environmental considerations, Mining-Calculator ensures the basic parameters regarding these are requested for all machines. This general data input is followed by machine-specific forms for all loaders, haulers and/or belt conveyors. This is necessary for cost calculation and determination of CO₂ emissions of the different systems.

The most important elementary data consists of the fuel price, the electricity tariff and power consumption, as well as the levels of CO₂ emissions, depending on different types of power generation.

Fuel consumption of diesel-powered, mobile equipment covers a wide range and is significantly influenced by the operational conditions of the project. Under poor conditions, the diesel consumption of trucks can more than double in comparison with optimum conditions. Since the conditions are the same for all previously calculated and selected machines, a flat default of the fuel consumption for both loaders and trucks can be set in three categories: minimum, medium or maximum. This value is used as an indicator for the consumption rate of specific machines later on.

Since the power consumption for belt conveyor systems is explicitly based on the calculated drive power and operating hours, at this point no input for continuous transport systems is required.

Diesel-powered equipment does not have alternatives for fuel. Calculations of CO₂ emissions are therefore based on a fixed value of 2.65 g of CO₂/1 of combusted diesel. CO₂ emissions of electric equipment are directly related to the type of power generation, which can be chosen from a list or entered as a specific project value.

All individual machines within the selected equipment combinations are listed in individual folders. Machine-specific data must be edited as the base for the economic and
environmental assessment of each equipment combination and the final comparison of results. The basic structure of the forms is the same for all machine types and is divided into two categories: capital and operating costs (Figure 3). Finally, an overview of capital, operating and total costs is displayed. As purchase prices are specific to regions or purchasing companies, no default values are specified. To avoid frequent repetition of entering the prices, the user can build up individual cost databases, which can be loaded into a project file.

When implementing an alternative loading and haulage solution, additional costs can be generated, which are not covered by data input for equipment. Examples are costs for the relocation of the primary crusher or extensive earthworks for new haul roads or conveyor tracks. With this in mind, the user can enter additional investments, which are integrated in the cost calculation as the sum of depreciation and interest.

**Results and data evaluation**

The final table includes all chosen equipment combinations and displays the most important calculation results, such as cost/t, gCO₂/t or operation cost/hour. By sorting the table by any column, the user can analyse the resulting data and focus on the most important criteria.

In addition to the resulting data table, a variety of diagrams are available for graphical analysis of the resulting data. Different dual bar charts, based on two calculation parameters, can be created (Figure 4). Furthermore, an individual analysis of the cost structure for a selected project variant can be performed by pie charts, showing either only the percentage ratio between the capital and operating costs or a detailed partition with subcategories for the two types of costs. Finally, a direct comparison of the cost structure of two project variants is possible by choosing a second equipment combination that shows the percentage difference in specific costs (Figure 5).

All resulting data tables and diagrams can be exported either to spreadsheets, or into a screenshot for presentations or documentation.

**Project comparison**

The primary goal of the Mining-Calculator is the comparison of different loading and haulage alternatives for a given project. This implies that, ideally, all the basic project parameters, i.e. material properties and production rate, are identical for the chosen project alternatives. The software offers a copy function for the entire basic project, which can be modified into a new project alternative, for example, by changing the haulage system.

The calculation results of all project alternatives can be compared with each other to detect the overall optimum variant. The project comparison always includes two project alternatives. Similar to the evaluation of variants within a single project, the comparison of equipment combinations in different project alternatives are provided in a table and can be displayed in dual bar charts for all selectable calculation parameters and cost structure pie charts.

**Conclusion**

The Mining-Calculator aims to optimise mass transport in mining and earthmoving projects.

The software includes equipment selection and dimensioning, as well as cost calculation and determination of CO₂ emissions for discontinuous and continuous haulage. Thus, in a single step, different scenarios can be compared and evaluated by illustrating the results in various diagrams and tables.

Calculation results offer a reliable base for in-house decisions on technical aspects, such as equipment modifications, monetary aspects, including specific cost/t or total investments, and finally greenhouse gas emissions.