MINE TWIN

OPENPIT AND UNDERGROUND MINES SIMULATION

MineTwin Undergound

User guide

https://mine-twin.com/

Content

1. Introduction

1.1. Purpose of the document

This document describes the tool for planning and simulation of mining operations. The document is designed for users of MineTwin as a source of knowledge about the tool.

1.2. System description

MineTwin Underground allows to perform scheduling and simulation of mining operations that occur in underground mines.

MineTwin Underground consists of the following modules:

1. Editor
2. Scheduler
3. Simulation model

The editor allows you to create and edit scenarios directly in the MineTwin Underground user interface or in MS Excel files.

MineTwin logic is divided into two blocks - a scheduler and a simulation model. MineTwin's work consists of two sequential stages:

1. Equipment scheduling is performing by the scheduler.
2. Simulation of equipment and transport operation is performing by the simulation model based on a plan created by the scheduler.

In MineTwin scheduling mode one shift scheduling and simulation is performed sequentially. At the end of the shift the scheduler performs scheduling for the next one based on the results of the execution of the previous shift plan by the simulation model.

1.3. System requirements

MineTwin requires 32- or 64-bit Windows 7 or higher.

Microsoft Office Excel 2007 or higher must be installed on the PC.

2. Scenario creation and editing

2.1. Preparing the input file

The MineTwin Underground scheduler and simulation model require the preparation of a scenario - an Excel file that contains the needed set of input data.

MineTwin Underground allows you to create scenarios directly in the system, providing the user with the ability to conveniently add/remove elements of the mine field, types and units of equipment, change equipment and transport schedules, assign equipment and transport to mining areas, etc.

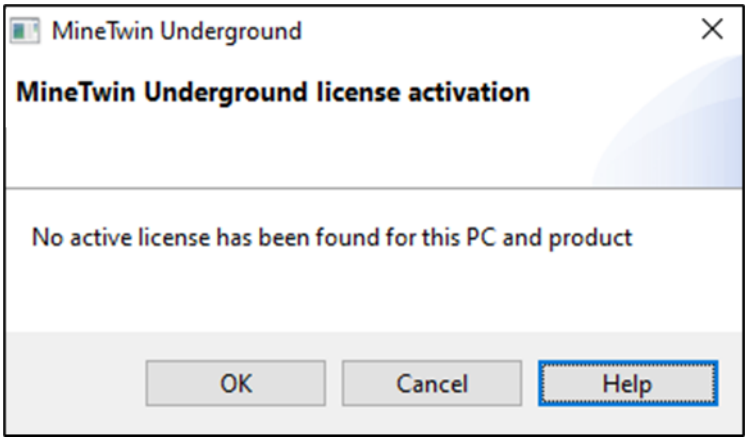
A MineTwin Underground user can also create a scenario in an Excel file using data from the mine's own internal information systems.

For industrial operation at the stage of implementation of MineTwin Underground, it is planned to integrate MineTwin with internal systems of the client.

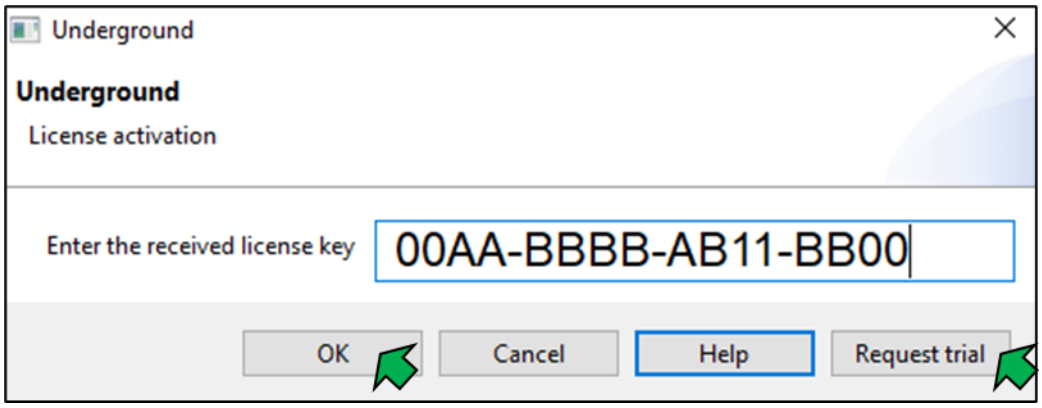
2.2. Launching the application, loading the editing mode

To install the MineTwin Underground application on your computer, you need to unzip the ***"MineTwin 0.1.0"*** folder and save it on your local computer.

1. MineTwin Underground is launched from the unzipped folder by launching the ***MineTwin.exe*** application ( ).
2. If MineTwin is launched on a PC for the first time, the system will inform you that the license was not found.



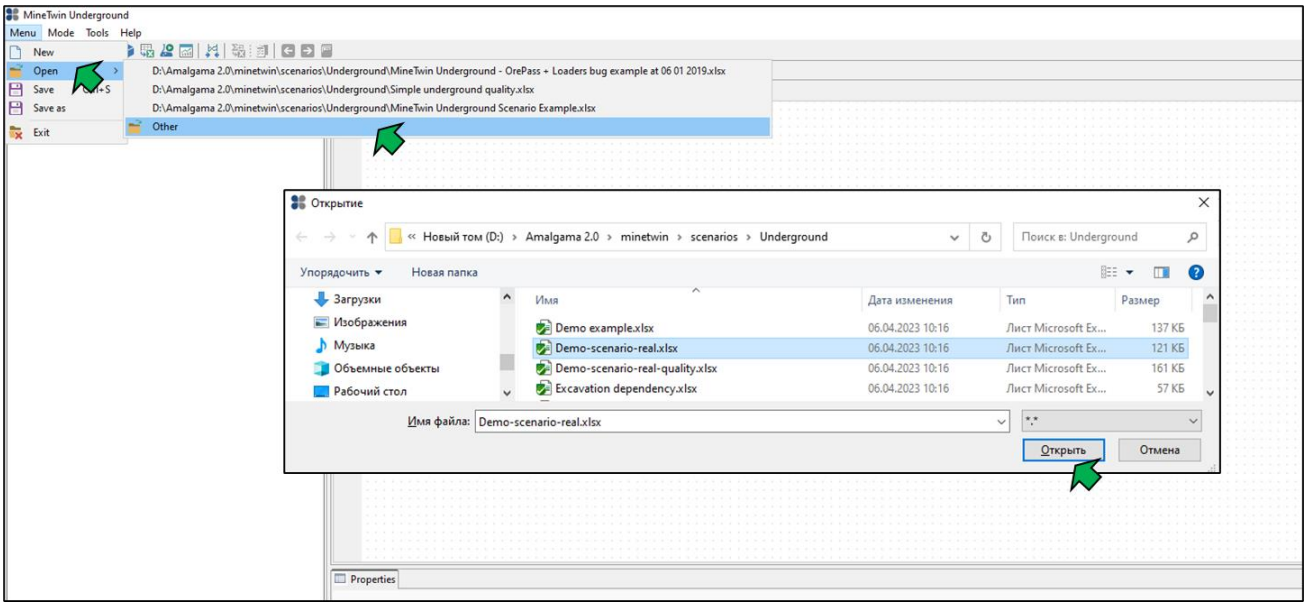
3. After clicking on the "OK" button, a license entry window will open, where you need to enter the received license key.



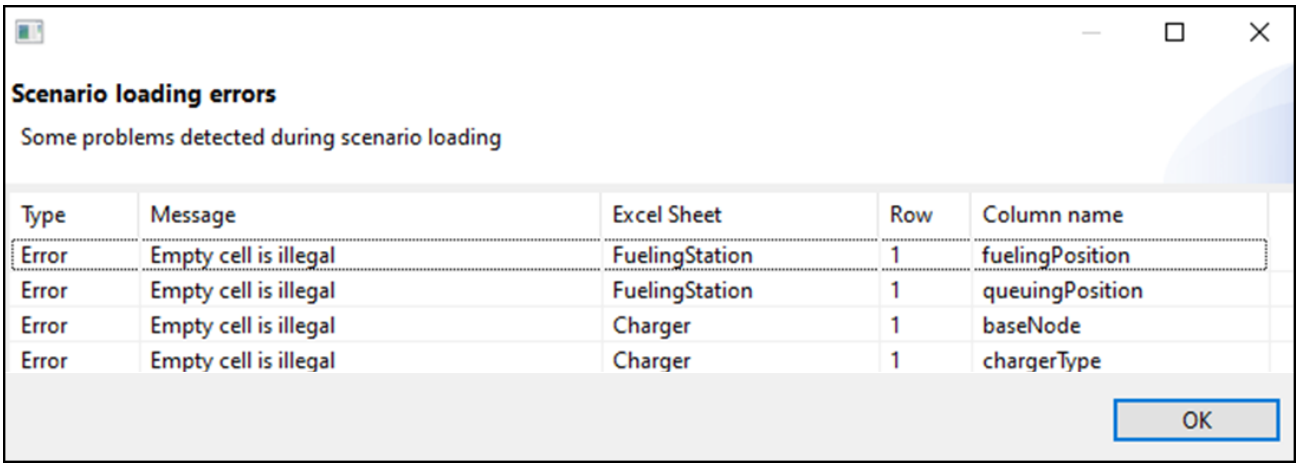
If the key is correct and it is not activated on another PC, MineTwin Underground will be launched.

4. If there is no commercial license, the user can use a trial license, by clicking on Request trial.
5. If there is no access to the Internet while the application is open, you must connect to the Internet or contact the developer, telling a unique PC ID, which opens when you click on Help.

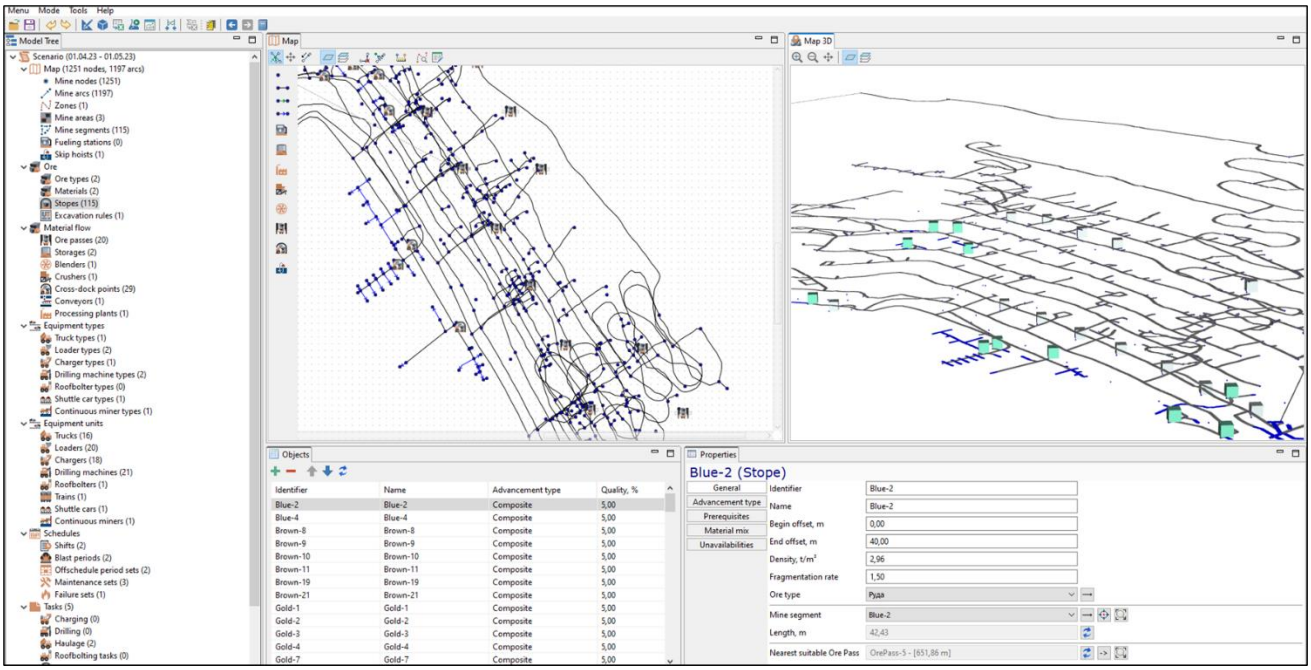
6. After launching MineTwin Underground, an editor mode window will open. Next, open the scenario file by selecting it from the list of recently opened scenarios or from the scenario storage location, or create a new scenario.



If the opened scenario contains errors, a window with a list of errors will open, indicating the name of the Excel file sheet, the numbers of columns and lines that contain errors. The user can open the list in a separate file and sequentially correct them in the downloaded Excel file, or download the scenario file with errors and then fix them in the system.



After opening the scenario in the MineTwin Underground interface, the scenario editing mode window will open, the appearance of which is shown in the figure.



The editing mode contains several windows, which sizes can be changed by selecting the side of the window and holding down the left mouse button. Any window can be moved from one part of the interface to another by clicking on the required window with the left mouse button and holding it while moving.

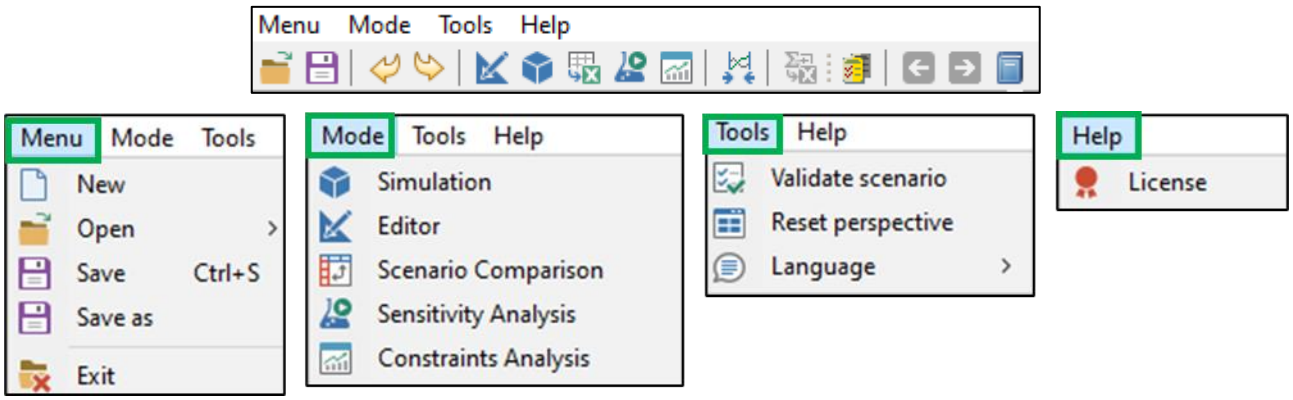
To open the selected window to full screen, you need to double-click on it, to return to normal mode, double-click again or use the function "Restore windows arrangement".

2.3. Elements of the scenario editor

The scenario editor allows you to create, review, edit and save scenarios.

2.3.1. Toolbar

There is a toolbar at the top of the editing module.



The "Menu" button contains the following functions:

- create a new scenario ( )
- open scenario ( )
- save scenario ( )
- the "Save As" function
- exit ( ).

The "Views" button is used to switch between the modes:

- Editor ( )
- Simulation ( )
- Scenario Comparison ( )
- Sensitivity Analysis ( )
- Constrains Analysis ( ).

The "Tools" button contains the function:

- validate scenario after its creation/editing
- reset perspective
- language switch (Russian and English are available)

The "Help" button contains information about the license under which the system is open.

If it is necessary to cancel/return a canceled action, use the buttons .

The button synchronizes graphs in the simulation mode.

The button allows to upload simulation results to an Excel file (general statistics, costs, equipment performance indicators, etc.)

The button  allows to import files in .dxf format.

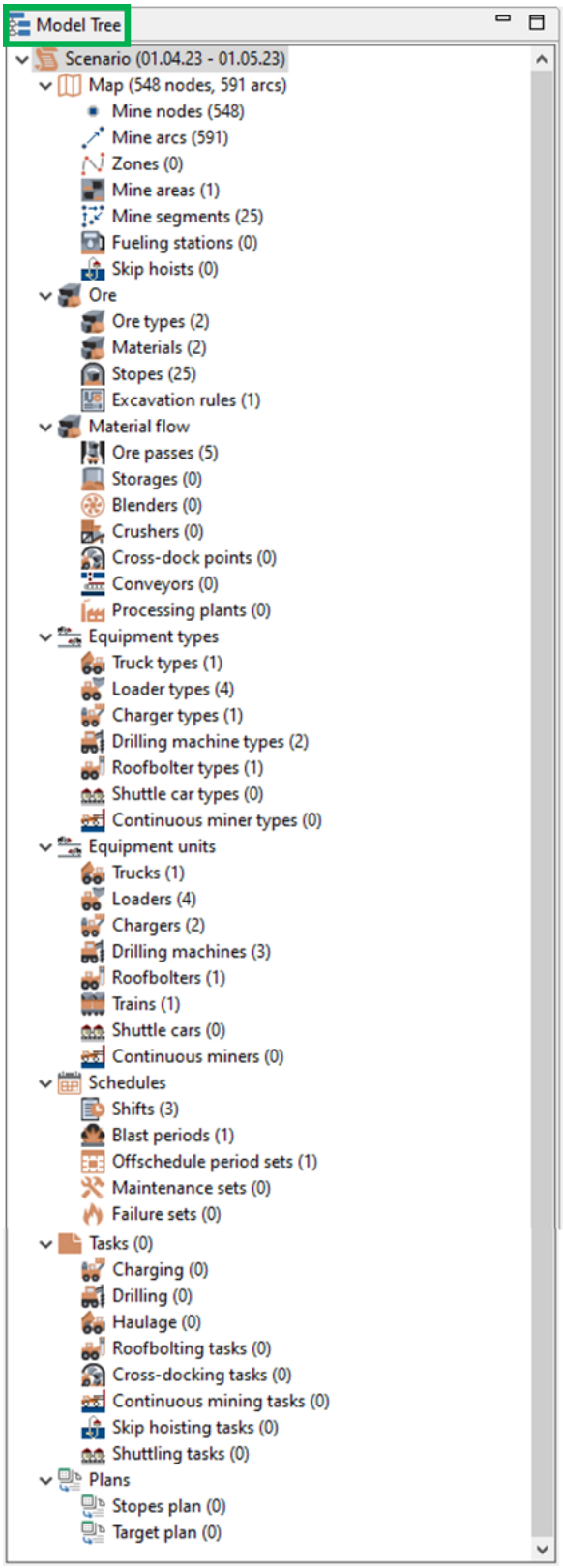
The buttons  provide transitions along related elements, for example, from a mine segment to the related mine arcs or to the stope.

The button  searches any scenario element by its name.

2.3.2. Model tree

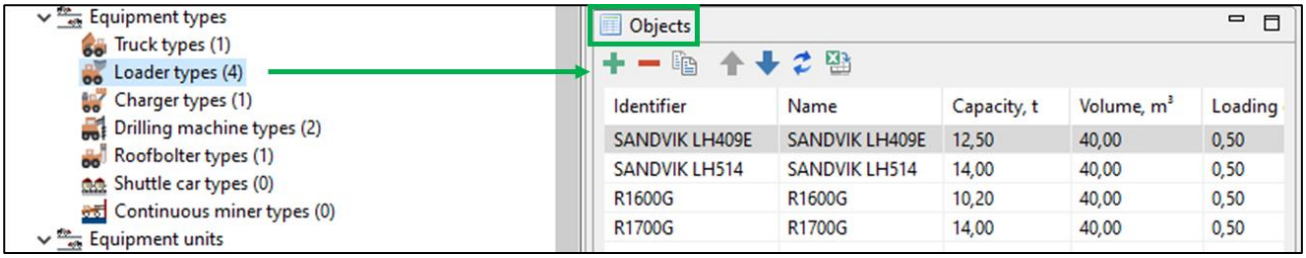
All scenario objects and entities data (parameters of stopes, dump areas, equipment units, equipment operation schedules, etc.) are displayed in the form of a tree and are grouped by types. For each type of object/entity, the number of units of the object/entity is shown.

Blocks of the model tree can be expanded/minimized for easy viewing.

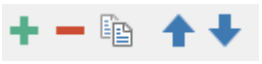

Model Tree
Scenario (01.04.23 - 01.05.23)
Map (548 nodes, 591 arcs)
Mine nodes (548)
Mine arcs (591)
Zones (0)
Mine areas (1)
Mine segments (25)
Fueling stations (0)
Skip hoists (0)
Ore
Ore types (2)
Materials (2)
Stopes (25)
Excavation rules (1)
Material flow
Ore passes (5)
Storages (0)
Blenders (0)
Crushers (0)
Cross-dock points (0)
Conveyors (0)
Processing plants (0)
Equipment types
Truck types (1)
Loader types (4)
Charger types (1)
Drilling machine types (2)
Roofbolter types (1)
Shuttle car types (0)
Continuous miner types (0)
Equipment units
Trucks (1)
Loaders (4)
Chargers (2)
Drilling machines (3)
Roofbolters (1)
Trains (1)
Shuttle cars (0)
Continuous miners (0)
Schedules
Shifts (3)
Blast periods (1)
Offschedule period sets (1)
Maintenance sets (0)
Failure sets (0)
Tasks (0)
Charging (0)
Drilling (0)
Haulage (0)
Roofbolting tasks (0)
Cross-docking tasks (0)
Continuous mining tasks (0)
Skip hoisting tasks (0)
Shuttling tasks (0)
Plans
Stopes plan (0)
Target plan (0)

2.3.3. Objects

The "Objects" window displays a list of all units of objects/entities of the type selected in the object tree, for example, a list of all loaders, stopes, etc.

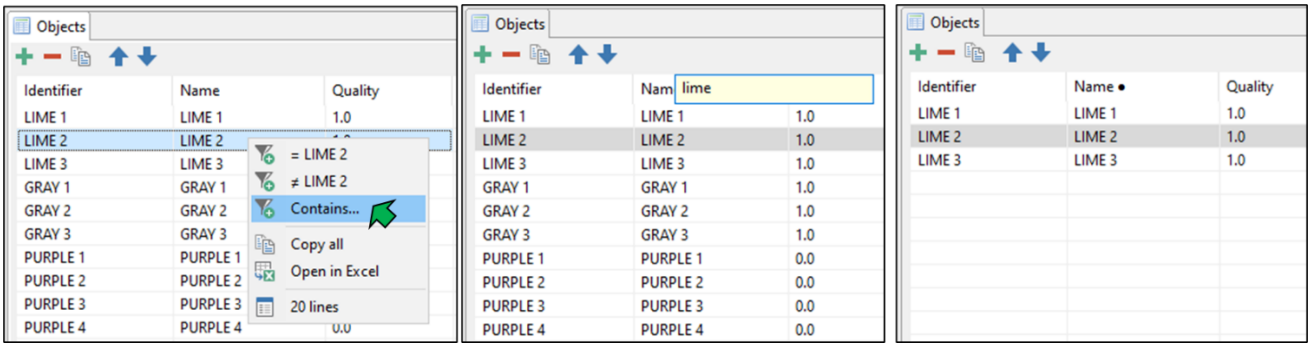


At the top of the "Objects" window there is a toolbar with functions for adding, deleting, copying objects, moving objects up and down.

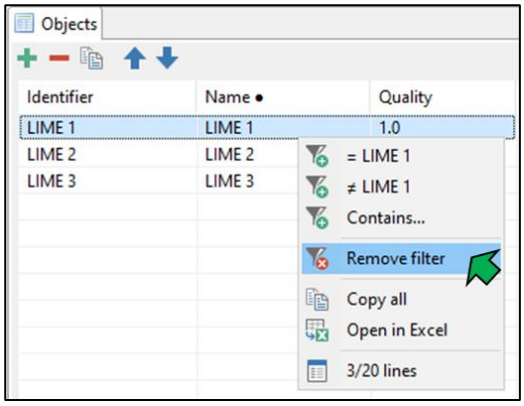


When you hover the mouse over the icon, the name of the function performed by the corresponding button will be displayed.

Sorting of all columns of the data table is available in the table, as well as filters. To apply a filter, right-click on a line in the required column and set the required filter.



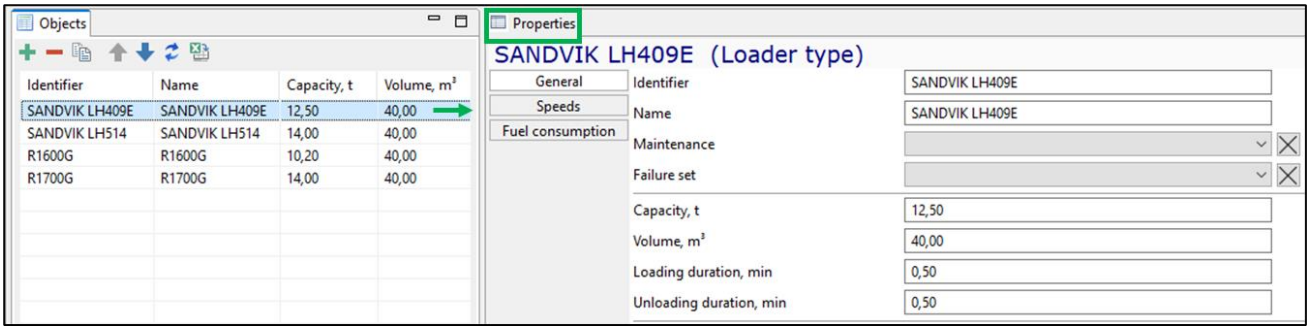
To remove the filter, use the "Remove filter" button in the pop-up window.



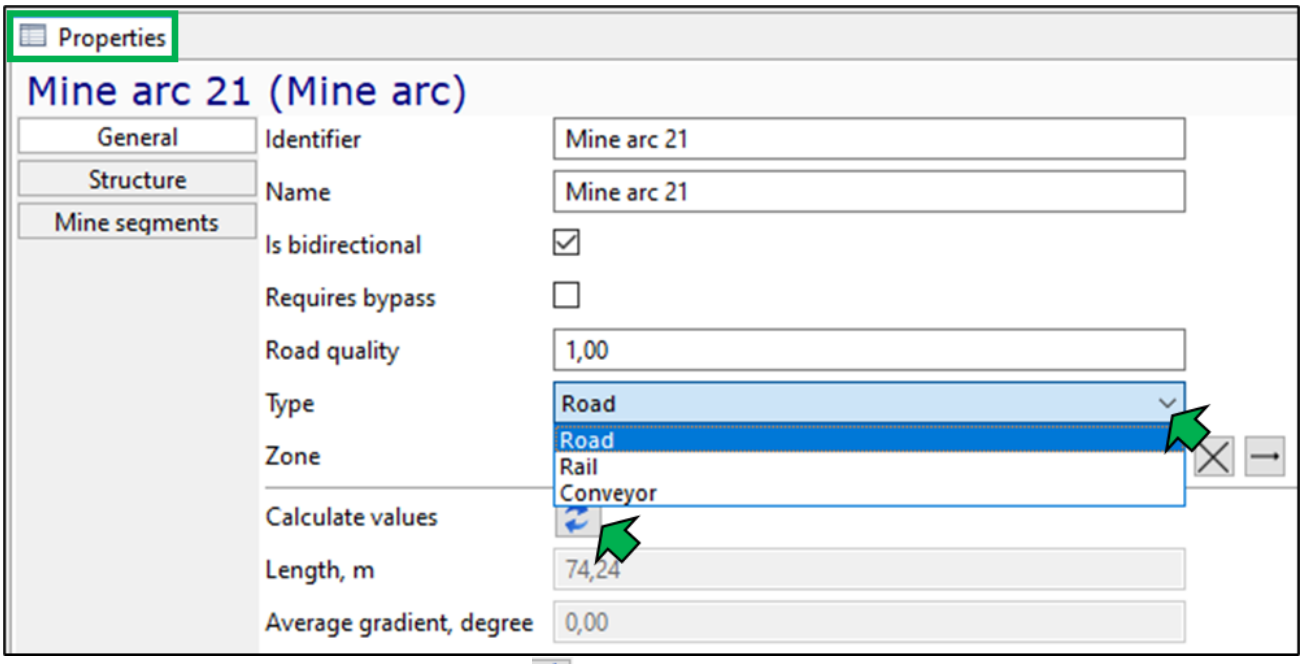
You cannot edit the values in the "Objects" window.

2.3.4. Properties

In the "Properties" window, the properties of the unit of the object/entity selected in the list in the "Objects" window are displayed/edited. To edit the properties of the object, select the object in the list (the "Objects" window) and browse to the "Properties" window.

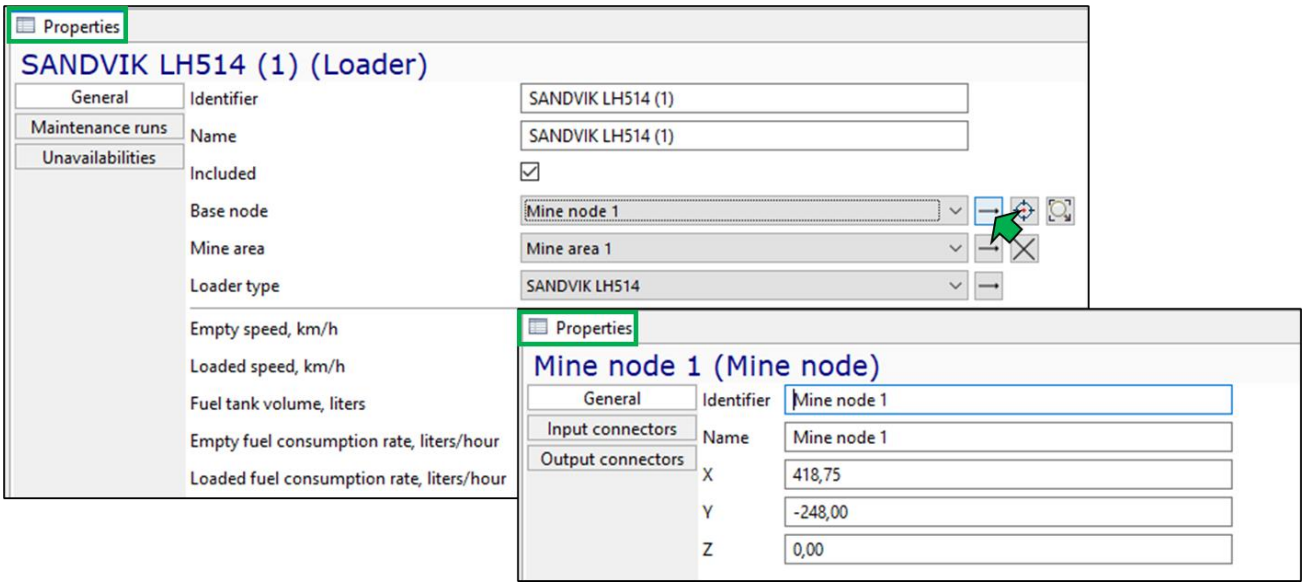


To change the parameters, the values of which are limited by the enumeration, the required value is selected from the drop-down list, removed by clicking on the cross to the right of the field.

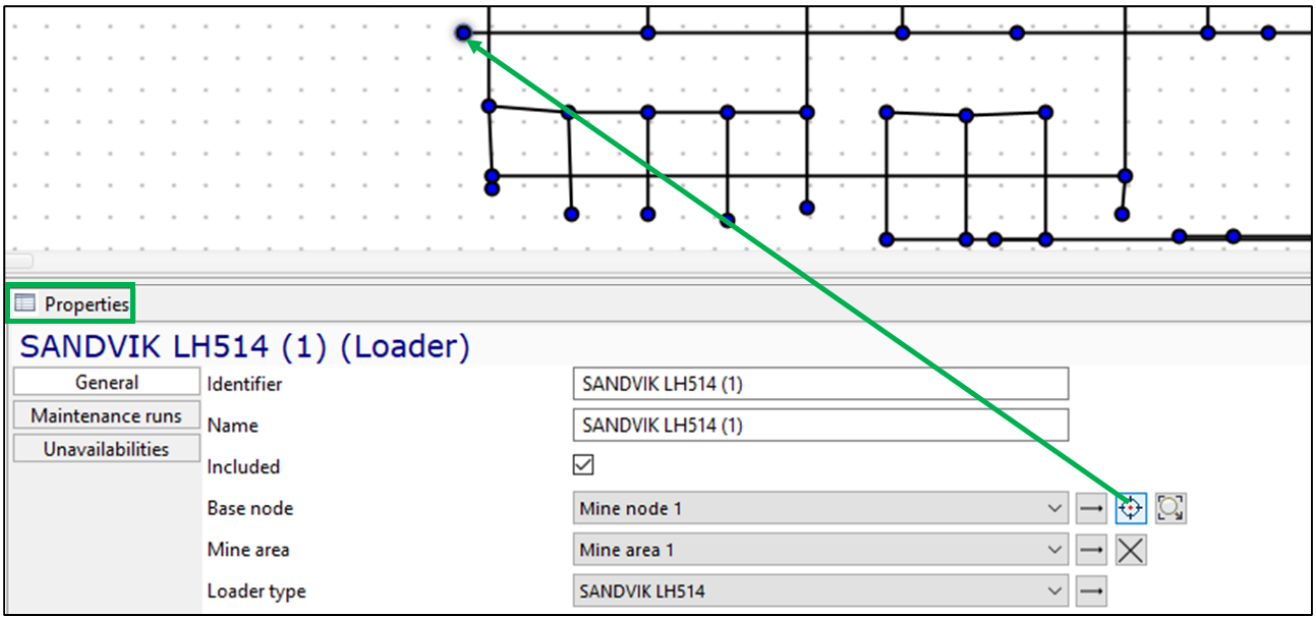


To update the data, use the button  .

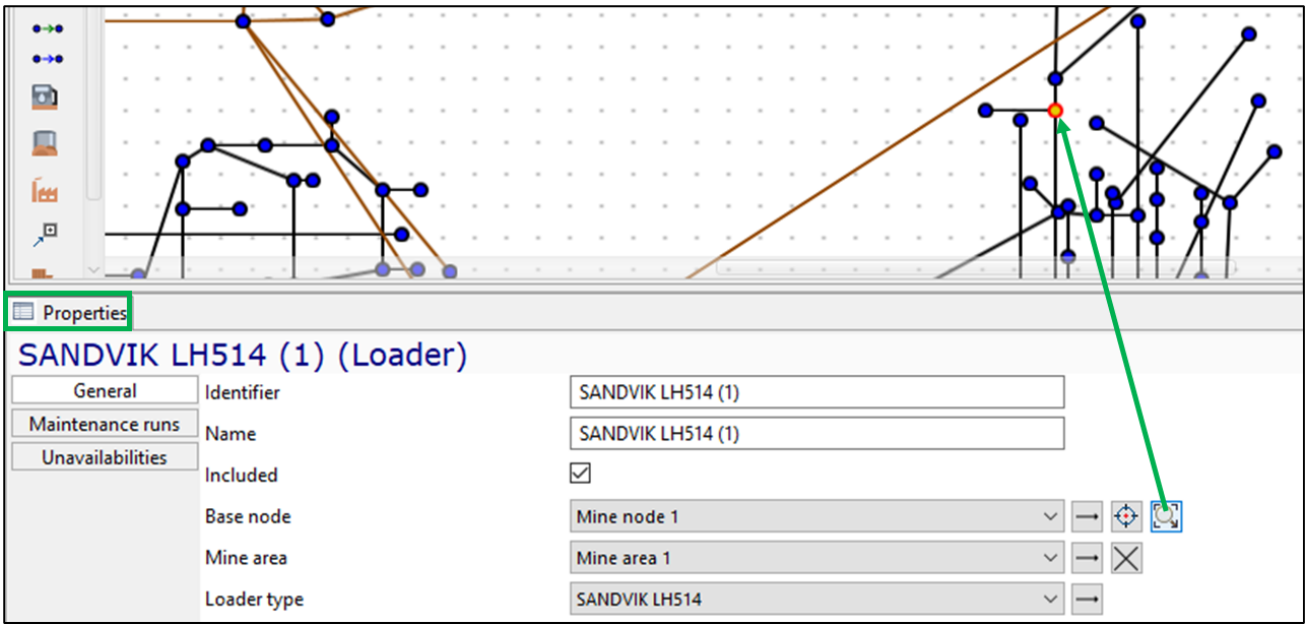
From the properties of the object unit, you can go to the properties of related objects, for example, from the properties of the equipment unit to properties of the type of this equipment unit or to the properties of its base node. To do this, click on the arrow to the right of the field.



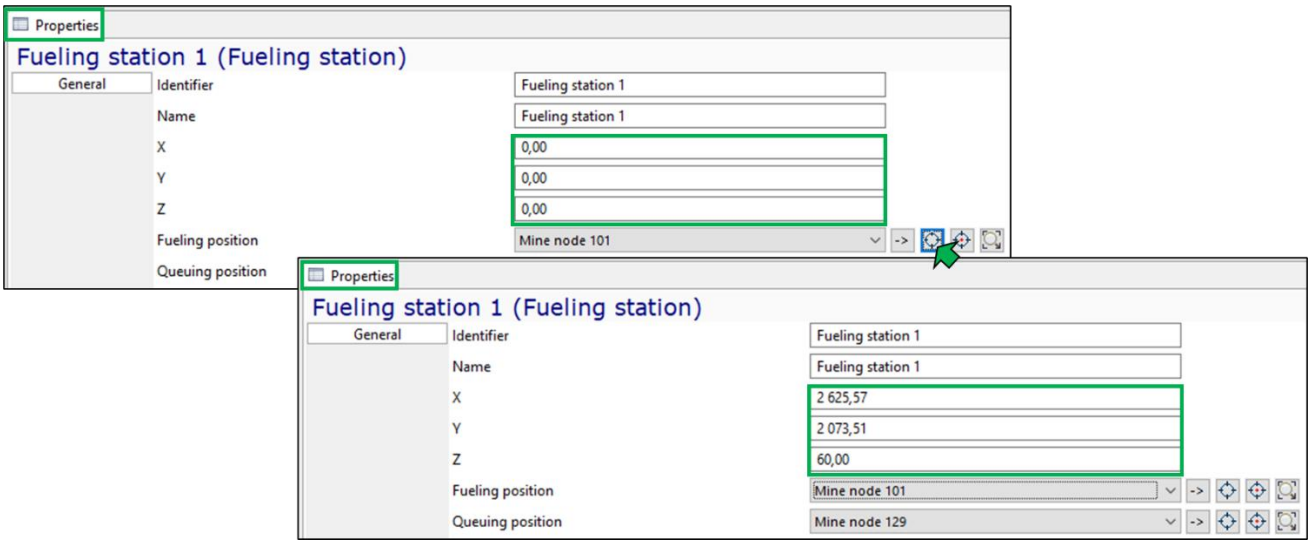
The button  allows you to define a different base node by selecting it on the map in 2D mode.



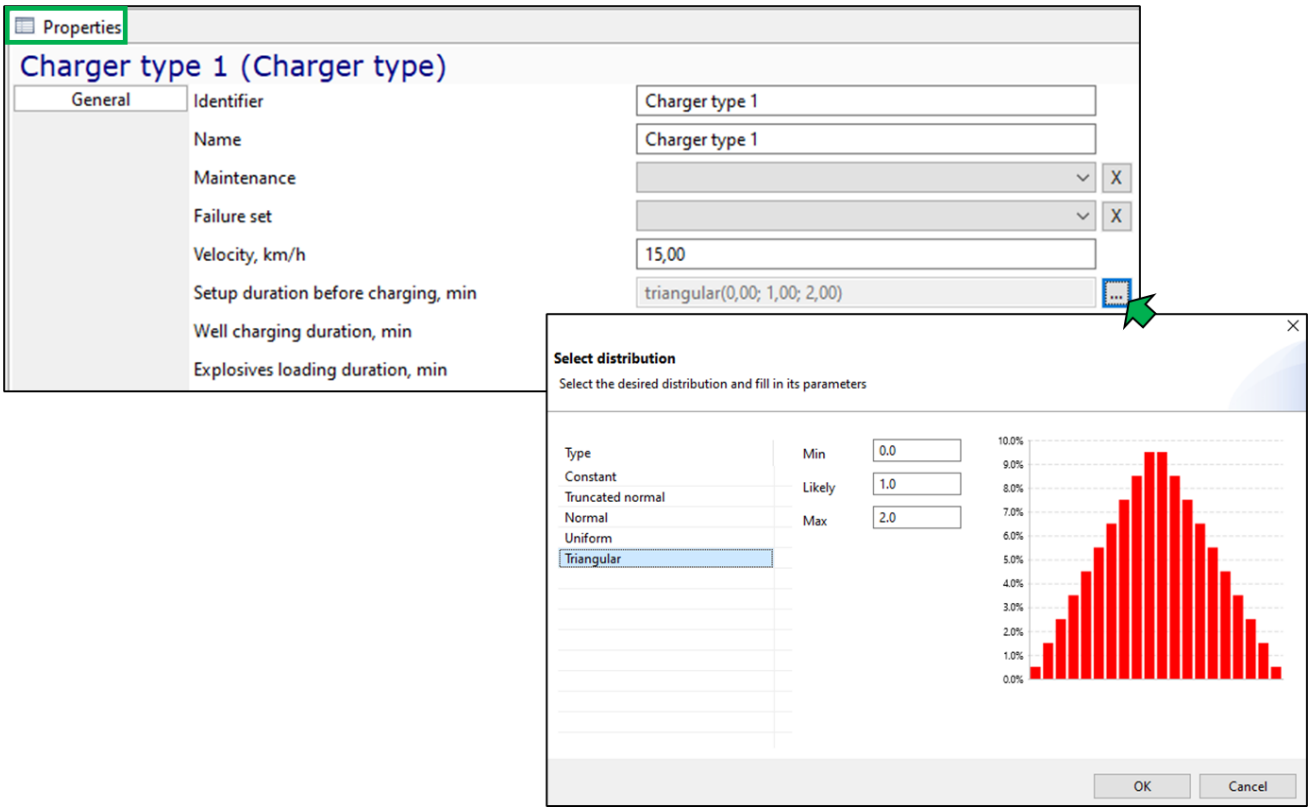
The button  highlights the selected node in the graphical editor (on a 2D map).



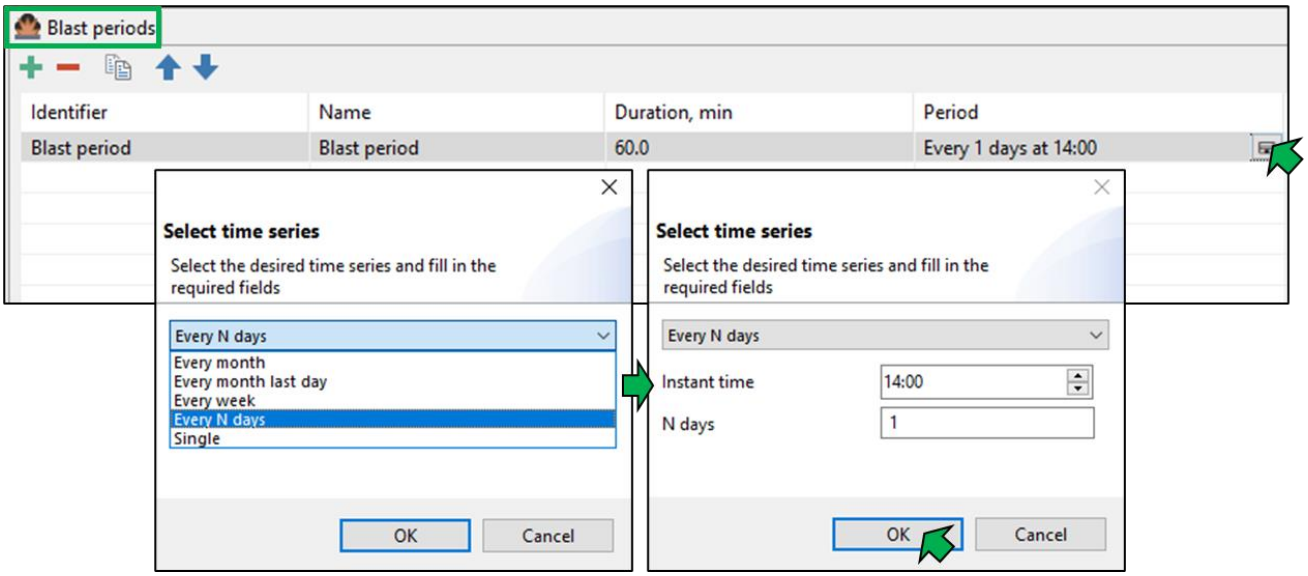
To move the object unit on the mine map to the point of its base node, use the button  .



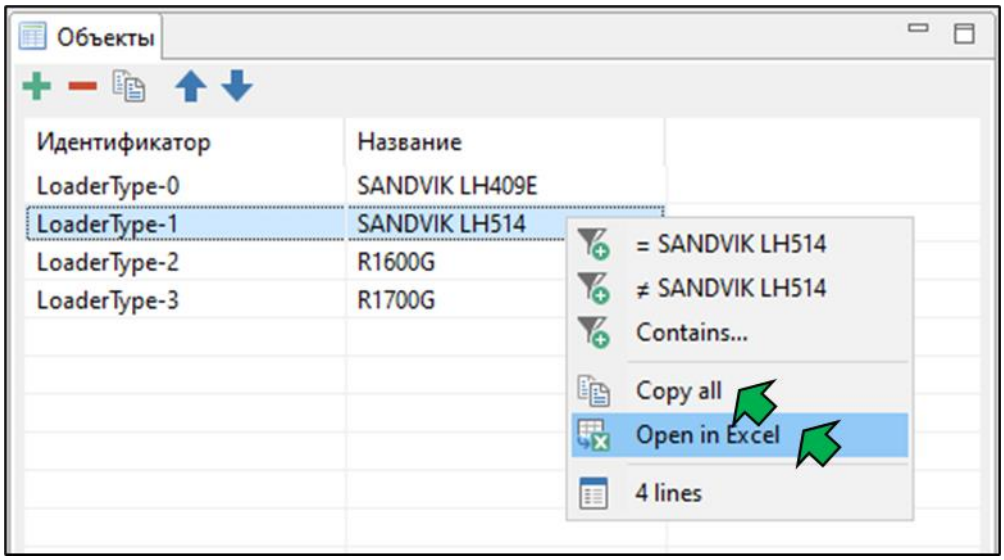
All durations in MineTwin can be set by a constant value or one of the distributions (normal, truncated normal, uniform, triangular). To set the duration, you need to go to the pop-up window by clicking on the button with the ellipsis to the right of the duration value field and select the appropriate distribution in the appeared window.



The time of occurrence of all periodic events in MineTwin can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days).

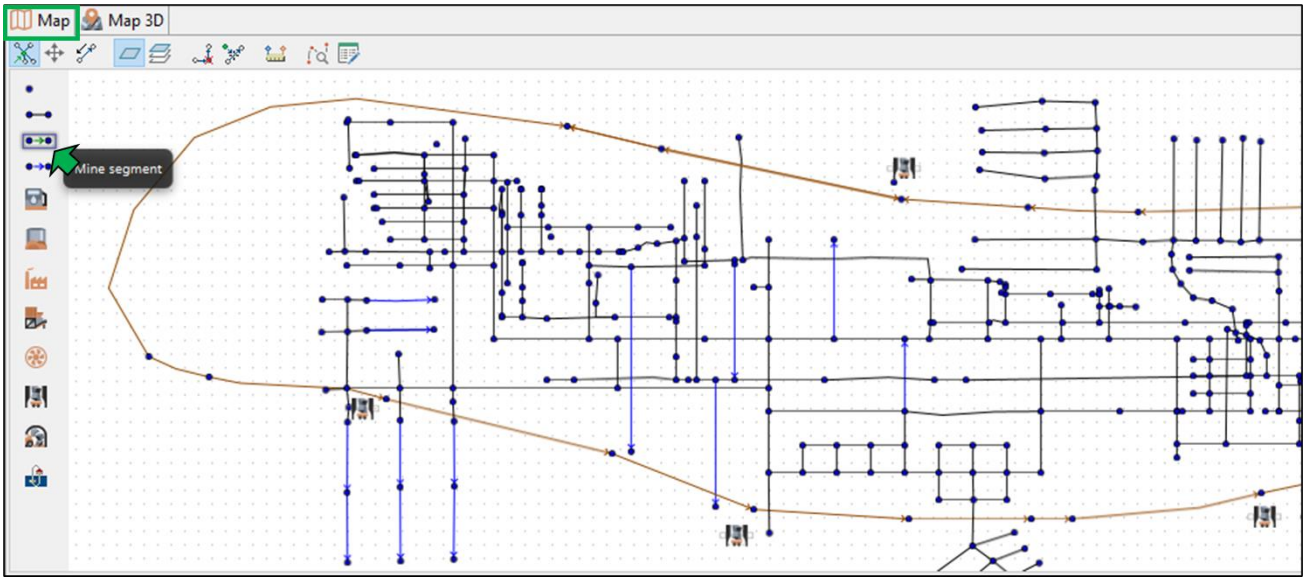


All data from tables can be copied and pasted into Excel for further analysis or directly exported to Excel.



2.3.5. Map

The “Map” window displays a mine plan in two dimensions. The plan in this mode is editable.



Zooming in/out of the mine plan is performed by the mouse wheel while holding down the "Ctrl" key. The plan is moved with the mouse while holding down the right mouse button.

The button  in the upper left corner allows to display on the map the input and output connections of the elements of the system ensuring the material flow.

The button  allows you to center the map.

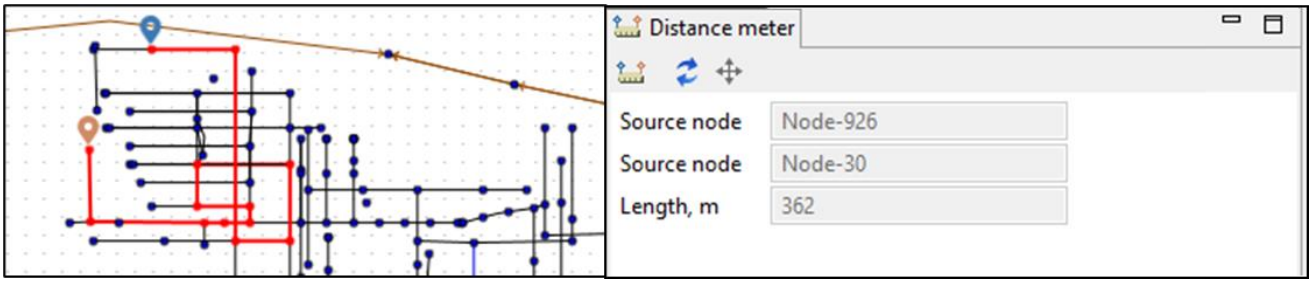
The button  allows you to quickly change the direction of the stope.

The button  activates the illumination of the mine arcs by default, the button  activates the illumination of the arcs by mine zones (Clause 2.5.3).

The button  optimizes arc inflection points - removes inflection points that are on the same line between two consecutive inflection points, of selected mine arcs or all arcs of the scenario, if no arc is selected (Clause 2.5.2).

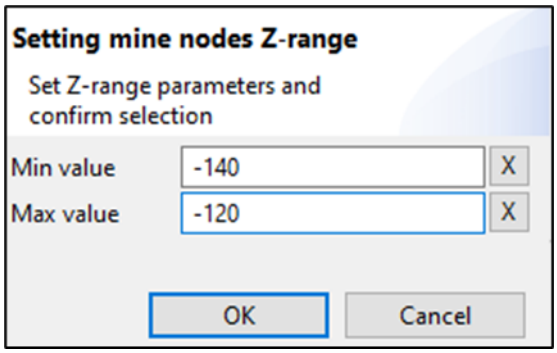
The button  divides mine segments by mine nodes at the intersections of the selected section of the map or all segments, if no segment is selected.

The button  allows to determine the shortest distance between two nodes of the mine field. After clicking on this button, a label  appears, which must be placed on the node of the beginning of the path and clicked with the mouse. Then the second label  will appear, which must be set on the destination node. After that, the route between the nodes will be highlighted on the map, and information about the distance between the selected mine nodes will appear in the "Distance meter" window that opens.



To exit the distance measurement mode, use the "Esc" key.

In the graphic editor MineTwin Underground, viewing of individual sections of the mine field located at a given depth is available. The button  is used to set the range in the Z-coordinate of the mine nodes for viewing, for example, from -140 to -120.



The button  enables/disables viewing of the selected area.

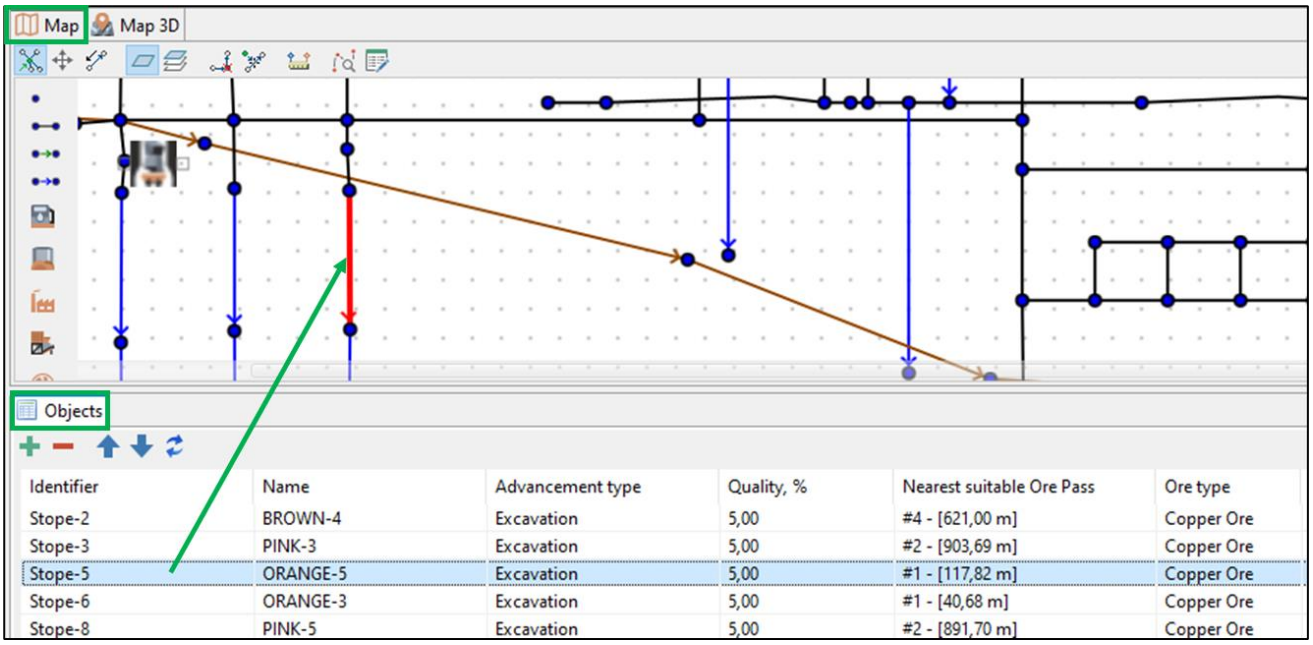
The left panel of the editor window (palette) contains objects that can be added to the enterprise plan: mine nodes, arcs and segments, stopes, fueling stations, storages, processing plants, crushers, blenders, ore passes, cross-dock points and skip hoists.

To add any mine object, except for arcs and segments, you need to left-click on the object on the palette, and then on the place of the plan where you want to add the object.

To add the mine arc or segment, left-click on the corresponding object on the palette, then sequentially click on the start (it will be highlighted in green) and the end mine node.

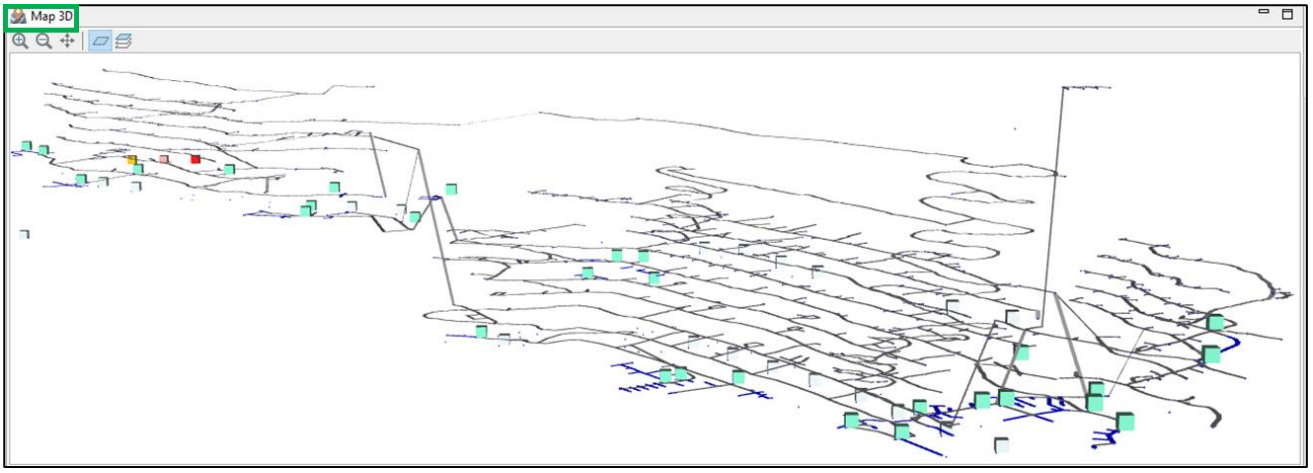
The objects are moved with the mouse while holding down the left mouse button. Multiple selection and movement of objects is available in the "Map" window.

When you select the object unit in the "Objects" window, the corresponding object is highlighted on the map.



2.3.6. Map 3D

The "Map 3D" window displays a mine plan in three dimensions. The plan in this mode is available only for viewing.



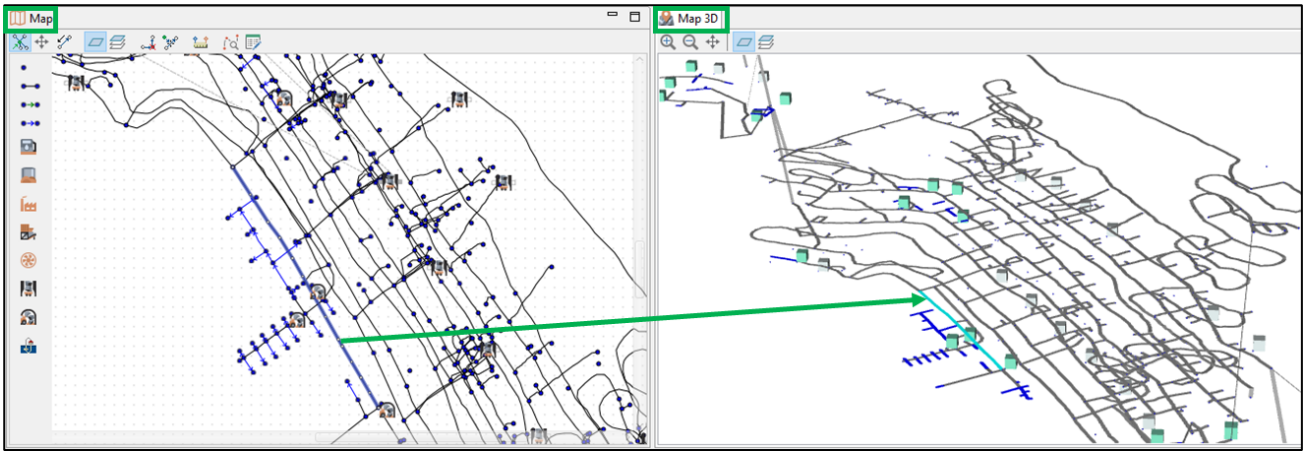
The plan is moved with the mouse while holding down the left mouse button, rotation - while holding down the right mouse button.

The button  in the upper left corner allows you to center the map 3D.

The buttons  allow you to zoom in and out on the map 3D of the mine.

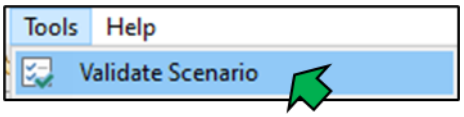
The button  activates the illumination of the mine arcs by default, the button  activates the illumination of the arcs by mine zones (Clause 2.5.3).

Maps in 2D and 3D are synchronized: when you select an object on one map, it is highlighted on the other.

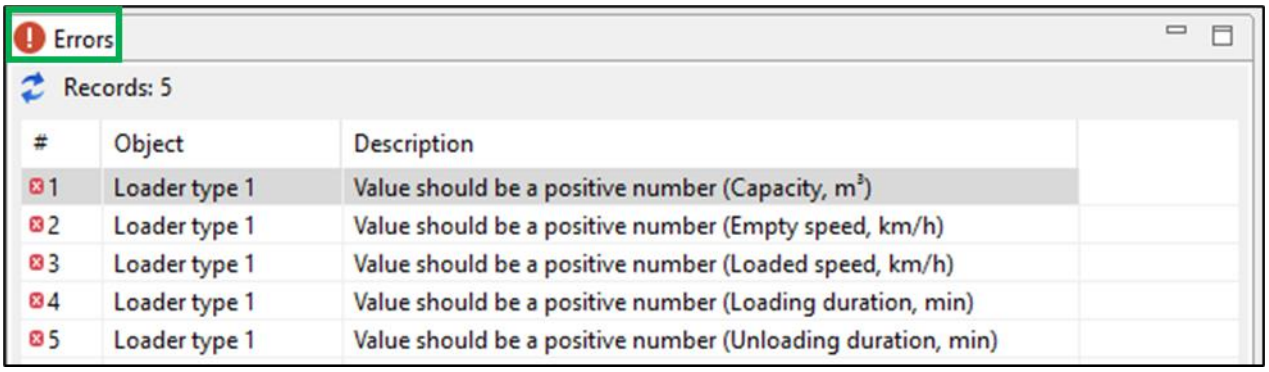


2.3.7. Errors

After creating/editing a scenario, you need to check its correctness using the "Validate scenario" button in the "Tools" button menu on the toolbar.



If the data is set incorrectly or there is not enough data, an error message will appear, a list of which will be shown in the "Errors" window.



Error messages can be of two types:

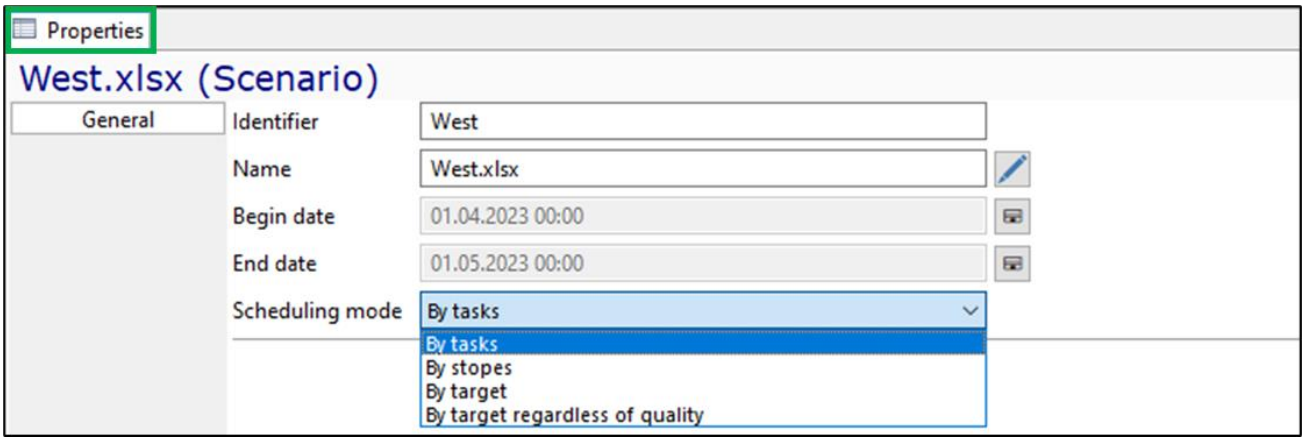
- errors that make scheduling impossible;
- warnings about the lack of some data that do not interfere with scheduling.

Clicking on each line of the error list in the “Properties” window opens the properties of the object in which the error occurred, and the user can quickly fix it.

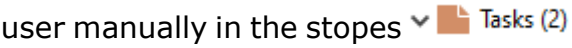
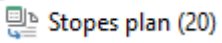
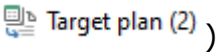
The button  in the upper right corner of the "Errors" window serves to update the error list after they have been fixed.

2.4. Scenario

A scenario is the root object of the subject area under consideration.



The Scenario object tree element contains global parameters related to scheduling and simulation of an underground mine:

- Unique identifier and name of the scenario.
- Date and time of start and end of scheduling and simulation.
- One of the possible scheduling modes:
  - by tasks - only tasks created by the user manually in the stopes  of the model tree are scheduled (Clause 2.9.1)
  - by stopes - scheduling is carried out in accordance with the plan by stopes () (Clause 2.9.2.1)
  - by target - scheduling is carried out in accordance with the plan by target () (Clause 2.9.2.2).
  - by target regardless of quality - scheduling is carried out in accordance with the plan by target regardless of quality of the ore.

2.5. Underground mine parameters

The "Map" model tree element contains the following elements of an underground mine:

- Mine nodes
- Mine arcs
- Zones
- Mine areas
- Mine segments

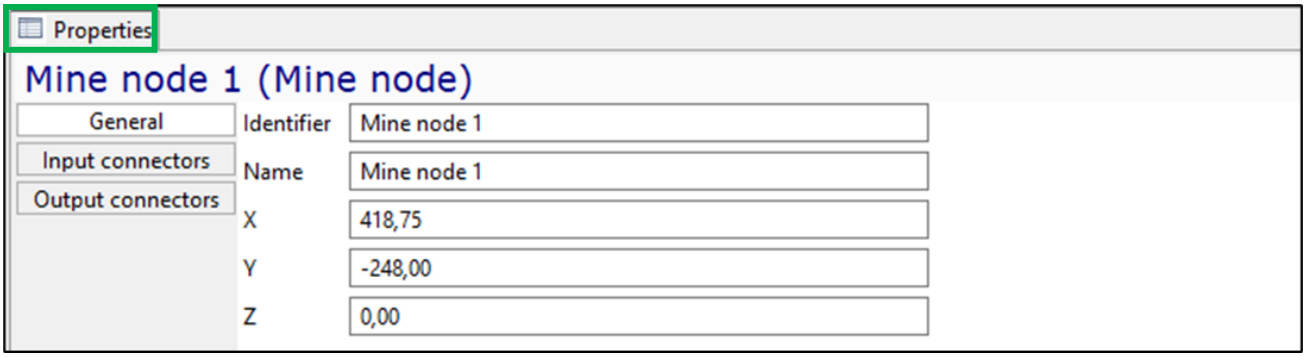
- Fueling stations
- Skip hoists.

The "Ore" model tree element contains the following elements of an underground mine:

- Ore types
- Materials
- Stopes
- Excavation rules.

2.5.1. Mine node

Mine node is an element of the mine transport network graph, which corresponds to one point in two-dimensional space.



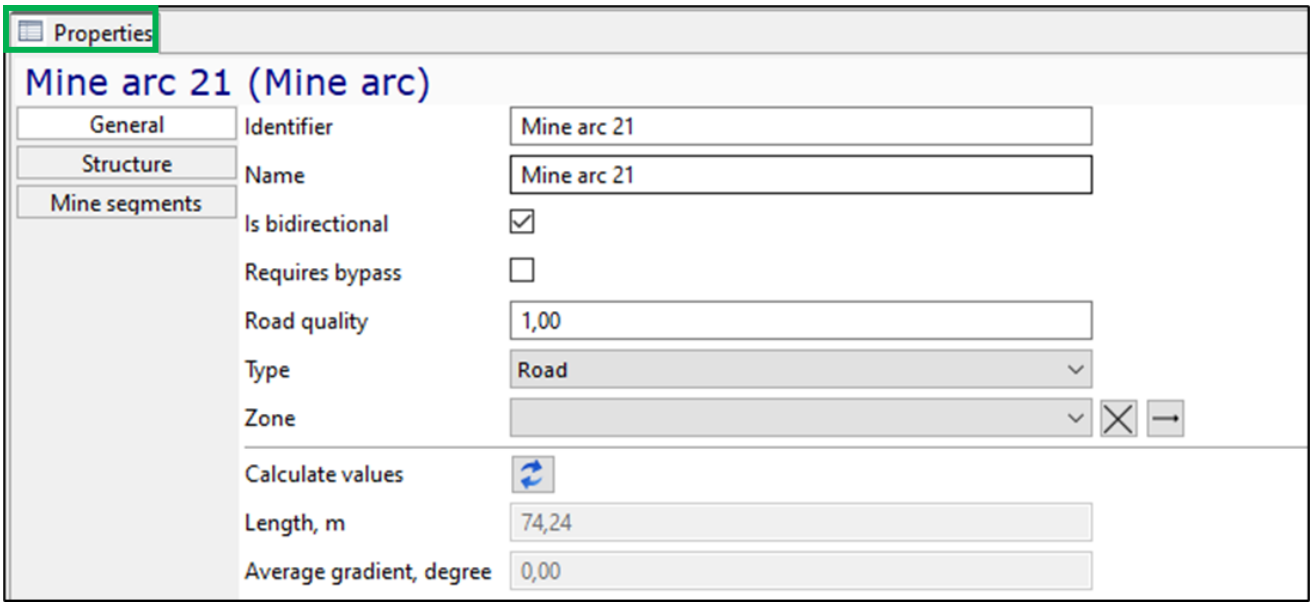
The mine node is characterized by the following parameters:

- Unique identifier and name
- X-, Y- and Z-coordinates

Also, input and output connectors with elements of the system providing material flow can be set for the node (Clause 2.6).

2.5.2. Mine arc

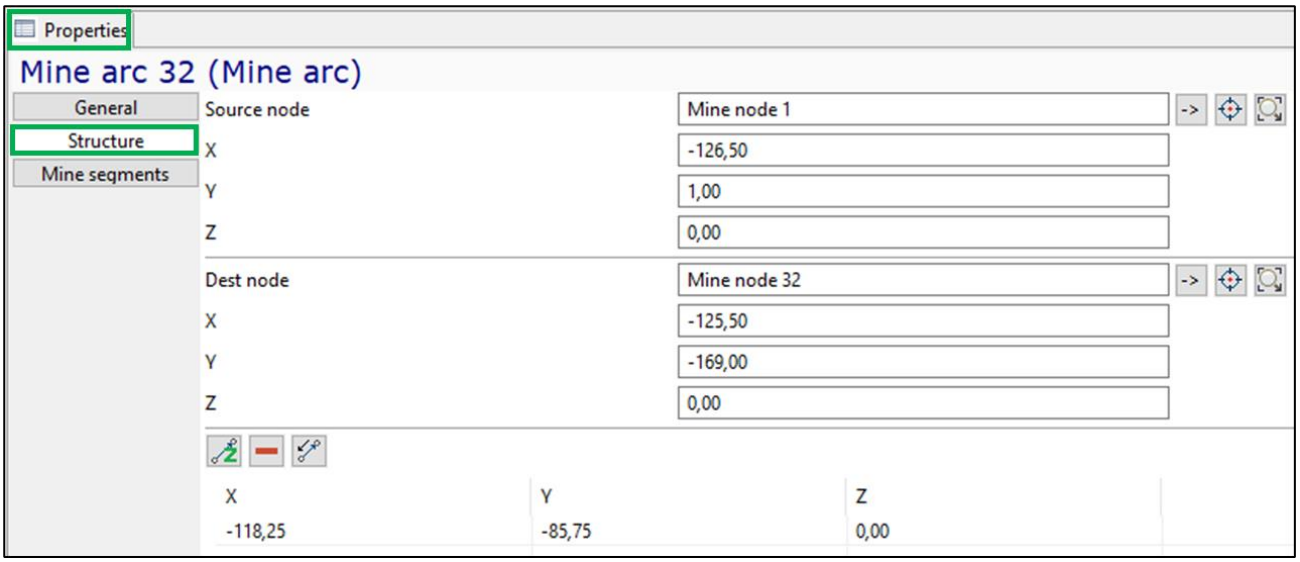
Mine arc is an element of the transport network graph that connects two mine nodes.



The mine arc is characterized by the following parameters:

- Unique identifier and name
- Is bidirectional - parameter that indicates whether movement along the mine arc in both directions is possible
- Requires bypass - parameter indicating whether simulation of the passing of vehicles on this arc is required or several vehicles can move along the arc without restrictions
- Road quality is a factor that adjusts the base speed of the equipment when moving along this arc
- Type – one of three possible options: road (railless), rail or conveyor
- Zone – conditional marking with color
- Length in meters, calculated depending on the X and Y coordinates of the nodes and bend points of the arc
- Average gradient in degrees indicating the angle of the arc and calculated depending on the Z coordinate of the nodes and bend points of the arc.

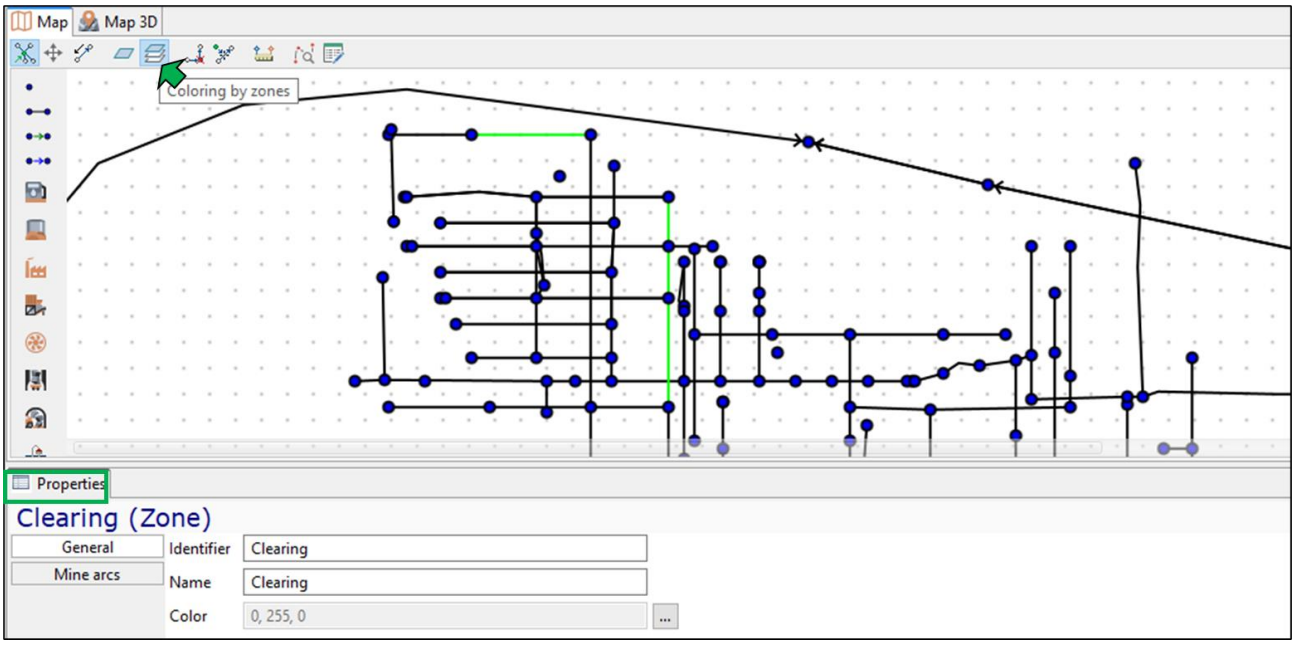
A separate tab of the properties of the mine arc displays the structure of the arc - references to the start and end node of the mine arc and the list of broken line points (arc inflection points).



Reference to the mine segment of which this arc is a part is displayed in the "Mine segments" tab of the arc properties.

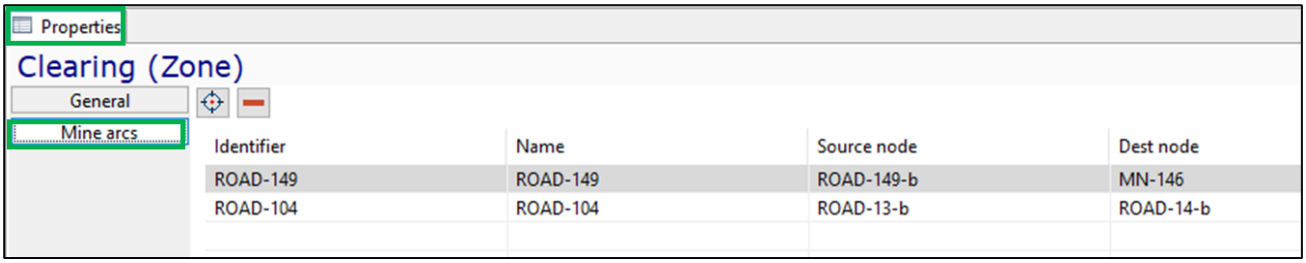
2.5.3. Zone

In the "Zones» object, a list of options for the color conditional marking of arcs on the map is specified. For example, the user can create a zone of the mine field, indicating the roads to be cleaned, and then apply this zone (color) to all arcs that require cleaning.



Zone is characterized by a unique identifier, name and color.

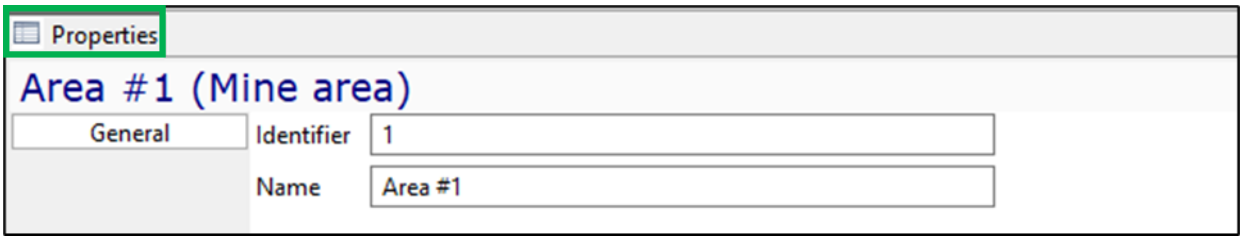
The "Mine arcs" tab of the zone properties contains a list of the mine arcs included in this zone.



Here you can add arcs by selecting them on a mine field using the button  or remove an arc from the list ().

2.5.4. Mine area

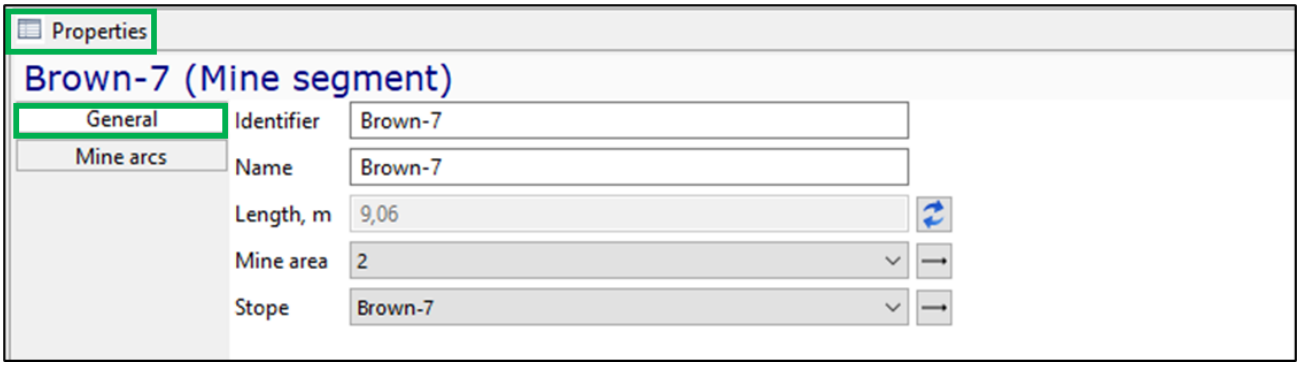
A mine area is used to logically combine several adjacent stopes. Specific equipment/ transport unit may be assigned to areas.



An area in MineTwin Underground is characterized only by a unique identifier and name.

2.5.5. Mine segment

Mine segment is an ordered set of mine arcs used to define the location of a stope. A mine segment corresponds to a directed broken line in three-dimensional space.



The mine segment is characterized by the following main parameters:

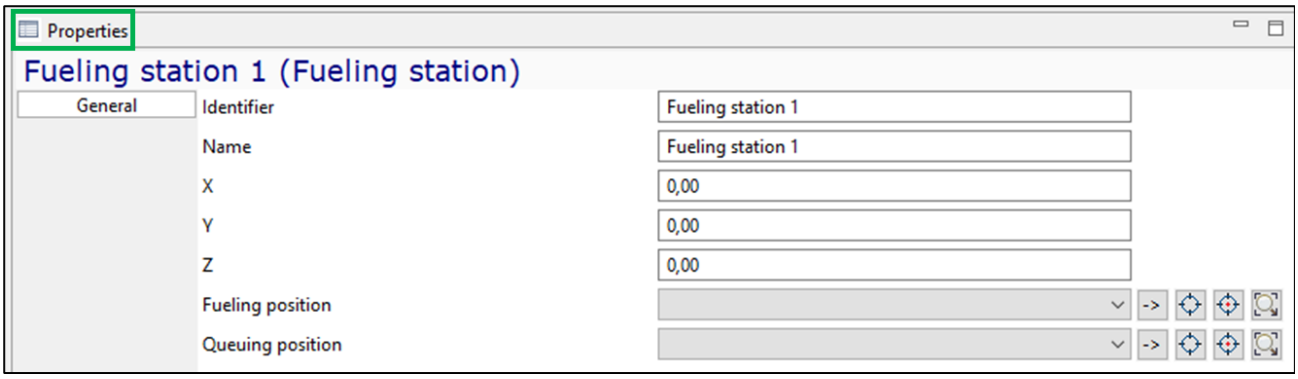
- Unique identifier and name
- Length, m - automatically calculated as the sum of the lengths of the mine arcs, of which this segment consists
- Mine area - a mine area to which this mine segment belongs
- Stope - a reference to a stope, to which this segment corresponds.

The "Mine arcs" tab of the mine segment properties contains a list of the mine arcs that this segment consists of.

Here you can add arcs by selecting them on a mine field using the button  or remove an arc from the mine segment ().

2.5.6. Fueling station

Fueling station is a stationary equipment designed for refueling transport and equipment units.



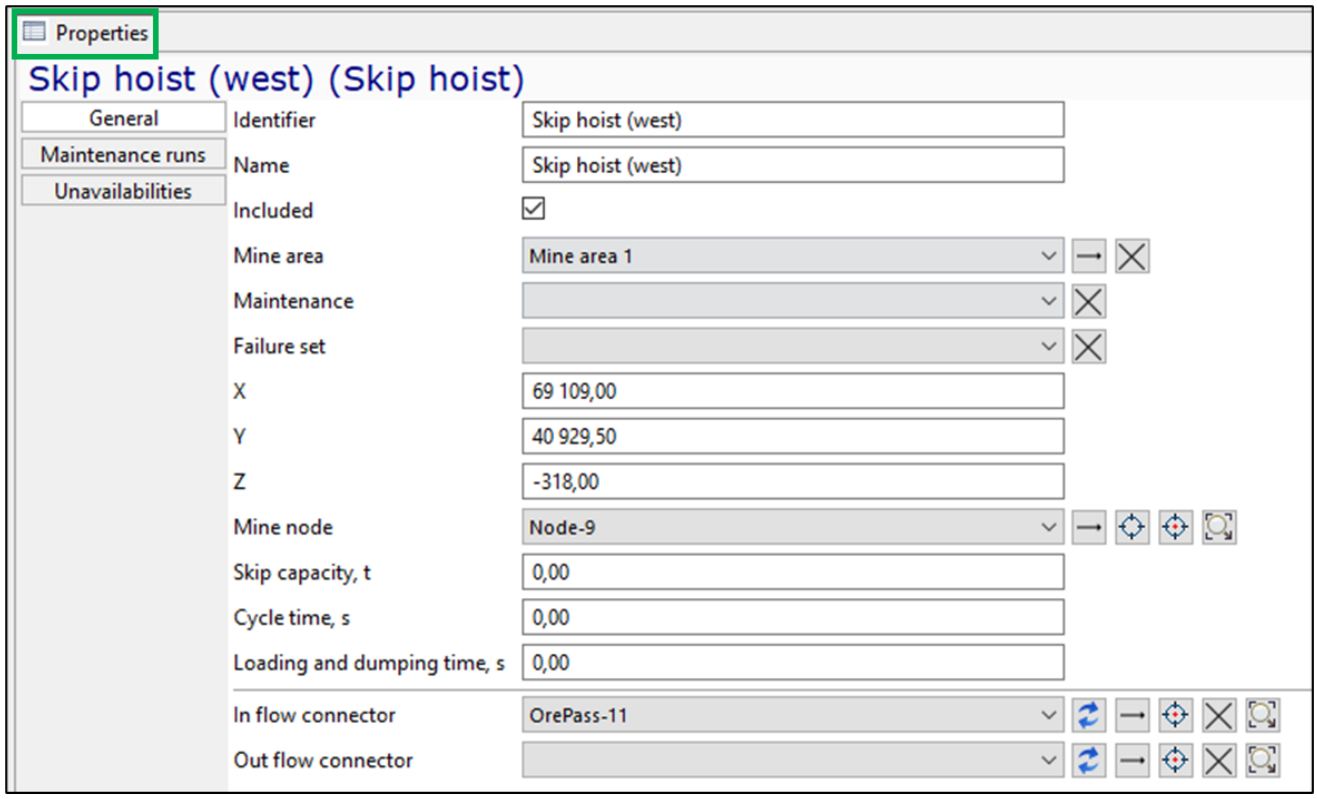
The fueling station is characterized by the following parameters:

- Unique identifier and name
- X-, Y- and Z-coordinates
- Fueling position - reference to the mine node where the equipment unit is located while refueling at the fueling station
- Queuing position - reference to the mine node where the equipment unit is waiting its turn to be refueled at the fueling station.

2.5.7. Skip hoist

Skip hoist - equipment designed to lift the ore mass from an underground mine to the surface of the earth.

A skip hoist consists of a pair of skip trolleys (skips). In the process of lifting the ore mass, the ore is alternately loaded into one skip and transported to the top. While one skip is being raised, the other skip is lowered.



The skip hoist is characterized by the following main parameters:

- Unique identifier and name
- Included - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- Area to which the equipment unit is assigned
- X-, Y- and Z-coordinates
- Mine node - reference to the mine node where the skip hoist is located
- Scip capacity, t – capacity of skip trolley in tones
- Cycle time, s - the duration of lifting and lowering of skip trolley (as the processes of lifting one skip and lowering the other occur in parallel, the duration of these cycles is the same), in seconds
- Loading and dumping time, s - the duration of loading and unloading of one skip trolley (as the processes of loading one skip and unloading another occur in parallel, the duration of these cycles is the same), in seconds
- In flow connector - reference to the ore pass from which the ore mass enters the skip hoist
- Out flow connector - reference to the storage to which the ore mass enters from the skip hoist.

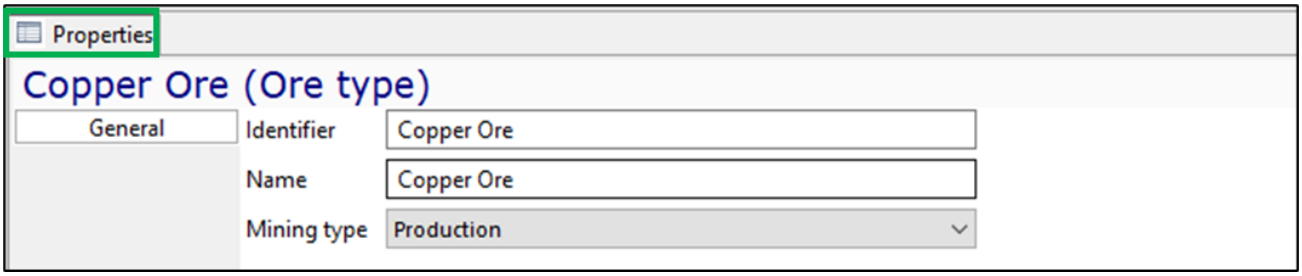
Also, the following parameters can be specified for the skip hoist:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).

- Failure set - a reference to the failure set records (Clause 2.8.5).

2.5.8. Ore type

Ore - all minerals and empty rock that are broken-up during mining operations. The "Ore type" object tree element contains a list of all ore types that can be used for scheduling.

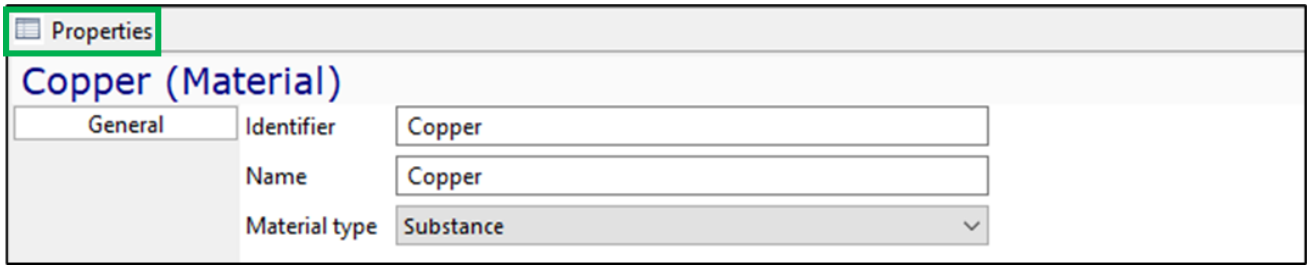


For each ore type, the following properties must be set:

- Unique identifier and name
- Ore category: production or development.

2.5.9. Material

Material - a type of substance contained in the ore mass. The "Material" object tree element contains a list of all materials that can be used for scheduling.



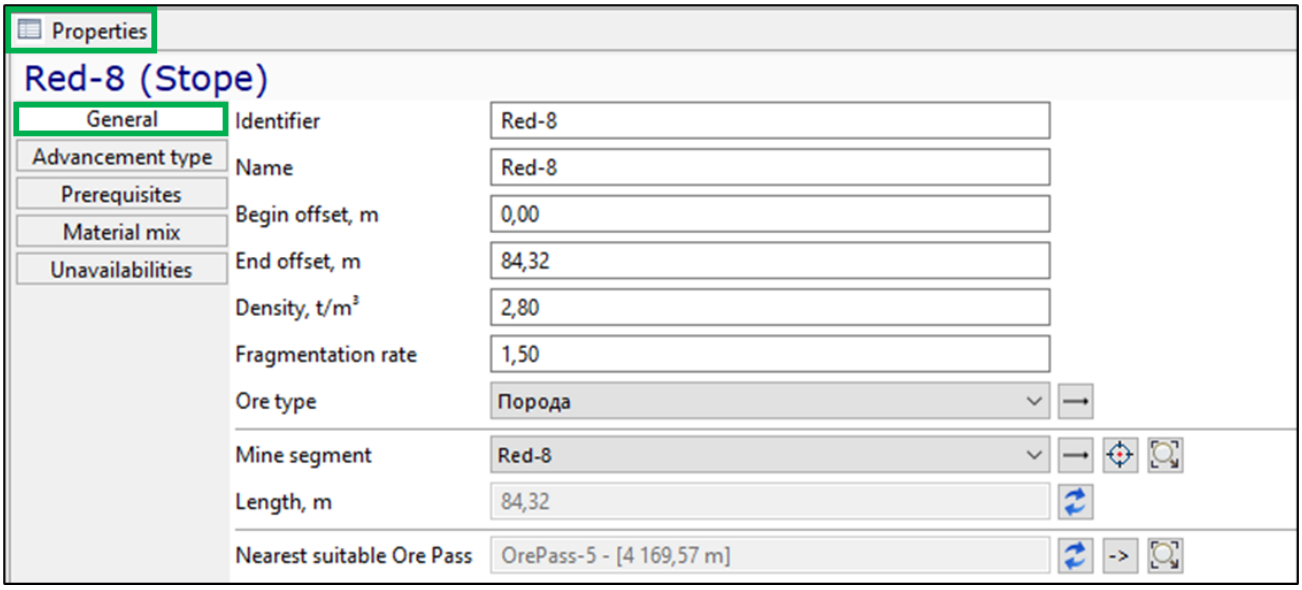
The following properties must be set for each material:

- Unique identifier and name
- One of two logical types: substance or empty rock.

2.5.10. Stope

In MineTwin Underground terms, a stope is where the equipment performs operations. On the mine plan the stope corresponds to the mine segment.

2.5.10.1 *General parameters*



The stope is characterized by the following main parameters:

- Unique identifier and name
- Begin offset, m – distance from the begin of the stope that was already developed at the start of planning/simulation, determines the working place in the stope
- End offset, m – distance from the begin of the stope, determines the end of the stope for development
  For example, the length of the stope is 60 meters, begin offset is 20m, end offset is 55 m. It means, that the equipment will work in the stope only on the length from 20 to 55 m, because 20 m is already finished, last 5 m is not available for works.
- Density, t/m^3 - ore mass per unit volume minus the volume of pores, voids and cracks, in t/m^3
- Fragmentation rate - coefficient characterizing the increase in the volume of ore mass during destruction (blasting or cutting by continuous miner)
- Ore type - one of the possible types of ore mass in the scenario
- Mine segment - reference to the mine segment that corresponds to the stope
- Length in meters is equals to the length of the mine segment, which corresponds to the stope
- Nearest suitable ore pass - the closest ore pass to the stope that can take on the ore type of the stope. The nearest suitable ore pass is determined automatically.

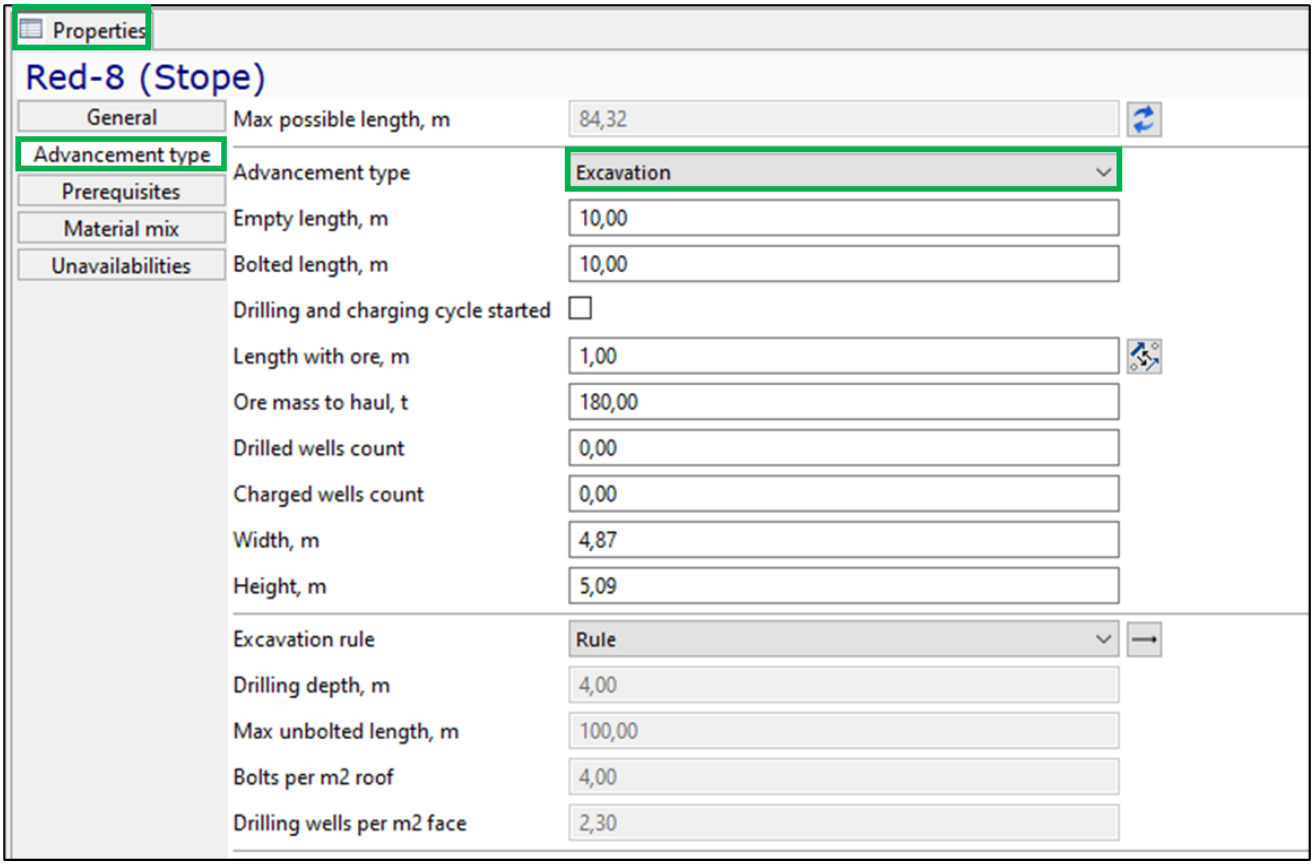
2.5.10.2 *Advancement type*

Parameters characterizing the way of the stope advancement and specifying the initial state of the stope at the moment of scheduling start must be necessarily specified for the stope.

First of all, you should set the advancement type of the stope. In MineTwin Underground the following advancement types are developed:

- Excavation – front advancement of the stope with horizontal drilling
- Cleaning – stope advancement with vertical or diagonal drilling that is performing according to the rules set for the whole stope
- Composite – stope advancement with vertical or diagonal drilling that is performing according to the rules set for each drill ring
- Continuous – cutting the ore with a continuous miner forward with subsequent ore excavation

2.5.10.3 *Excavation*

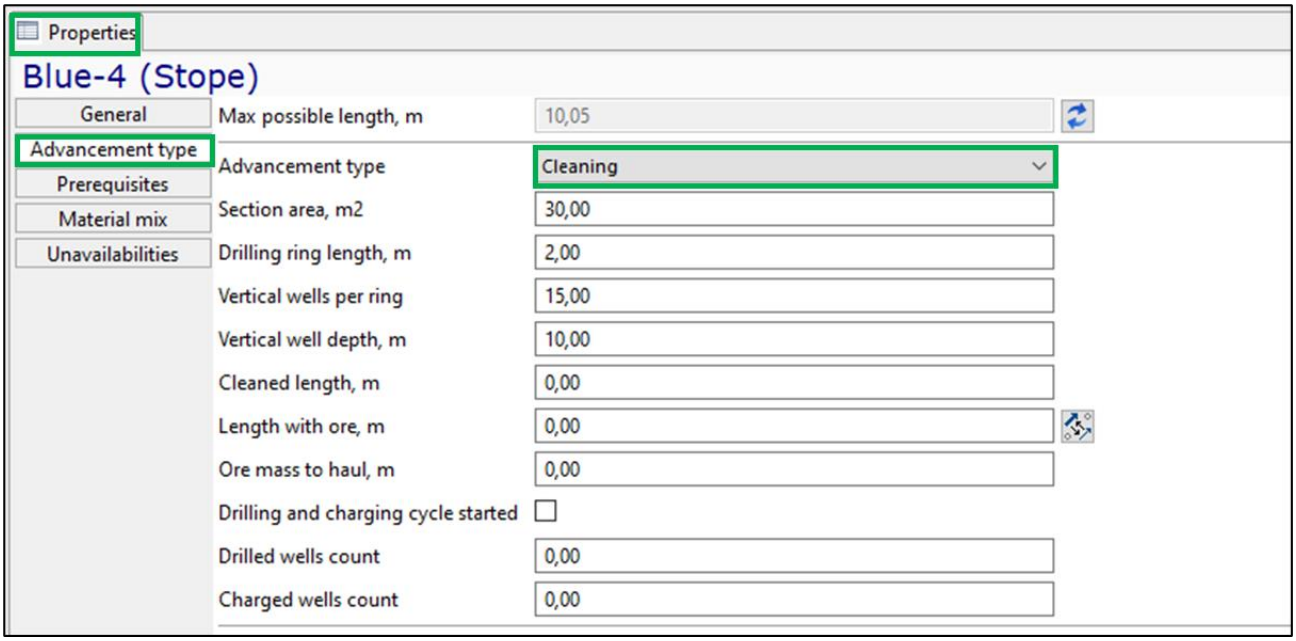


With the " Excavation " advancement type, the following parameters must be set for the stope:

- Empty length, m – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- Bolted length, m – the length of the stope part where drilling, blasting and transportation of ore and roof bolting have already been fully completed
- Drilling and charging cycle started - a parameter that indicates that drilling or charging is started but not yet completed in the stope

- Length with ore, m – the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required
- Ore mass to haul, t
- Number of drilled wells
- Number of charged wells
- Width of the stope, m
- Height of the stope, m.
- Excavation rule – one of the possible rules containing additional information about the drilling rules (maximum drilling depth, number of wells per m^2 face, etc.) (Clause 2.5.11).

2.5.10.4 *Cleaning*

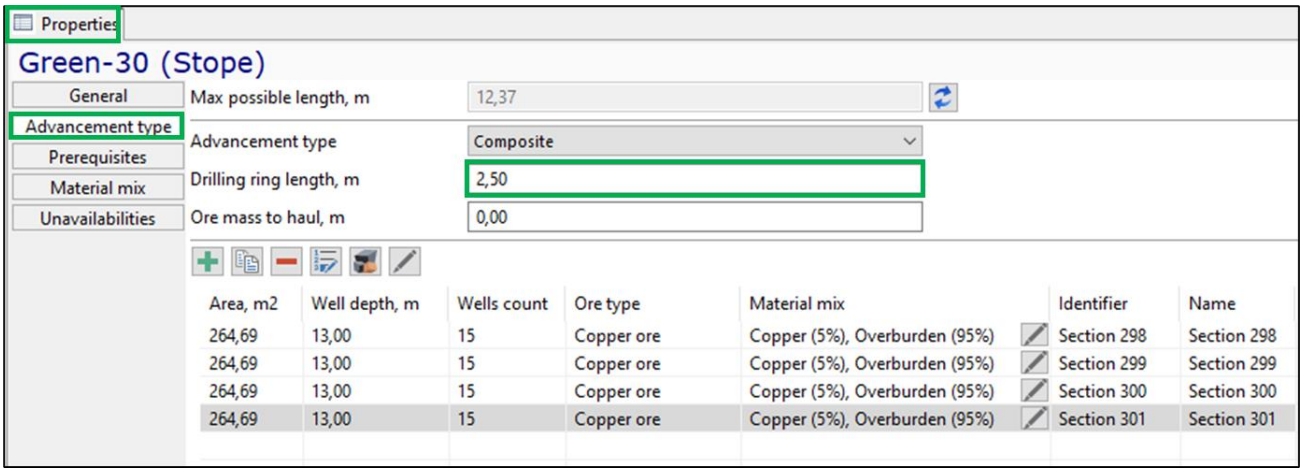


With the "Cleaning" advancement type, the following parameters must be set for the stope:

- Section area, m^2 – average section area of the stope during cleaning
- Drilling ring length, m – distance between two drill rings
- Number of vertical wells per one ring
- The average depth of a vertical well, m
- Cleaned length – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- Length with ore, m – the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required

- Drilling and charging cycle started - a parameter that indicates that drilling or charging is started but not yet completed in the stope
- Number of drilled wells
- Number of charged wells.

2.5.10.5 *Composite*



With the "Composite" advancement type, the following parameters must be set for the stope:

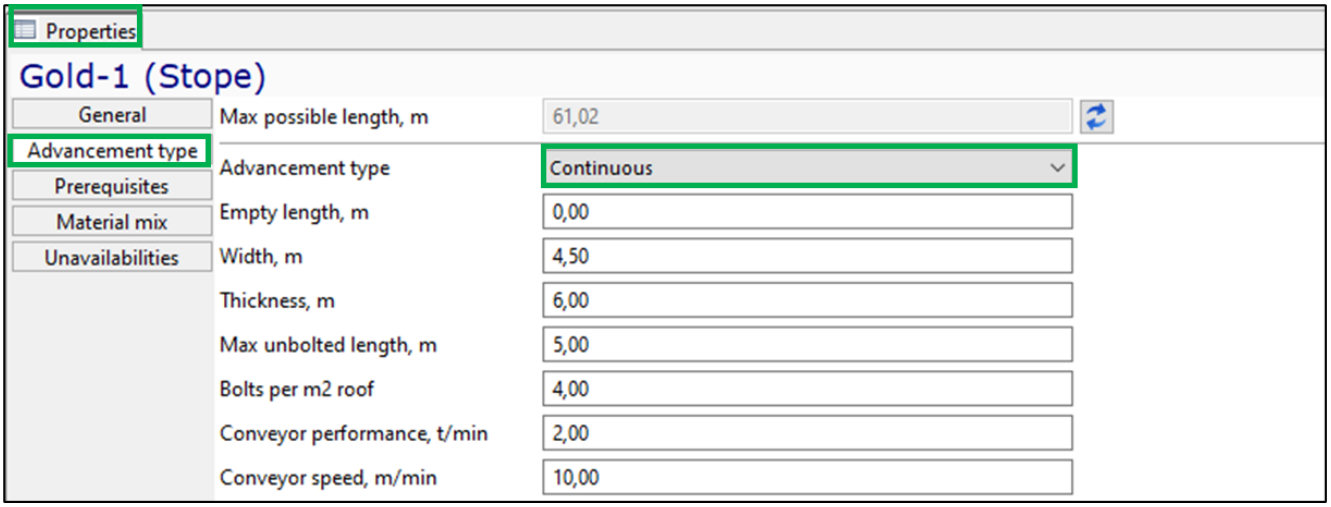
- Drilling ring length, m – distance between two drill rings
- Ore mass to haul, t
- For each drill ring must be set:
  - Section area, m^2 – average section area of the stope during cleaning
  - The average depth of a vertical well, m
  - Number of vertical wells
  - Ore type
  - Material mix

The button allows to automatically set the material mix for all drills, corresponding to the materials mix of the entire stope.

The button allows to automatically set the ore type for all drills, corresponding to the ore type of the entire stope.

The button allows to edit material mix of all drills of the stope in a separate window (Clause 2.5.10.8).

2.5.10.6 *Continuous*

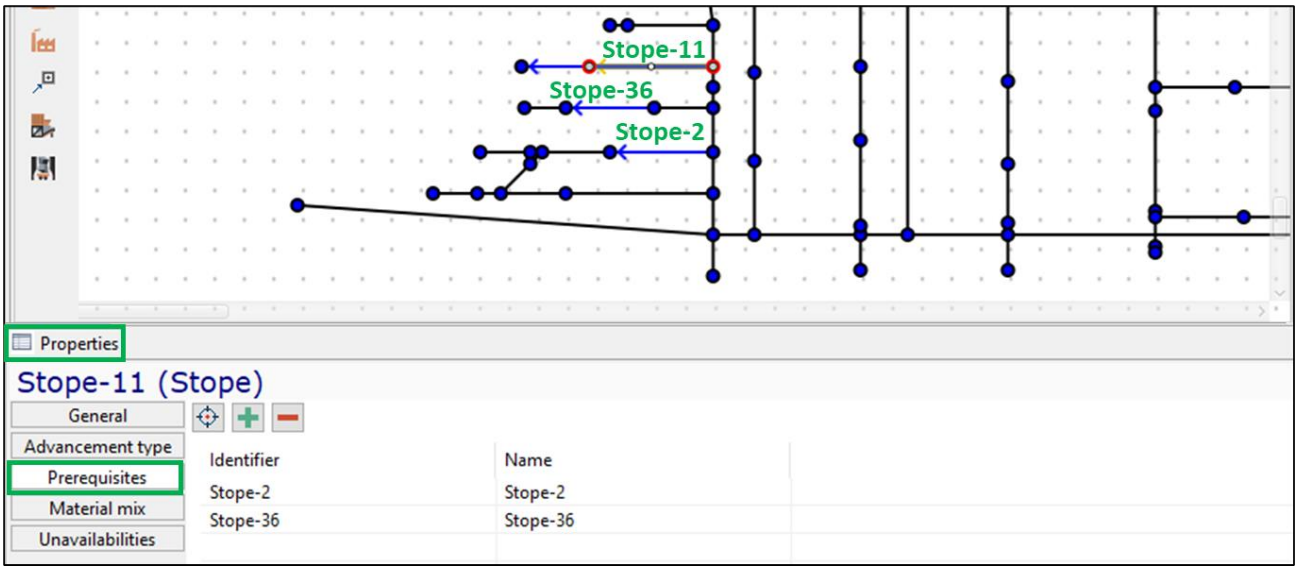


With the "Continuous" advancement type, the following parameters must be set for the stope:

- Empty length, m – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- Width of the stope, m
- Thickness of ore mass cutting by a continuous miner, m
- Maximum unbolted length, m – the maximum length of the stope on which the continuous miner is allowed to work without strengthening the stope roof
- Number of bolts per m^2 of the stope roof
- Performance of the conveyor serving the stope, t /min
- Speed of the conveyor serving the stope, m/min.

2.5.10.7 *Prerequisites*

MineTwin Underground allows to set prerequisites between stopes - prohibit the advancement of one stope until the stopes connected to it have been completely advanced.

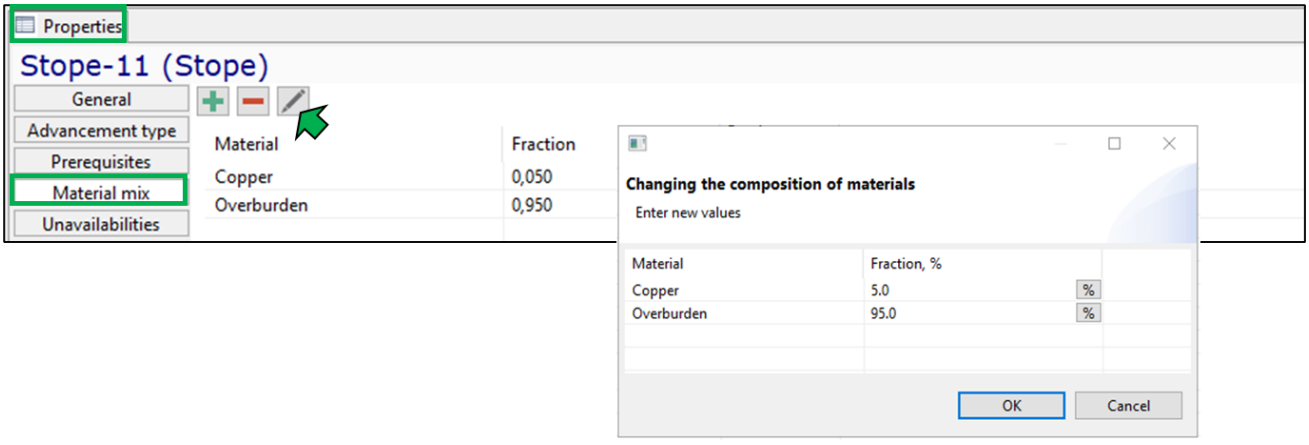


In the figure above, the advancement of the Stope-11 will be started only after the completion of the Stope-2 and Stope-36 advancement.

The button  allows you to select on a 2D map and add related stopes, the button  allows you to add related stopes from the list. The button  removes related stopes from the list.

2.5.10.8 *Material mix*

It is mandatory to fill in the Material mix in the stope.



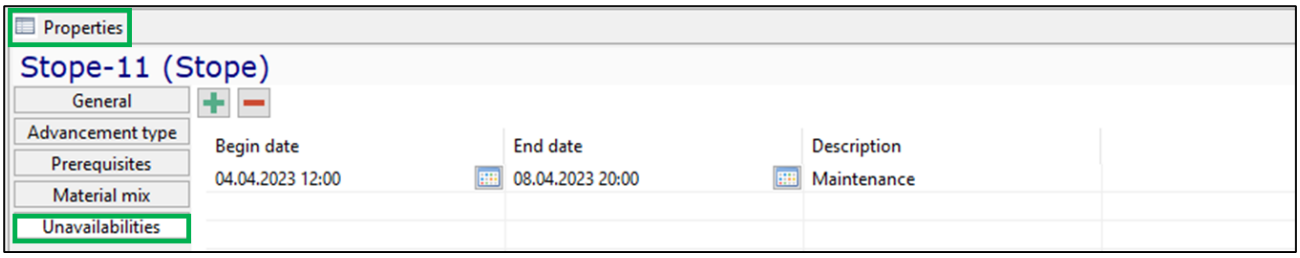
The buttons  allow to add/remove material to stope properties.

The button  allows to edit material mix in a separate window.

For each material, its proportion in the mix of the ore mass must be specified (from 0 to 1). The total fraction of the material mix should be equal to one.

2.5.10.9 *Unavailabilities*

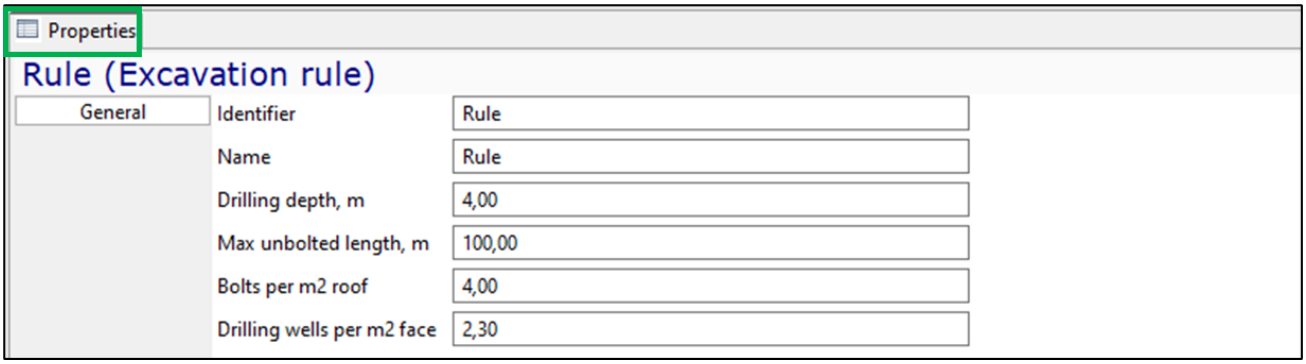
The periods of unavailability for advancement can be set for the stope. No equipment or transports will be scheduled in the stope during these periods.



The buttons  allow you to add/remove stopes periods of unavailability.

2.5.11. Excavation rule

Excavation rule - an entity that contains the parameters of excavation in underground mines.



The excavation rule contains the following information about drilling:

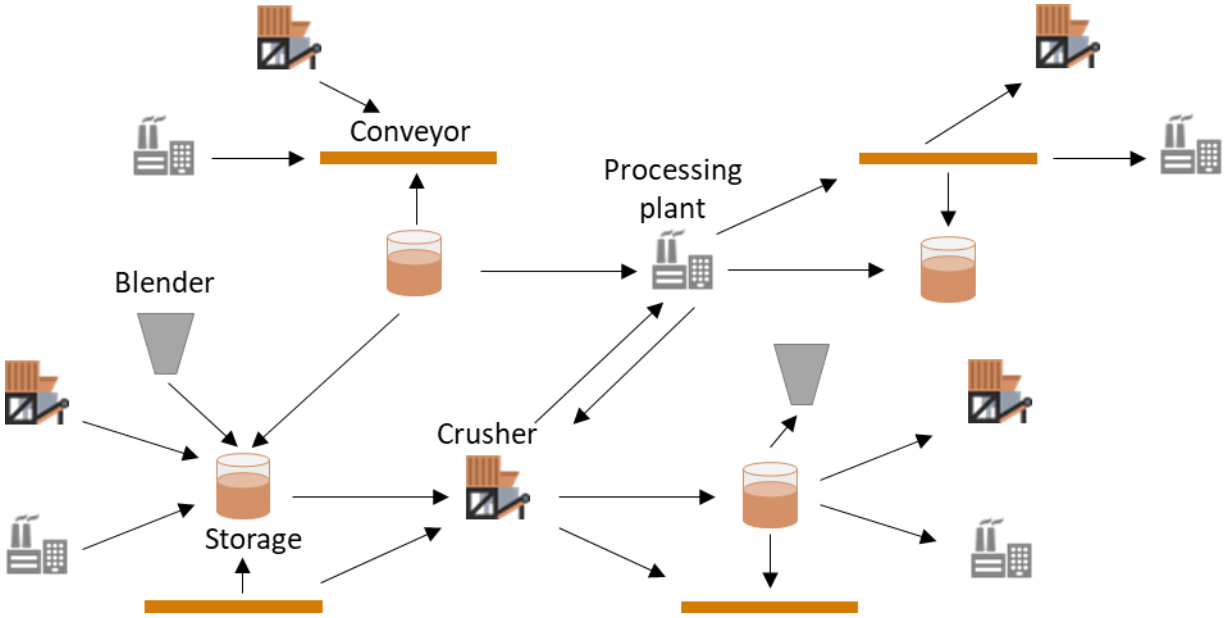
- Unique identifier and name of the rule
- Maximum drilling depth in meters
- Maximum unbolted length, m – the maximum length of the stope on which the drilling machine is allowed to work without strengthening the stope roof
- Number of bolts per m^2 of the stope roof
- Number of wells per m^2 of the stope face

The element of the tree of objects " Excavation rules" contains a list of all the rules that can be used in planning and simulation.

2.6. Parameters of the system elements ensuring the material flow

MineTwin Underground allows to simulate the movement and processing of ore mass after its excavation from stopes. The mine elements serving the transportation and

further processing of the ore mass can be combined into a connected system, the diagram of which is shown in the figure below.



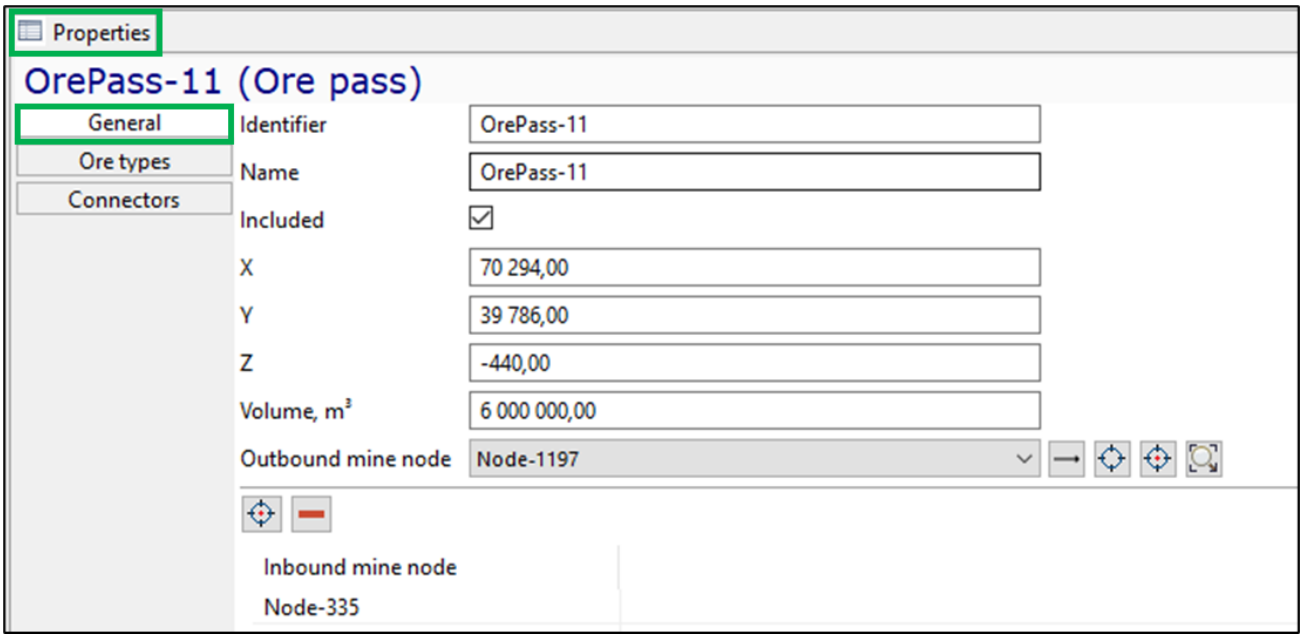
The ore mass goes from the storages to crushers, processing plants and blenders, and then goes back to the storages for further processing or is transported to dump areas.

Elements of the system of transportation and processing ore mass are combined into a block of the model tree "Material flow":

- Ore passes
- Storages
- Blenders
- Crushers
- Cross-dock points
- Conveyors
- Processing plants

2.6.1. Ore pass

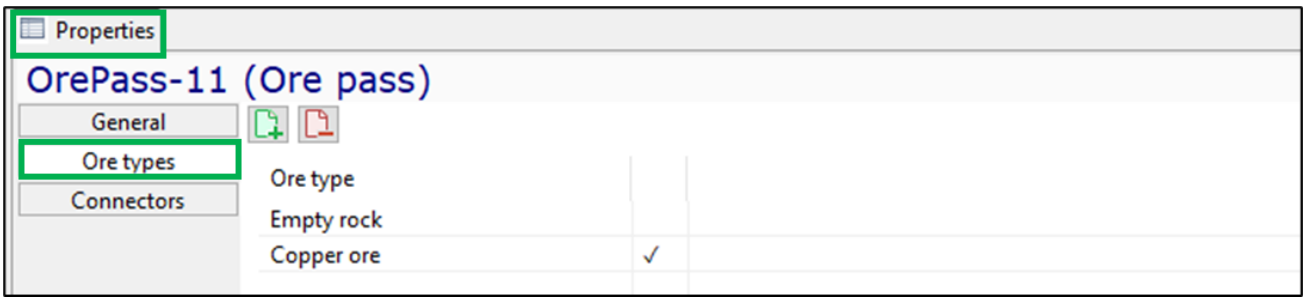
An ore pass is a part of the mine transport system involved in the movement of rock mass from the working area of the mine to the transport horizon.



The ore pass is characterized by the following main parameters:

- Unique identifier and name
- Included - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- X-, Y-and Z-coordinates
- Volume, m^3 - the maximum quantity of ore that can accommodate the ore pass
- Outbound mine node – reference to the mine node where the equipment unit is located while receiving the ore mass from the ore pass
- Inbound mine node – reference to the mine node where the equipment unit is located while dumping the ore mass into the ore pass.

The user can restrict the ore types that an ore pass can accept by deleting the default checkboxes next to the unallowed ore types.

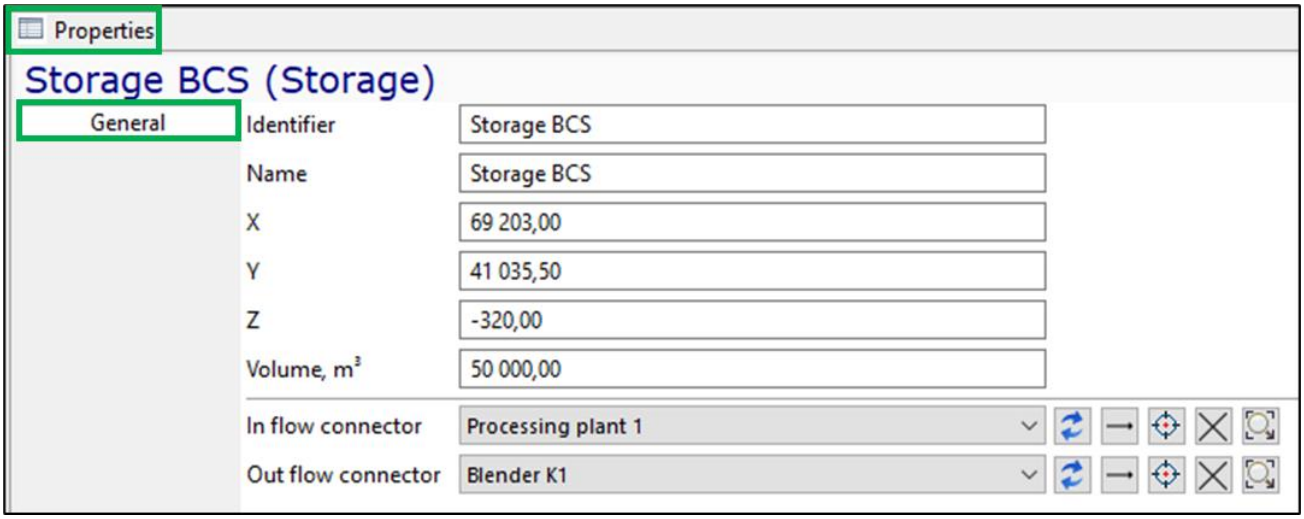


The buttons  allow to select all ore types / remove all selections.

On the "Connections" tab, the logical relationships of the ore pass with other elements of the transport system are indicated. A conveyor can be set as an in flow connector for an ore pass, and a skip hoist as an out flow connector.

2.6.2. Storage

Storage - a place for intermediate storage of ore mass.

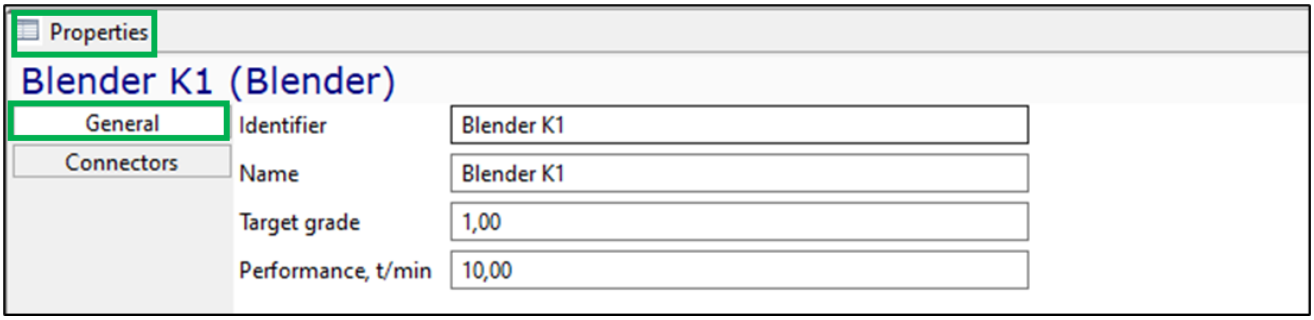


The storage is characterized by the following properties:

- Unique identifier and name
- X-, Y- and Z-coordinates
- Volume, m^3 - the maximum quantity of ore that can accommodate the storage
- In flow connector - reference to the equipment unit from which the ore mass enters the storage: blender, crusher, processing plant or skip hoist
- Out flow connector - reference to the equipment unit to which the ore mass enters from the storage: blender, crusher, processing plant or skip hoist.

2.6.3. Blender

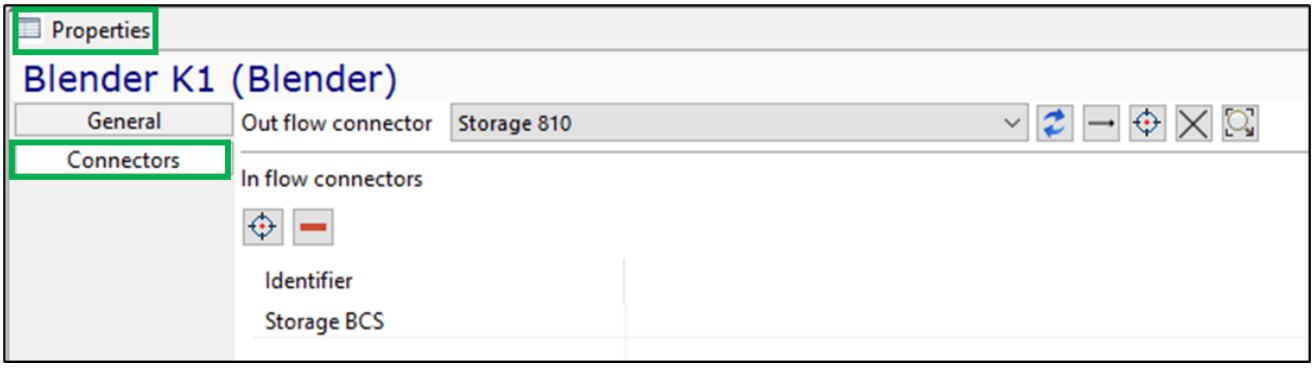
Mixer - equipment for mixing ore mass with different content of useful materials for uniform distribution of the useful component in a certain volume.



The mixer is characterized by the following main parameters:

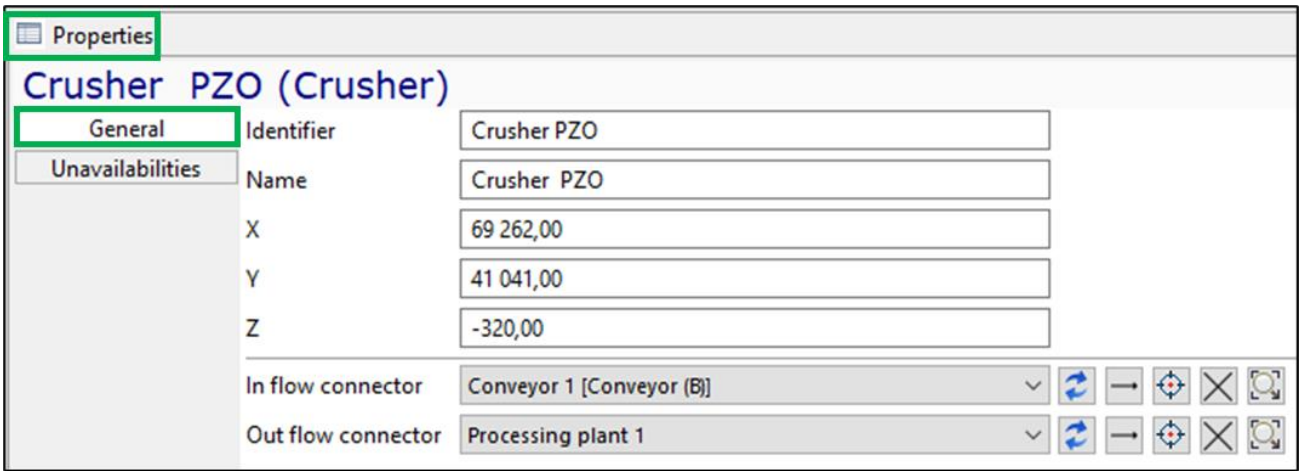
- Unique identifier and name
- Target grade - target quality of the ore mass, which should be ensured in the mixing process, in fractions of a unit
- Performance of ore mass mixing in tons per minute

On the "Connections" tab, the logical relationships of the mixer with other elements of the transport system are indicated. Stores can be specified as in flow and out flow connectors for a mixer.



2.6.4. Crusher

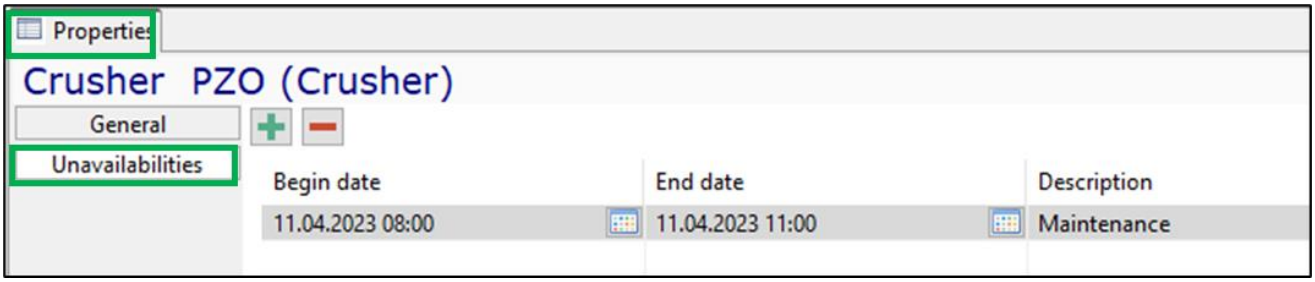
Crusher - equipment for crushing – mechanical impact on the rock in order to destroy it.



The crusher is characterized by the following main parameters:

- Unique identifier and name
- X-, Y- and Z-coordinates
- In flow connector - reference to the equipment unit from which the ore mass enters the crusher: storage or conveyor
- Out flow connector - reference to the equipment unit to which the ore mass enters from the crusher: storage, conveyor or processing plant.

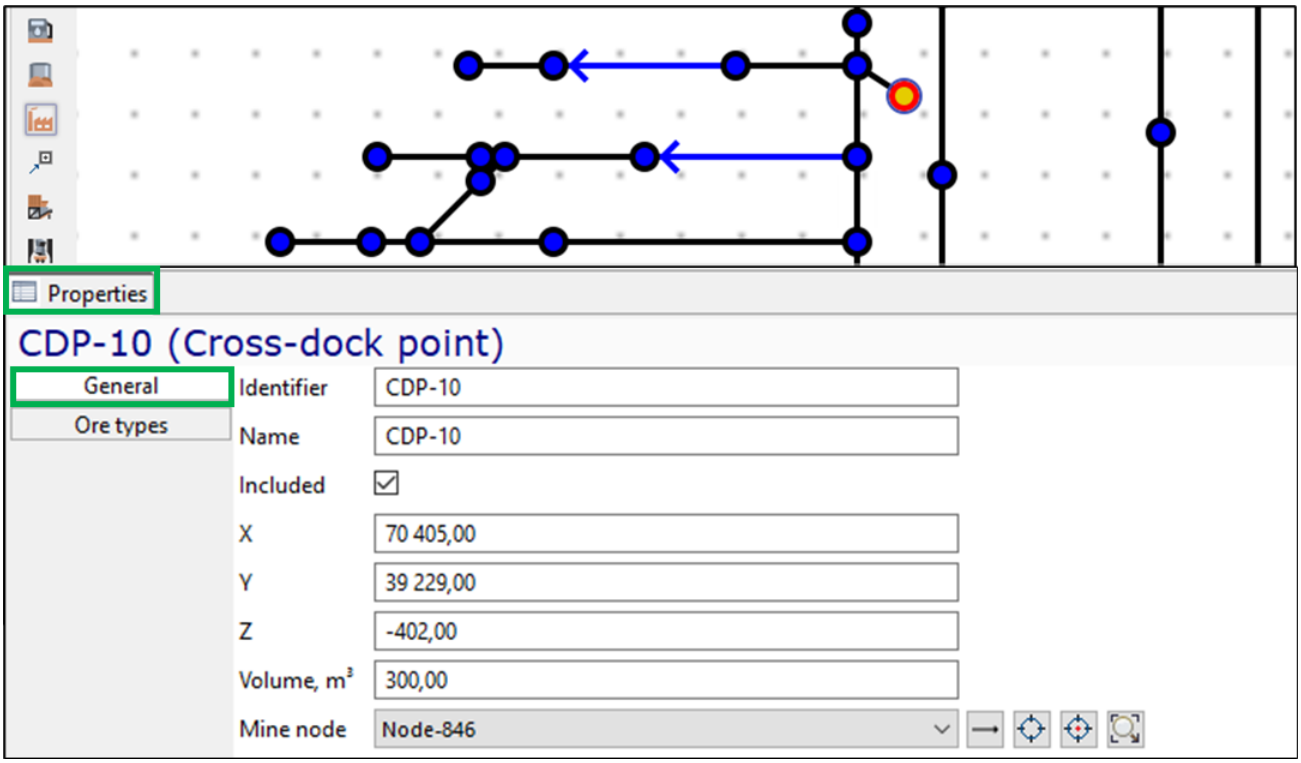
You can set periods of unavailability for the crusher.



The buttons  allow you to add/remove crusher unavailabilities.

2.6.5. Cross-dock point

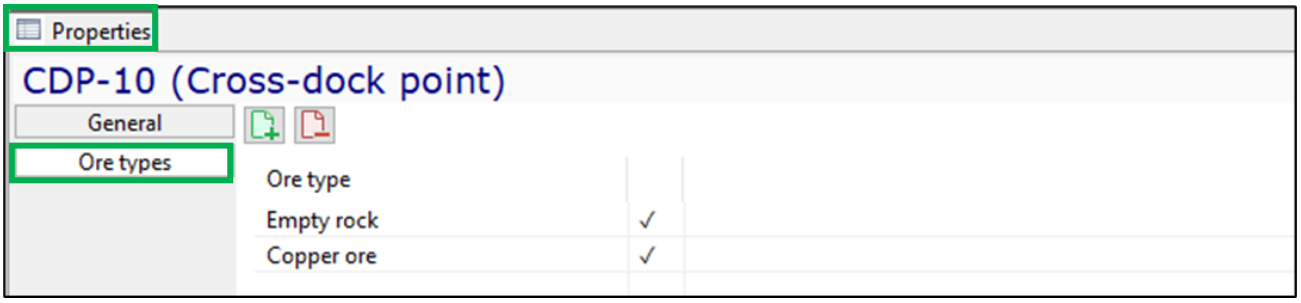
Cross-dock point - a mine node, where equipment stops while waiting for loaders and trucks and the ore mass is reloaded from loaders to trucks.



The cross-dock point is characterized by the following main parameters:

- Unique identifier and name
- Included - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- X-, Y-and Z-coordinates
- Volume, m^3 - niche volume for temporary storage of ore mass at the cross-dock point
- Mine node - reference to the mine node where the cross-dock point is located

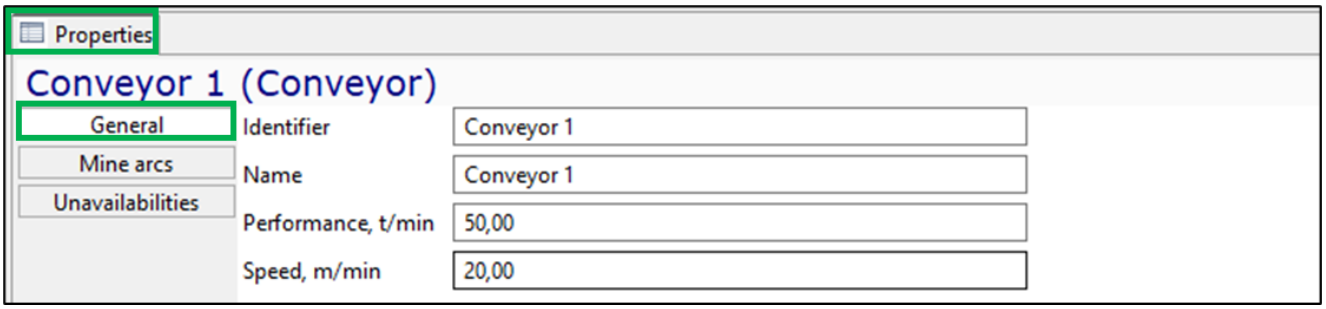
Also, for the cross-dock point the ore types should be indicated, which are allowed to be dumped into a niche at the cross-dock point.



The buttons  allow to select all ore types / remove all selections.

2.6.6. Conveyor

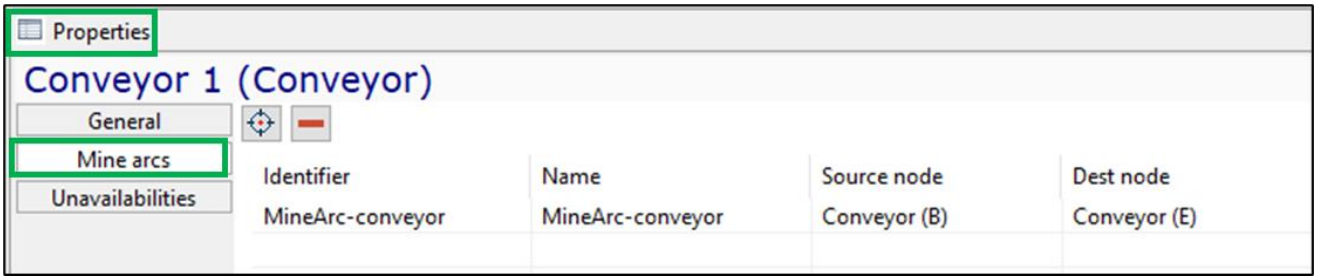
Conveyor is a continuous-action mechanism for transporting ore mass. The ore mass can enter the conveyor from storages, crushers and processing plants and is transporting to storages, crushers and processing plants.



The conveyor is characterized by the following main parameters:

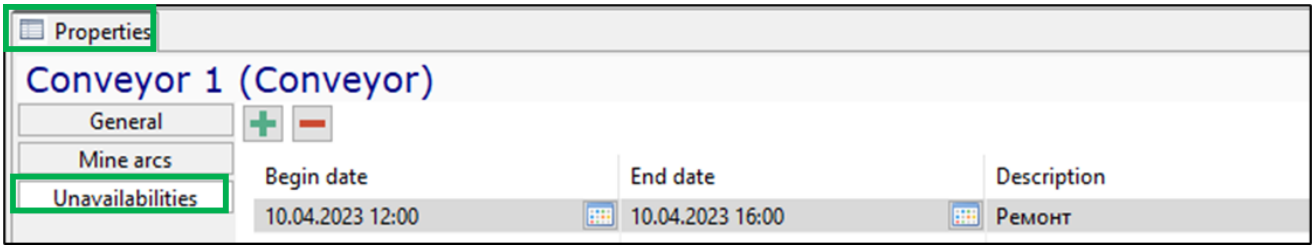
- Unique identifier and name
- Performance of ore mass transportation in tons per minute
- Conveyor belt speed, m/min.

In the "Mine arcs" tab you can set the list of mine arcs of the conveyor type, that make up the given conveyor.



Mine arcs are added by selecting them on the minefield using the button  and removed from the conveyor using the button  .

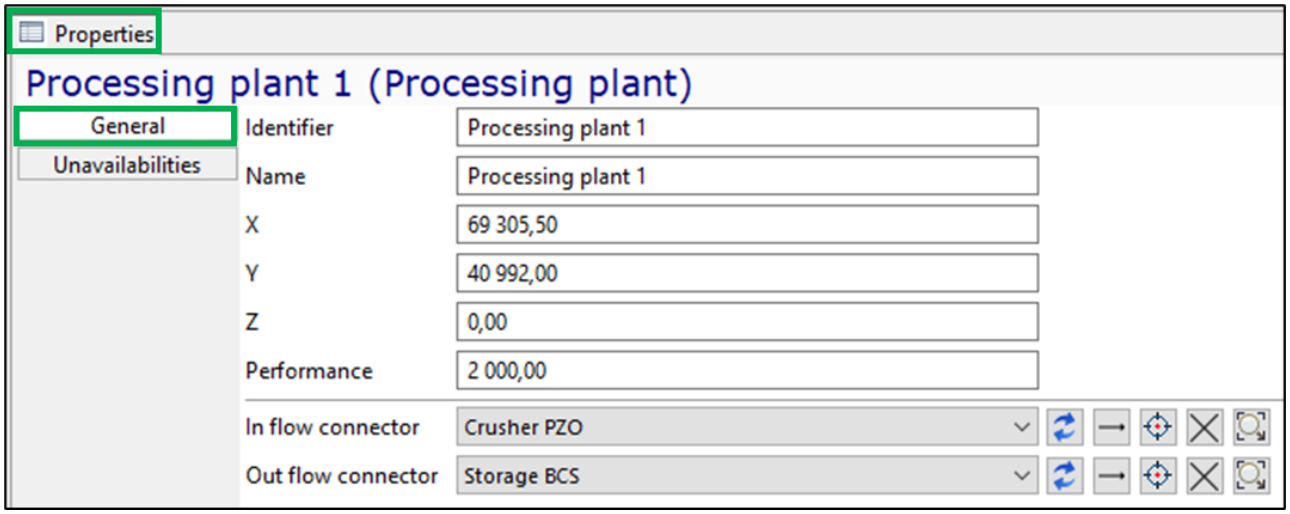
You can set periods of unavailability for the conveyor.



The buttons  allow you to add/remove conveyor unavailabilities.

2.6.7. Processing plant

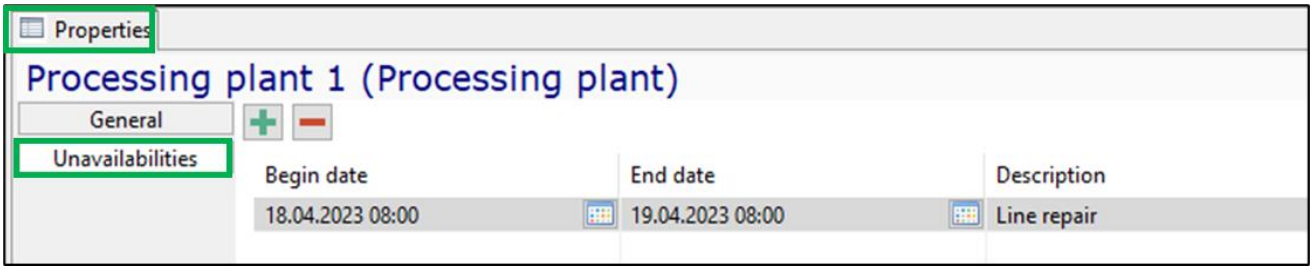
Processing plant is a mining enterprise for the primary processing of ore mass in order to obtain technically valuable products suitable for industrial use.



The processing plant is characterized by the following main parameters:

- Unique identifier and name
- X-, Y- and Z-coordinates
- Performance of ore mass processing in tons per hour
- In flow connector - reference to the equipment unit from which the ore mass enters the processing plant: crusher, storage or conveyor
- Out flow connector - reference to the equipment unit to which the ore mass enters from the processing plant: storage or conveyor.

You can set periods of unavailability for the processing plant.



The buttons  allow you to add/remove processing plant unavailabilities.

2.7. Parameters of mobile equipment

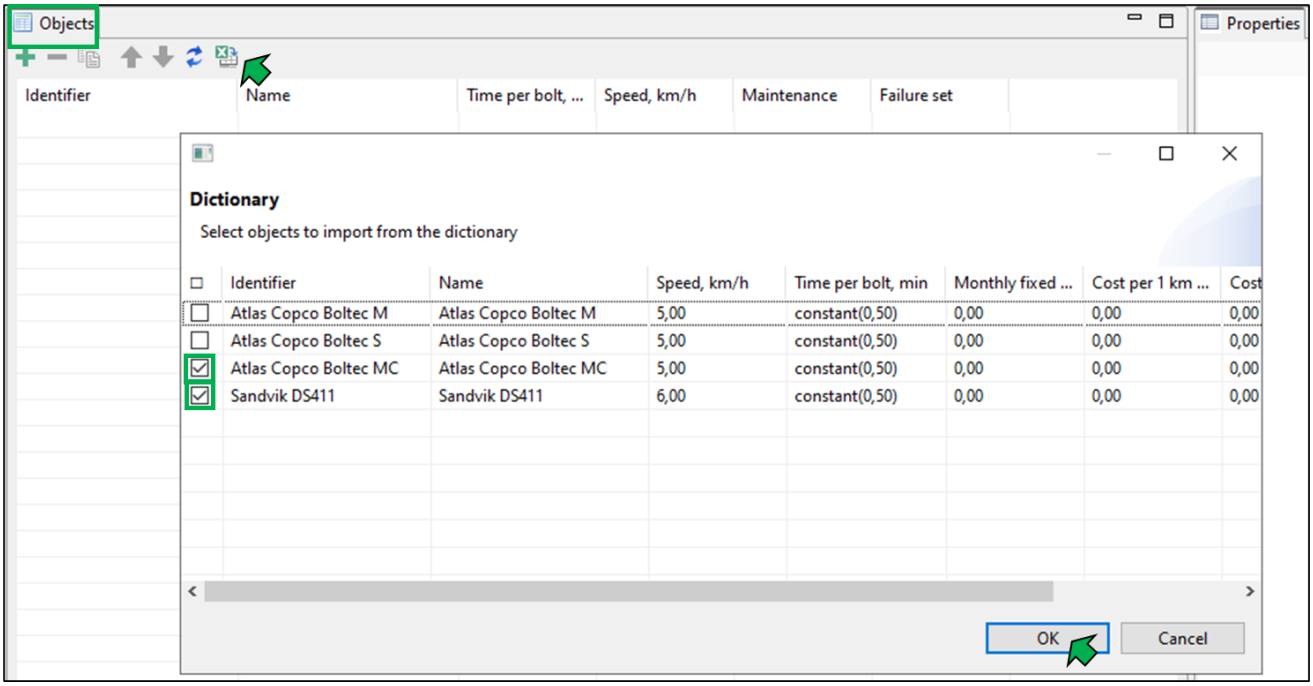
Mobile equipment in MineTwin Underground is grouped by types. Equipment type is an entity used to group equipment units with the same basic characteristics.

The "Equipment types" object tree element contains lists of all equipment types that can be used for scheduling/simulation:

- Truck types
- Loader types
- Charger types
- Drilling machine types
- Roofbolter types
- Shuttle car types
- Continuous miner types

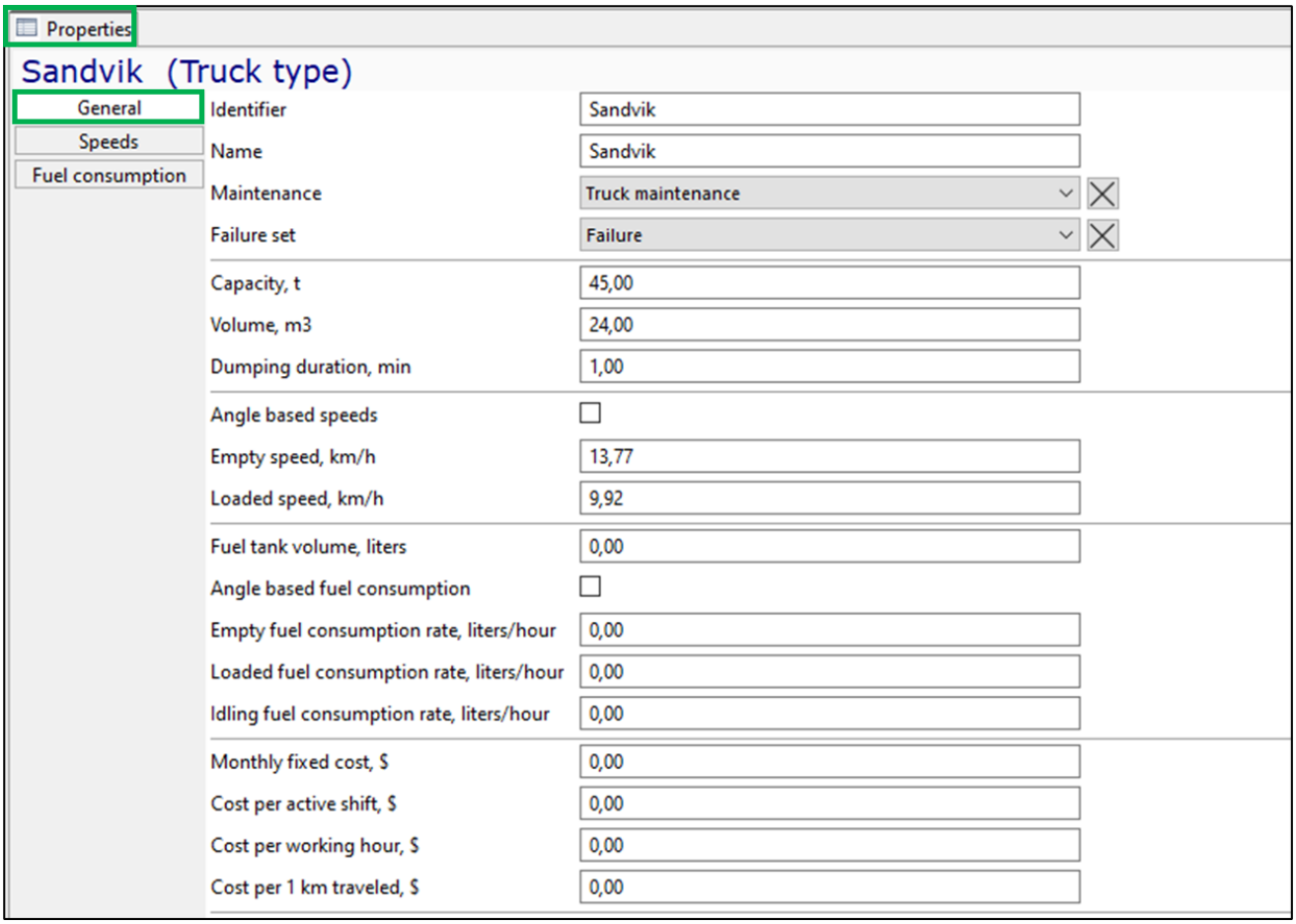
Scheduled repairs (maintenance) sets (Clause 2.8.4) and unscheduled (emergency) repairs sets (failure sets) (Clause 2.8.5) are specified in the context of equipment types.

MineTwin Underground contains the built-in reference book of commonly used equipment types. You can create an equipment type by going to the directory and selecting the required types of equipment.



2.7.1. Truck types

Truck is a machine designed for loading and transporting ore mass.



The following properties must be set for each truck type:

- Unique identifier and name
- Capacity of trucks of this type in tons
- Volume, m^3 - the maximum quantity of ore that can accommodate the truck of this type in m^3
- Dumping duration, min
- Truck speed without load, km/h
- Truck speed with load, km/h
- A parameter that shows whether the speed of this type of trucks depends on the angle of the road. If the speed is independent of the slope angle, it is determined by the constant speed values set on this tab. If the speed depends on the angle of the road, it is calculated taking into account the parameters set on the "Speeds" tab (Clause 2.7.1.1)
- Fuel tank volume of trucks of this type, in liters
- Fuel consumption rate when driving without load, l/h
- Fuel consumption rate when driving with load, l/h
- Fuel consumption rate without movement, l/h

- A parameter that shows whether the fuel consumption of trucks of this type depends on the angle of the road. If fuel consumption does not depend on the angle of inclination, it is determined by the constant flow rates set on this tab. If fuel consumption depends on the angle of inclination of the road, its calculation is performed taking into account the parameters set on the "Fuel consumption" tab (Clause 2.7.1.2).

For the truck type cost parameters can be set (but not necessarily):

- Fixed costs for trucks of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

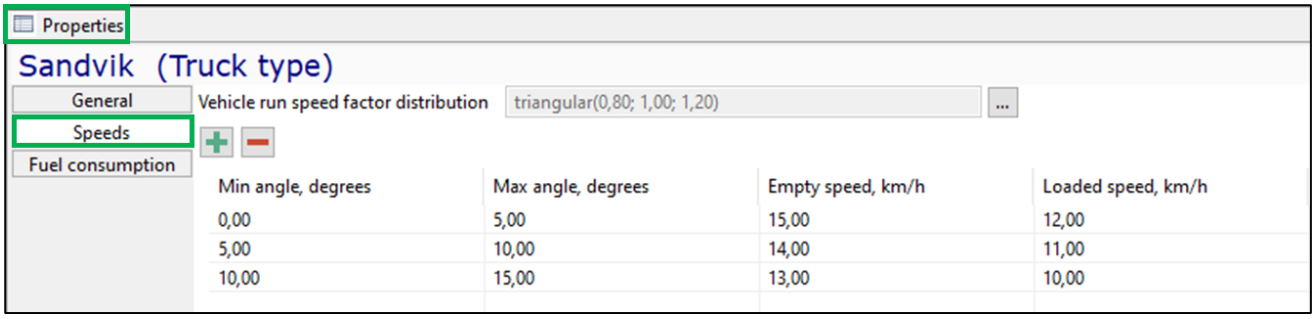
Also, the following properties can be specified for the truck type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.1.1 *Speeds*

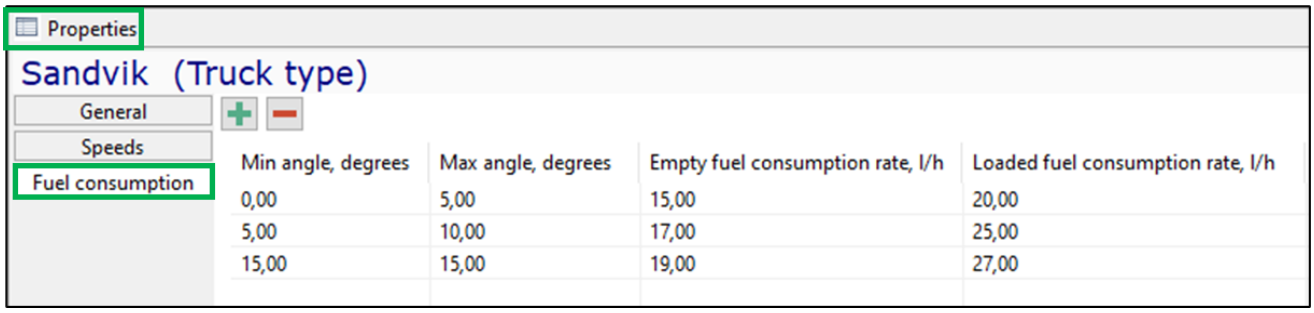
On the “Speeds” tab, the dependence of the equipment movement speeds on the road inclination angle is set. For each range of angles, the corresponding travel speeds with and without load are indicated. Intermediate values are determined by linear interpolation.

The vehicle run speed factor distribution of trips allows you to set the variability of speed within the range using distributions (Clause 2.3.4). In the example in the figure below, the speed of movement without load on a road with an angle from 0 to 5º will vary from 15 * 0.8 = 12 to 15 * 1.2 = 18 km / h, but most often it will be close to 15.



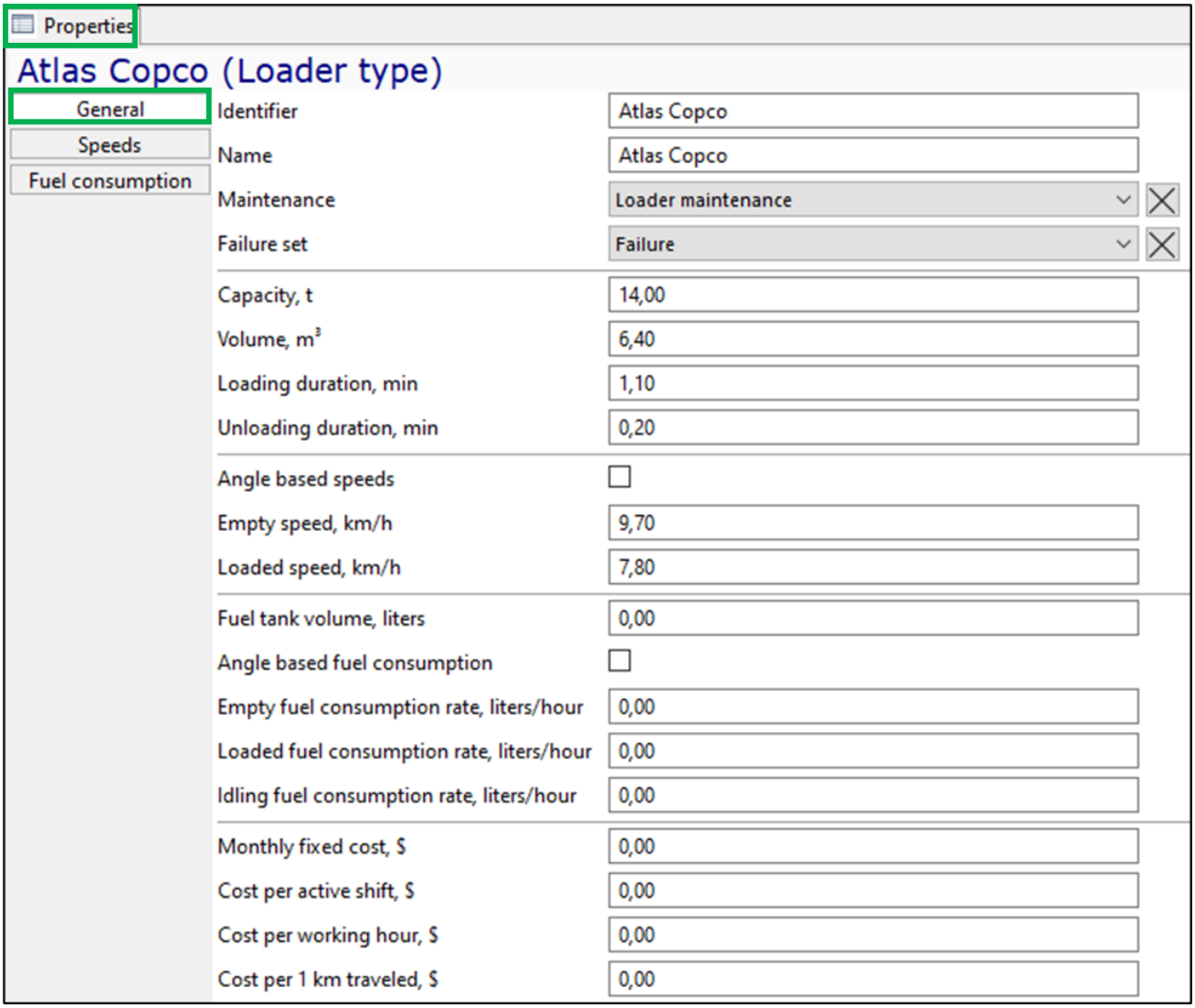
2.7.1.2 *Fuel consumption*

On the "Fuel consumption" tab, the dependence of the fuel consumption of the equipment on the road inclination angle is set. For each range of angles, the corresponding fuel consumption values when driving with and without load are indicated. Intermediate values are determined by linear interpolation.



2.7.2. Loader types

Loader is a machine designed for loading and transporting ore mass to the dump area.



The following properties must be set for each loader type:

- Unique identifier and name

- Capacity of load-carrying bucket of loaders of this type in tons
- Volume, m^3 - the maximum quantity of ore that can accommodate the load-carrying bucket of loaders of this type in m^3
- Loading duration, min
- Unloading duration, min
- Speed without load, km/h
- Speed with load, km/h
- A parameter that shows whether the speed of this type of loaders depends on the angle of the road. If the speed is independent of the slope angle, it is determined by the constant speed values set on this tab. If the speed depends on the angle of the road, it is calculated taking into account the parameters set on the "Speeds" tab (Clause 2.7.1.1)
- Fuel tank volume of loaders of this type, in liters
- Fuel consumption rate when driving without load, l/h
- Fuel consumption rate when driving with load, l/h
- Fuel consumption rate without movement, l/h
- A parameter that shows whether the fuel consumption of loaders of this type depends on the angle of the road. If fuel consumption does not depend on the angle of inclination, it is determined by the constant flow rates set on this tab. If fuel consumption depends on the angle of inclination of the road, its calculation is performed taking into account the parameters set on the "Fuel consumption" tab (Clause 2.7.1.2).

For the loader type cost parameters can be set (but not necessarily):

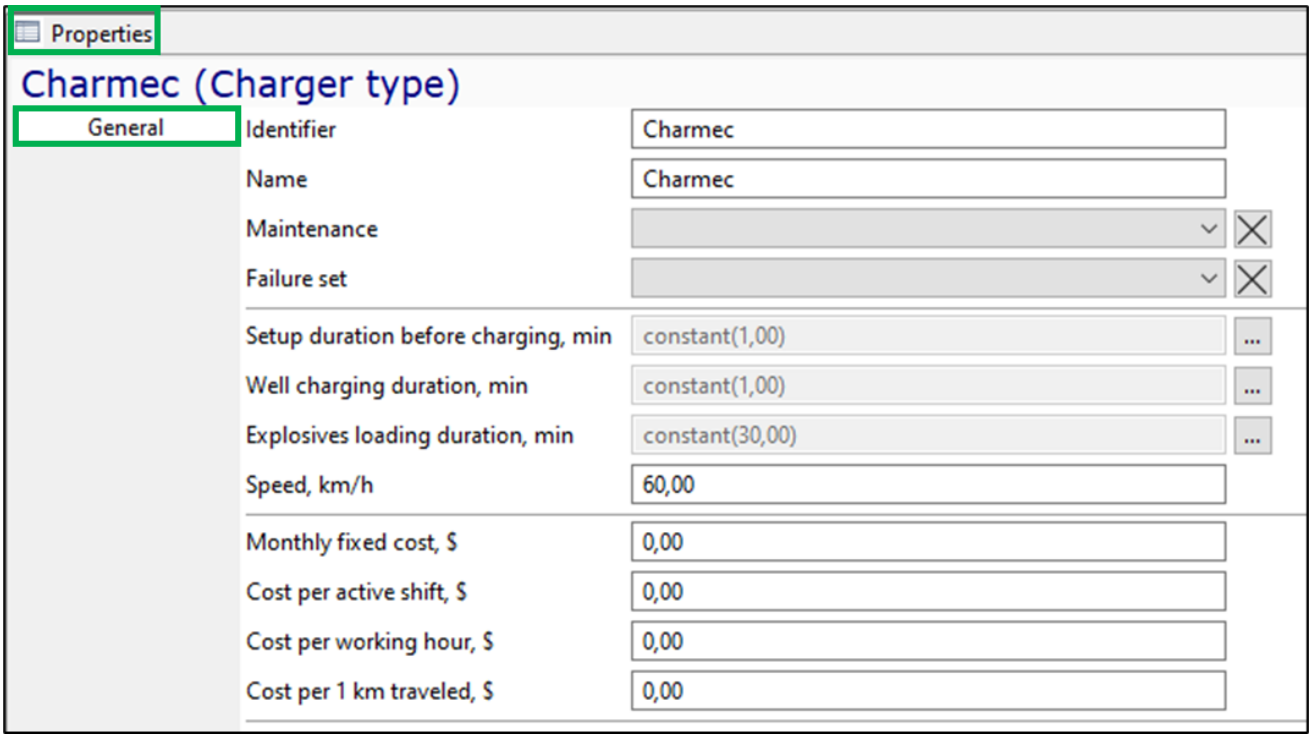
- Fixed costs for loaders of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

Also, the following properties can be specified for the loader type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.3. Charger types

Charger is a device for mechanized feeding of explosive material (EM) to charging planes (wells, blast holes).



The following basic properties must be set for each charger type:

- Unique identifier and name
- Duration of the setup before charging, min
- Duration of charging of one well, min
- Duration of explosives loading in the explosive store, min
- Constant travel speed of this type of chargers in km/h

The setup, charging and loading duration can be set by a constant value or by one of the distributions (Clause 2.3.4).

For the charger type cost parameters can be set (but not necessarily):

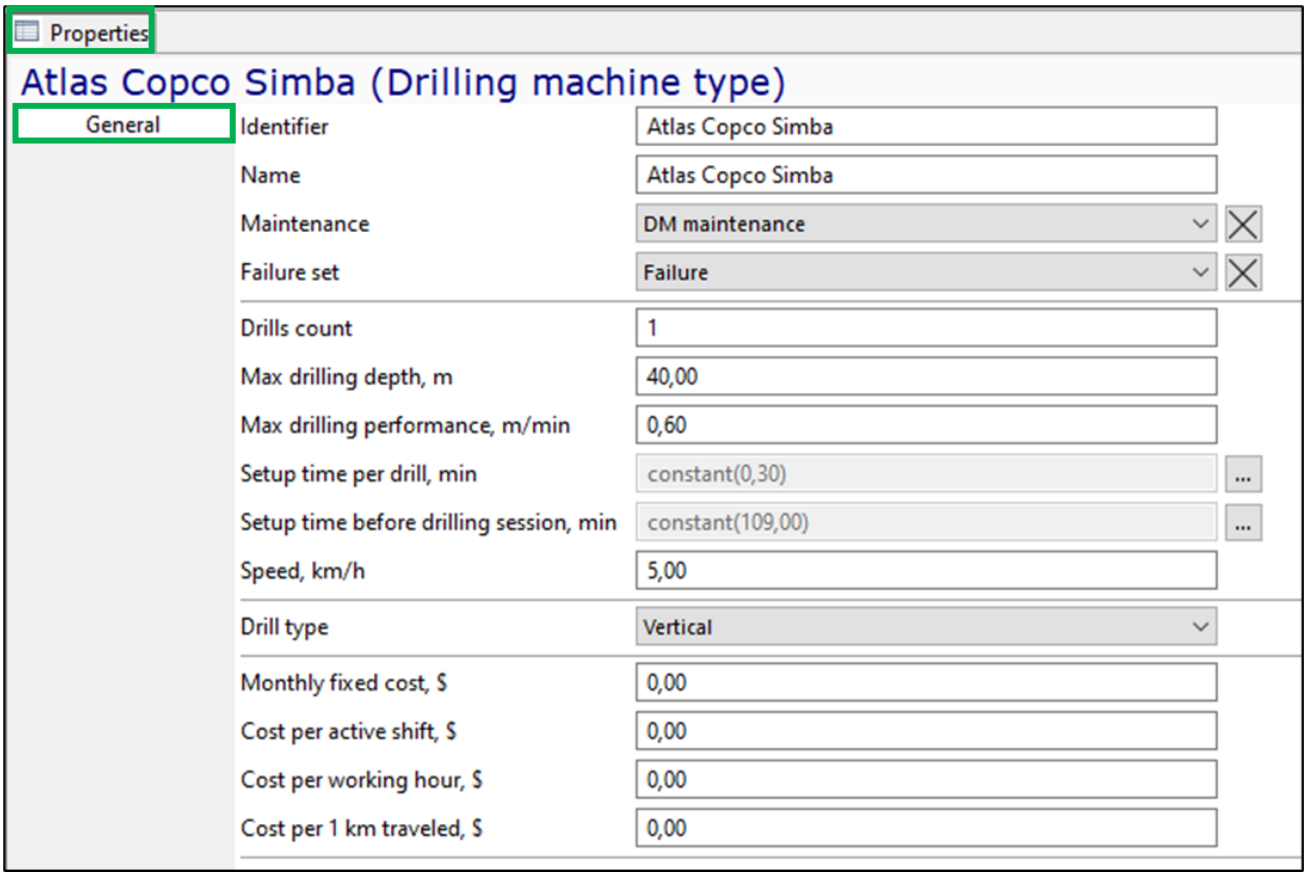
- Fixed costs for chargers of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

Also, the following properties can be specified for the charger type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.4. Drilling machine types

Drilling machine is the equipment designed for drilling wells/ holes, capable of independently moving around an open-pit mine.



The following basic properties must be set for each drilling machine type:

- Unique identifier and name
- Drills count - the number of drilling tools. As a rule, a horizontal drilling machine has 2 booms, a vertical drilling machine has 1 boom
- Max drilling depth possible for this type of drilling machine, m
- Max drilling performance, m/min
- Setup time per drill, min - duration of manipulations before drilling each well
- Setup time before drilling session, min - duration of preparatory work, such as installing the drilling machine, connecting electricity and water, etc.
- Constant speed of this type of drilling machines in km/h
- One of two possible types of drill: horizontal or vertical.

The setup time can be set by a constant value or by one of the distributions (Clause 2.3.4).

For the drilling machine type cost parameters can be set (but not necessarily):

- Fixed costs for drilling machines of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD

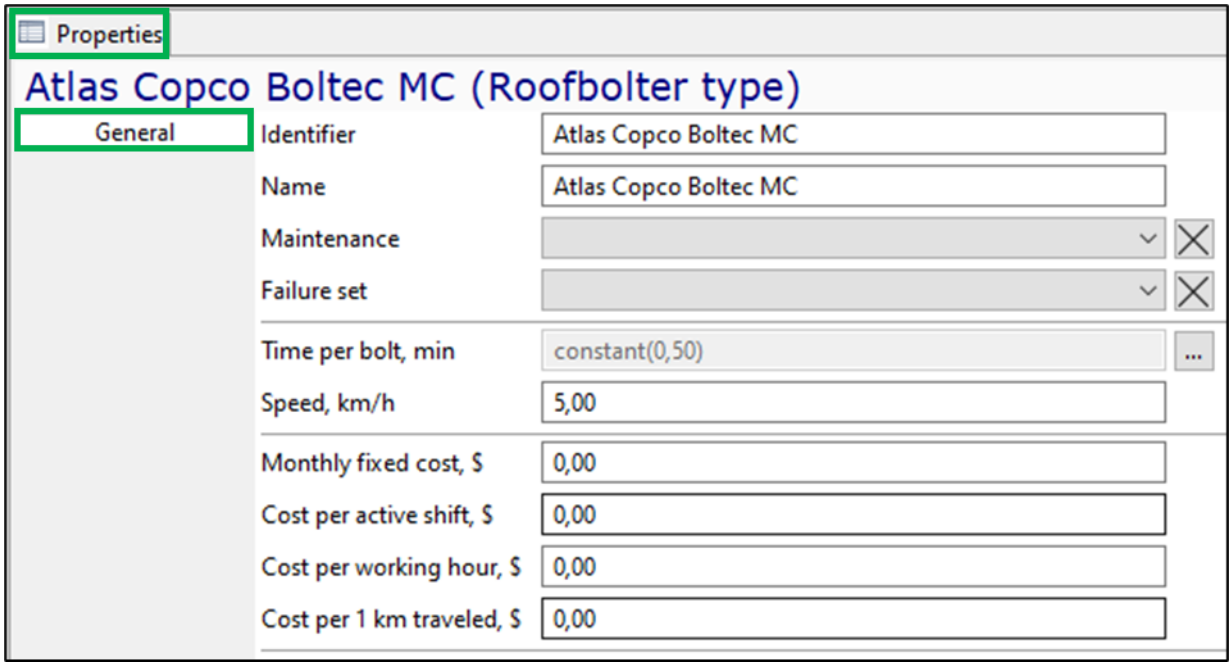
- Costs per 1 kilometer run, in USD.

Also, the following properties can be specified for the drilling machine type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.5. Roofbolter types

Roof bolter - equipment designed for installation of roof bolting during mining operations.



The following basic properties must be set for each roofbolter type:

- Unique identifier and name
- Duration of installation of a single bolt in minutes
- Constant travel speed of this type of roofbolter in km/h

Duration of bolt installation can be set by a constant value or by one of the distributions (Clause 2.3.4).

For the roofbolter type cost parameters can be set (but not necessarily):

- Fixed costs for roofbolters of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

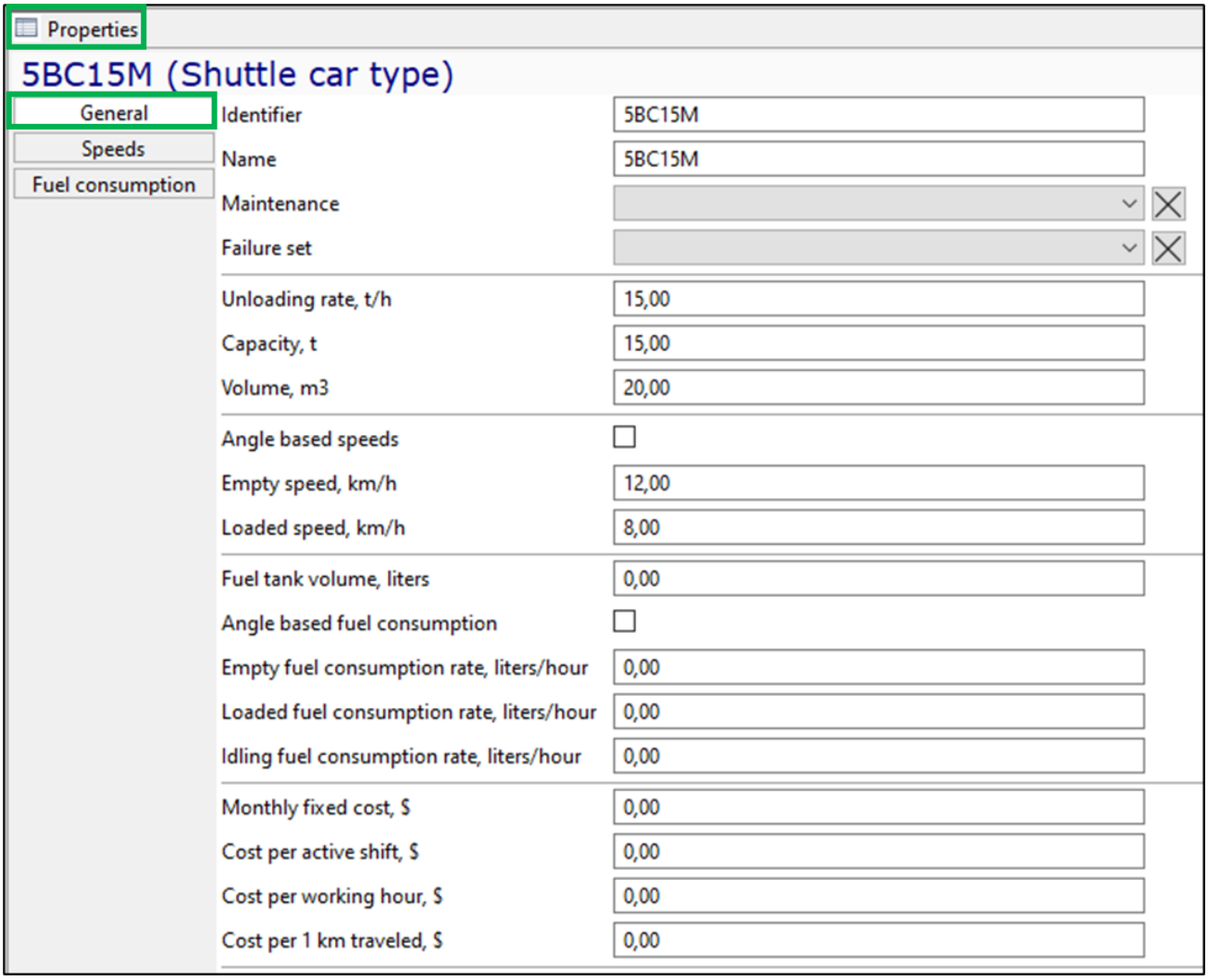
Also, the following properties can be specified for the roofbolter type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).

- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.6. Shuttle car types

Shuttle car - equipment contained a bottom conveyor and designed for transporting rock mass in underground mines when working with continuous miners. The continuous miners load the rock mass into shuttle cars, which transfer it to the mine conveyors.



The following properties must be set for each shuttle car type:

- Unique identifier and name
- Performance of ore mass unloading in tons per minute
- Capacity of shuttle cars of this type in tons
- Volume, m^3 - the maximum quantity of ore that can accommodate shuttle cars of this type in m^3
- Speed without load, km/h
- Speed with load, km/h

- A parameter that shows whether the speed of this type of shuttle cars depends on the angle of the road. If the speed is independent of the slope angle, it is determined by the constant speed values set on this tab. If the speed depends on the angle of the road, it is calculated taking into account the parameters set on the "Speeds" tab (Clause 2.7.1.1)
- Fuel tank volume of shuttle cars of this type, in liters
- Fuel consumption rate when driving without load, l/h
- Fuel consumption rate when driving with load, l/h
- Fuel consumption rate without movement, l/h
- A parameter that shows whether the fuel consumption of shuttle cars of this type depends on the angle of the road. If fuel consumption does not depend on the angle of inclination, it is determined by the constant flow rates set on this tab. If fuel consumption depends on the angle of inclination of the road, its calculation is performed taking into account the parameters set on the "Fuel consumption" tab (Clause 2.7.1.2).

For the shuttle car type cost parameters can be set (but not necessarily):

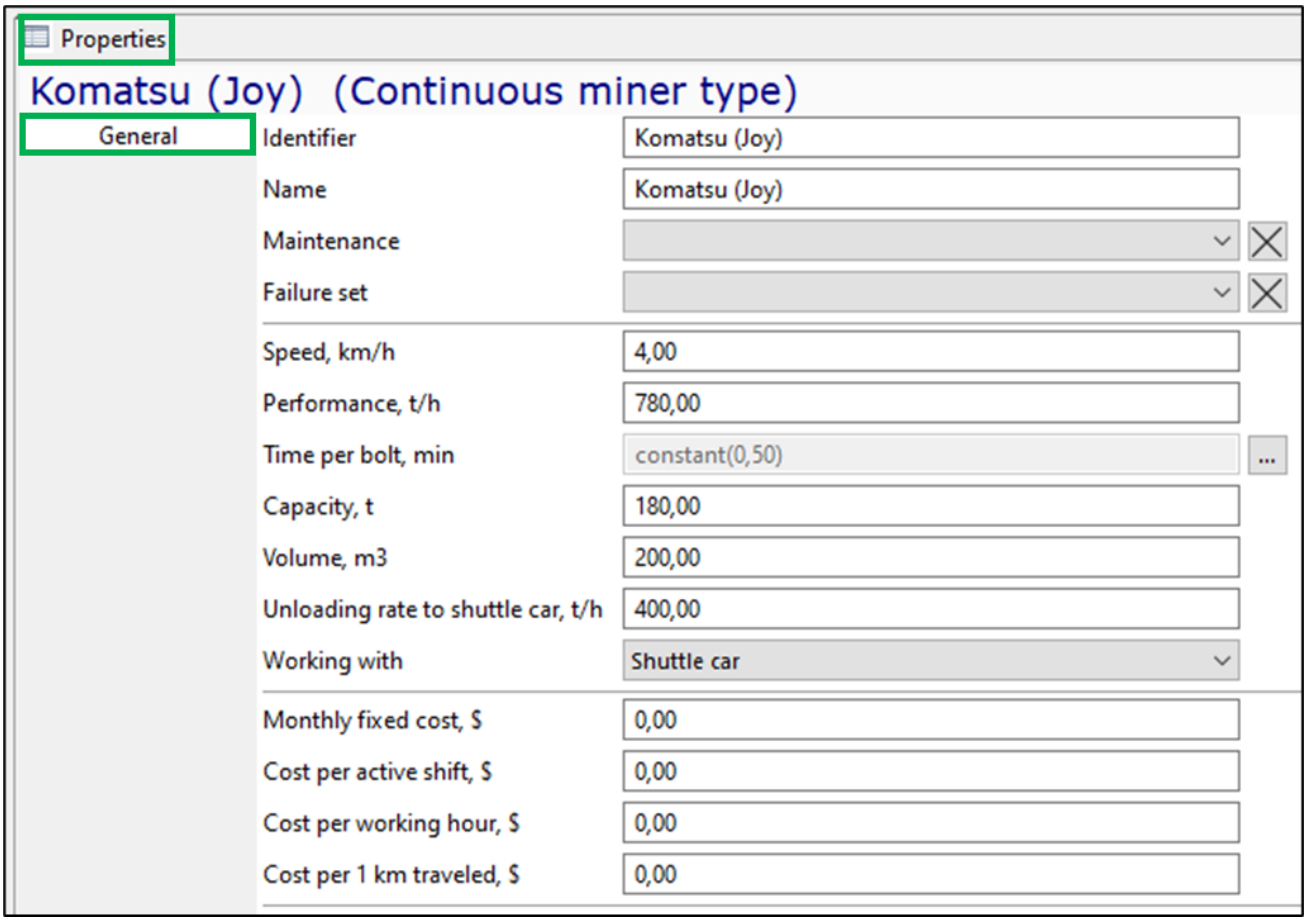
- Fixed costs for shuttle cars of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

Also, the following properties can be specified for the shuttle car type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

2.7.7. Continuous miner types

Continuous miner – mining equipment for mechanical breaking and destruction of the rock mass and its removal from the face. The continuous miner cuts the rock mass and transfers it to a conveyor or to a shuttle car. While working continuous miners can also install roof bolting.



The following properties must be set for each continuous miner type:

- Unique identifier and name
- Constant speed of this type of continuous miners in km/h
- Performance of ore mass cutting in tons per minute
- Duration of one bolt installation in minutes
- Capacity of a bunker of continuous miners of this type in tons
- Volume, m^3 - the maximum quantity of ore that can accommodate a bunker of continuous miners of this type in m^3
- Performance of transloading from bunker to shuttle cars in tons per minute
- Parameter that indicates whether continuous miners of this type work with shuttle cars or with conveyors.

For the continuous miner type cost parameters can be set (but not necessarily):

- Fixed costs for continuous miners of this type, in USD per month
- Costs per active shift, in USD
- Costs per working hour, in USD
- Costs per 1 kilometer run, in USD.

Also, the following properties can be specified for the continuous miner type:

- Maintenance - a reference to the maintenance records (Clause 2.8.4).
- Failure set - a reference to the failure set records (Clause 2.8.5).

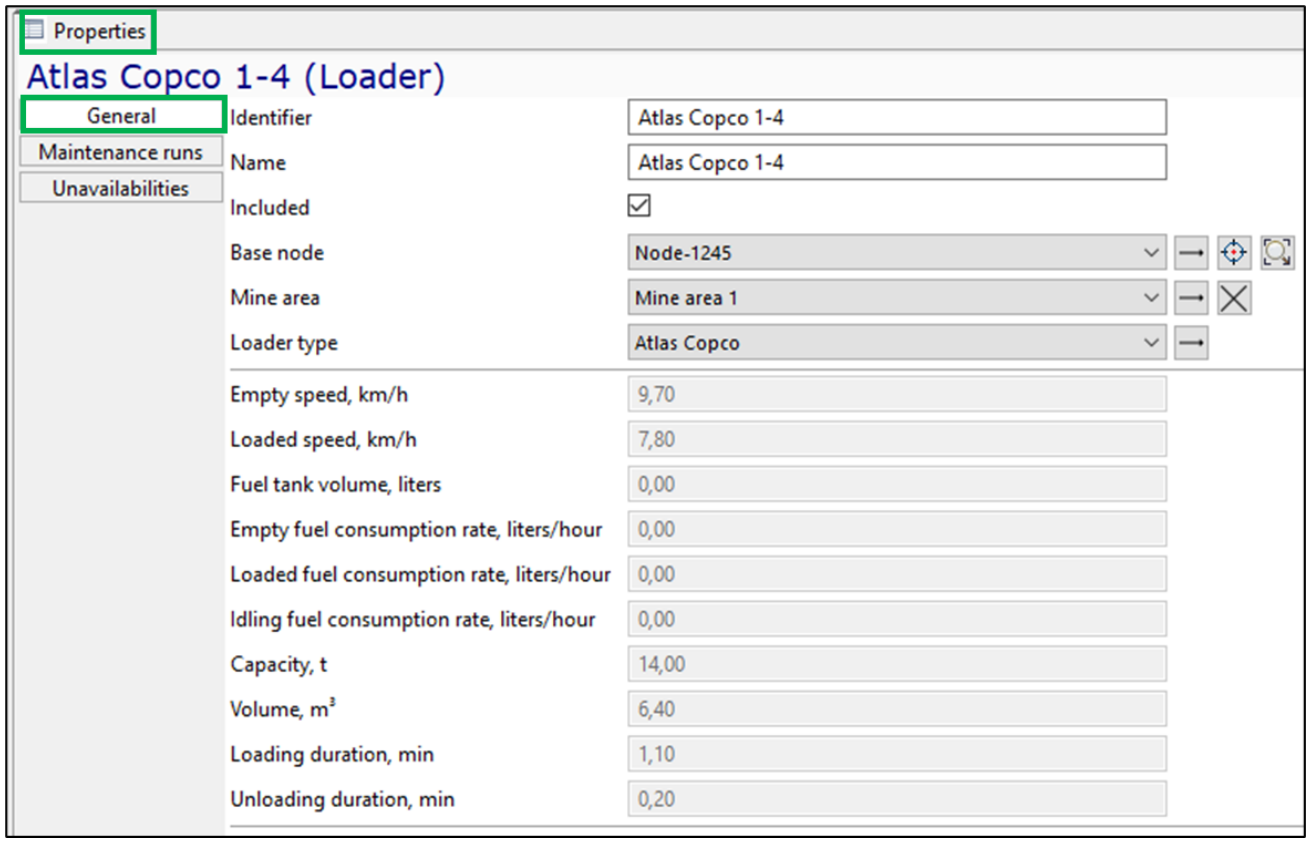
2.7.8. Mobile equipment

The " Mobile equipment" object tree element contains lists of all mobile equipment units used in the scenario, in terms of equipment types, as well as the list of trains which unlike other moving equipment, are not grouped into types.

2.7.8.1 *General parameters*

For each equipment unit, except for the underground train, the following basic properties must be set:

- Unique identifier and name
- Base node - base location (garage)
- Mine area to which the equipment unit is assigned
- Equipment type (in this case, the properties of the equipment type are displayed in the properties of the equipment unit as reference information and are not available for editing).
- Included - parameter that indicates whether the equipment unit will be used for scheduling/simulation.

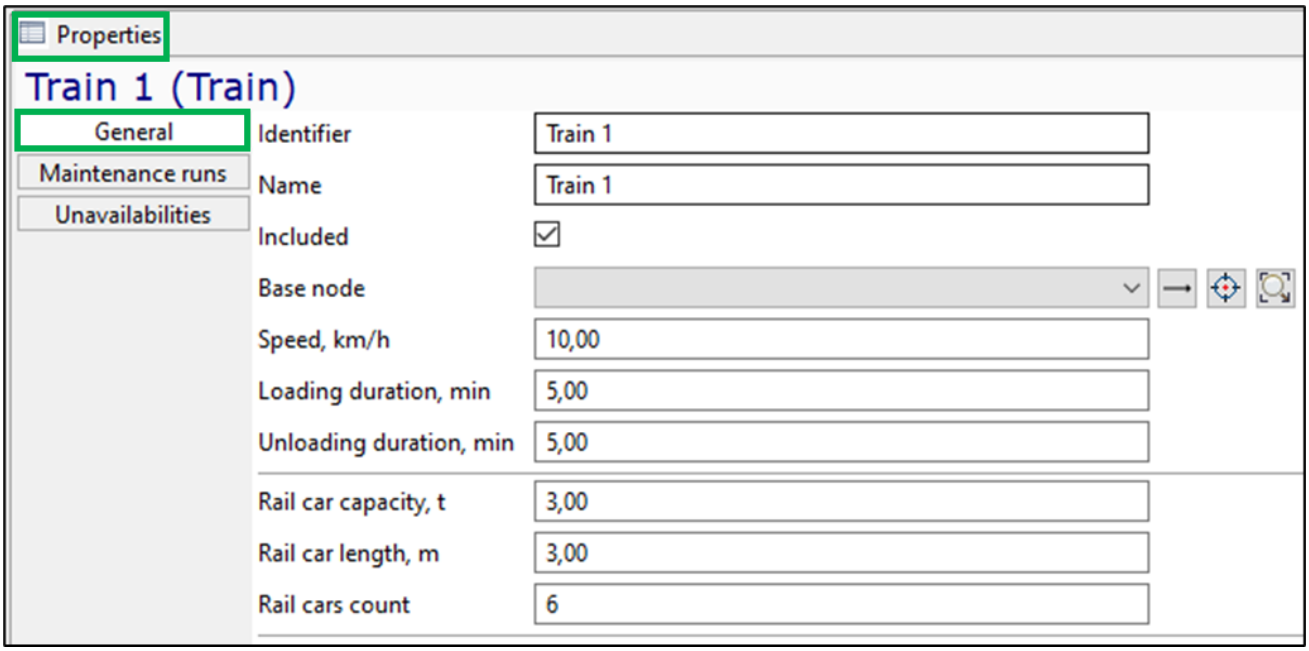


In addition to the specified basic properties, you should set for the charger unit "Explosive store" location - a reference to the mine node.

For the convenience of the user, the properties of the equipment unit in a non-editable format display the properties of its type.

2.7.8.2 *Train*

Train is a transport unit in the form of a separate train that consists of several rail cars, designed to transport ore mass on the rails. Unlike other mobile equipment, trains are not grouped into types.



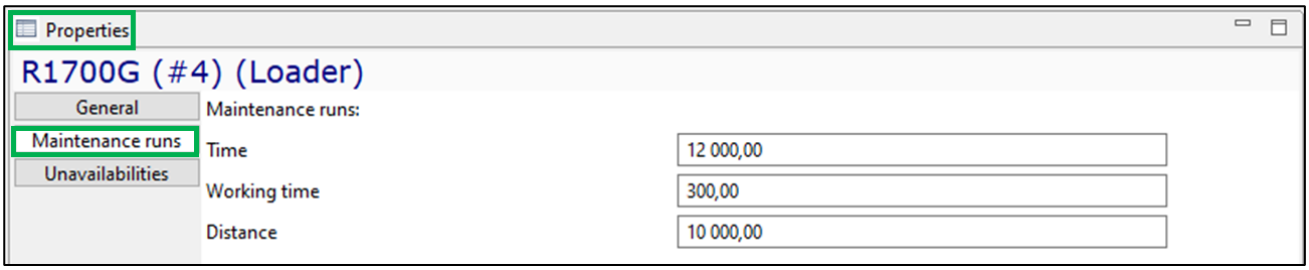
The following basic parameters are set for a train:

- Unique identifier and name
- Included - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- Base node - base location (garage)
- Speed, km/h
- Loading duration, min
- Unloading duration, min
- Capacity of one rail car in tons
- Length of one rail car in meters
- Number of rail cars in the train.

2.7.8.3 *Maintenance runs*

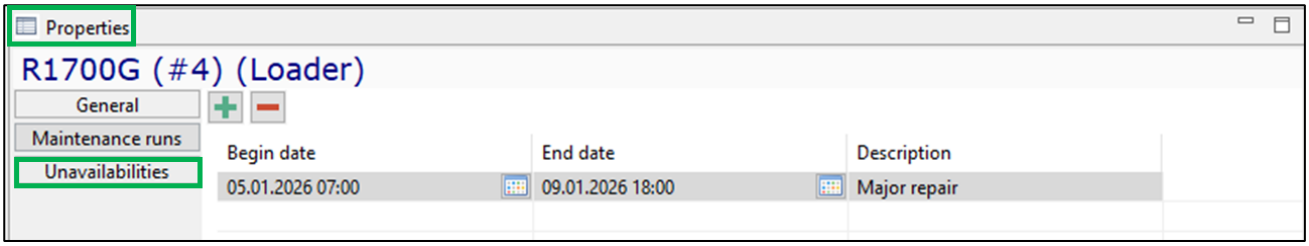
The initial state of the parameters related to its maintenance by working time is set for the mobile equipment unit:

- Initial working time according to the "Time" parameter - the total time that the equipment unit worked at the moment of the beginning of scheduling/simulation.
- Initial working time according to the "Working time" parameter - the number of motor hours (hours of the motor operation during movement, loading, unloading), that the equipment unit worked at the moment of the beginning of scheduling/simulation.
- Initial working time according to the "Distance" parameter - the number of kilometers traveled by the equipment unit at the moment of the beginning of scheduling/simulation.



2.7.8.4 *Unavailabilities*

The periods of unavailability for operation can be set for each equipment unit.



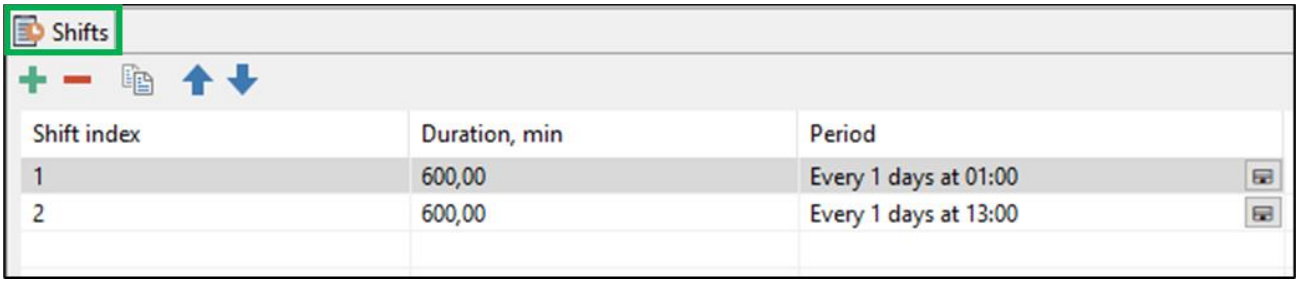
2.8. Schedules

The "Schedules" model tree element contains the following entities that regulate the work of the mine:

- Shifts
- Blast periods
- Off-schedule periods
- Maintenance
- Failure sets.

2.8.1. Shifts

Shifts are used to simulate the operation of equipment in accordance with the work schedule. Shifts determine the periods when equipment is available for operation.



Parameters are set for each shift:

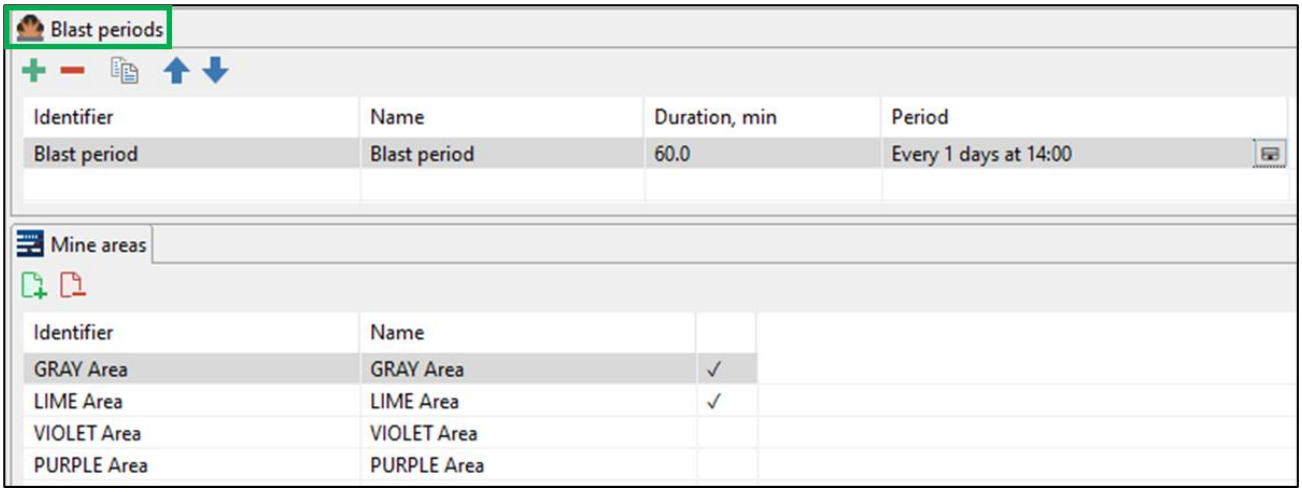
- Shift index - an optional field to indicate a shift
- Duration of shift, in hours

- The period of the shift which can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days) (Clause 2.3.4).

All shifts in the "Shifts" object tree are used for all equipment units during scheduling and simulation.

2.8.2. Blast periods

Blast periods define the time periods when the formation of broken-up ore mass is simulated in all stopes in selected mine areas, ready for blasting at the start of the blast period.



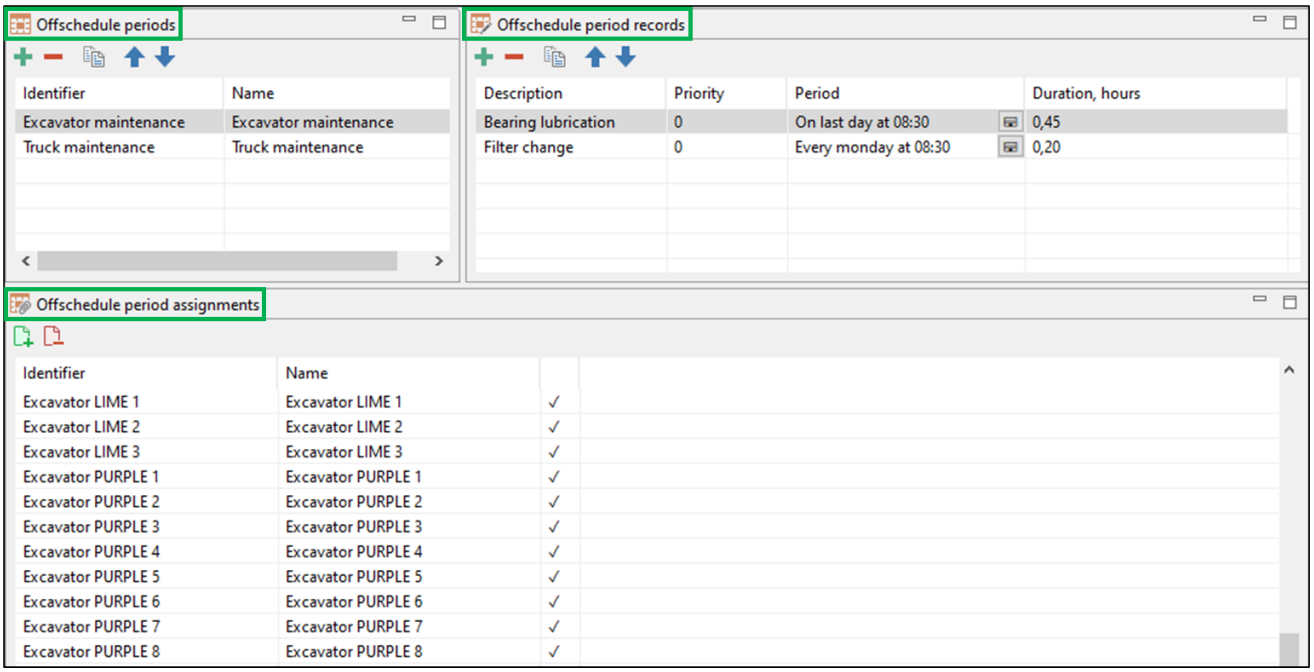
The "Blast period" entity is characterized by the following parameters:

- Unique identifier and name of the blast period
- The period of the blast period which can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days) (Clause 2.3.4)
- Areas where the above blasting operations are carried out.

The "Blast periods" object tree element contains a list of all blast periods that can be assigned to the mine areas during scheduling and simulation.

2.8.3. Off-schedule periods

Off-schedule periods are used to simulate the equipment unavailabilities in a strictly specified period of time, regardless of the operating time / working hours / run time of the equipment. Thus, maintenance, major repair, equipment unit modernization, commissioning and decommissioning can be specified.



Three types of entities are created in MineTwin Underground to set up off-schedule periods:

- Off-schedule periods in the "Off-schedule periods" window, which can include several individual off-schedule periods (off-schedule period records).
- Off-schedule period record is a line with data about one off-schedule period in the "Off-schedule period records" window. Off-schedule period record is characterized by the following parameters:
    - Description - optional description of the unavailability
    - Priority is an index that characterizes the hierarchy of repairs. Repairs with a higher index cancel the time or resource count before repairs with a lower index.
    - The period of the repair which can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days) (Clause 2.3.4).
    - Duration, hours.

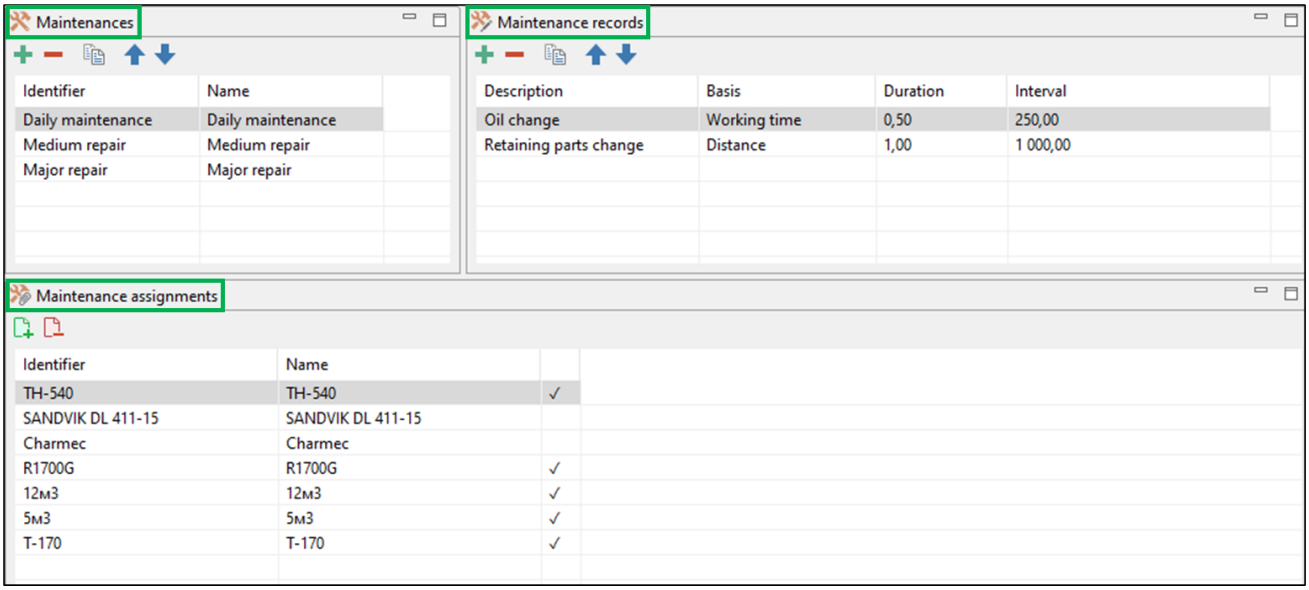
Assignment of off-schedule periods for selected equipment units is available in the "Off-schedule period assignments" window.

The buttons  allows you to select all equipment units / clear all selections.

The "Off-schedule periods" object tree element contains a list of all off-schedule periods that can be assigned to equipment during scheduling and simulation.

2.8.4. Maintenances

The "Maintenances" entity is used to simulate scheduled equipment repairs - repairs performed after a certain calendar time of equipment operation, when the equipment reaches a specified number of working hours of engine / percussive mechanism, or upon reaching a specified run time. In this way, maintenance, medium repair, major repair, etc. can be specified.



Three types of entities are created in MineTwin Underground to set up maintenances:

- Maintenances in the "Maintenances" window, which can include several individual repairs (maintenance records)
- Maintenance record - a line with data about one maintenance/repair in the "Maintenance records" window, which is characterized by the following parameters:
    - Description - optional description of the maintenance/repair
    - Type of maintenance time calculation - based on calendar time, based on the number of engine working hours, or based on the equipment run time
    - Duration, h
    - Interval, h - the period between two repairs of this type.

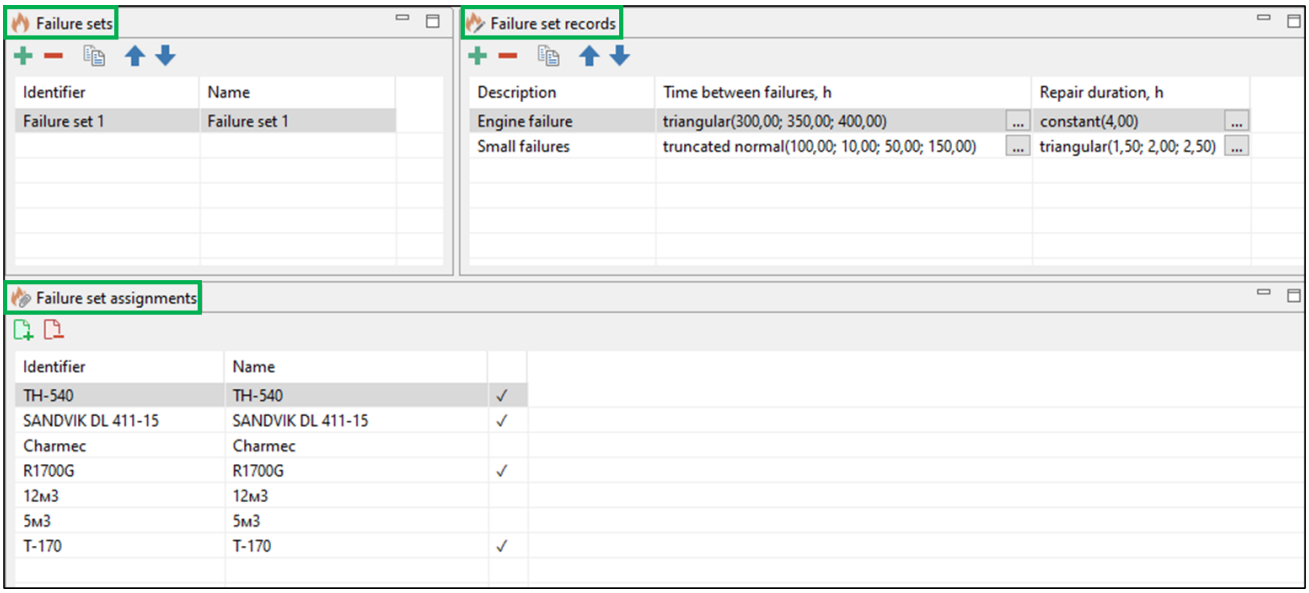
Assignment of maintenances for selected equipment types is available in the "Maintenance assignments" window.

The buttons  allows you to select all equipment types / clear all selections.

The "Maintenances" object tree element contains a list of all maintenance records that can be assigned to equipment during simulation.

2.8.5. Failure sets

Failure sets are used to simulate emergency equipment failures.



To define failure sets in MineTwin Underground, three types of entities are created:

- Failure set in the "Failure sets" window, which can include several individual failure sets (failure set records)
- Failure set record is a line with data about one failure set in the "Failure set records" window. Failure set record is characterized by the following parameters:
  - Description - optional description of the failure
  - Time between failures, h
  - Repair duration, h.

Assignment of failure sets for selected equipment types is available in the "Failure set assignments" window.

The buttons  allows you to select all equipment types / clear all selections.

The "Failure sets" object tree element contains a list of all failure sets that can be assigned to equipment during simulation.

2.9. Transaction data: tasks and plans

2.9.1. Tasks

MineTwin Underground provides the user with the ability to manually create a plan for the equipment operation, sending each specific equipment unit to a specific place of operation at a specific time (Clause 2.4).

In the "Tasks" block of model tree, the user can create drilling tasks, charging tasks, haulage tasks, roofbolting tasks, tasks of reloading the rock mass from loaders into trucks, continuous mining tasks, tasks of shuttle cars and skip hoists.

Drilling tasks

Begin date	End date	Wells count	Stope	Drilling machine
01.01.2019 00:00	02.01.2019 00:00	460,00	Blue-2	Atlas Copco Boomer 3-1
01.01.2019 00:00	02.01.2019 00:00	240,00	Gold-9	Atlas Copco Simba 10-2

Charging tasks

Begin date	End date	Wells count	Stope	Charger
01.01.2019 00:00	02.01.2019 00:00	460,00	Blue-2	Charmec-2- 6
01.01.2019 00:00	02.01.2019 00:00	240,00	Gold-9	Charmec-3-4

Haulage tasks

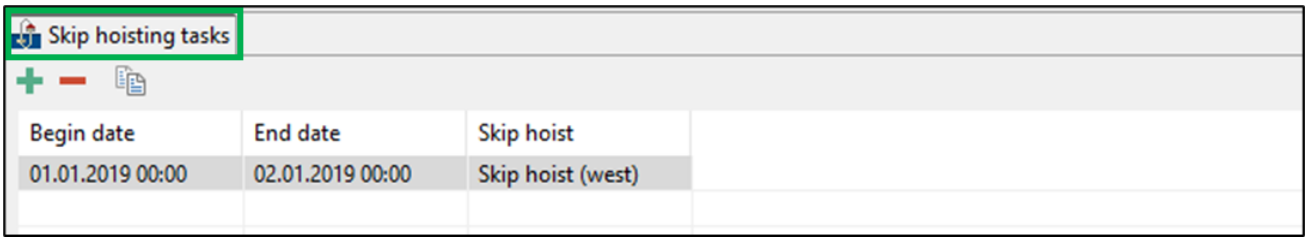
Begin date	End date	Runs count	Source stope	Loader	Destination
01.01.2019 00:00	02.01.2019 00:00	12.0	Gold-16	Atlas Copco 1-4	CDP-4
01.01.2019 00:00	02.01.2019 00:00	24.0	Brown-10	Atlas Copco 3-6	OrePass-15

Roofbolting tasks

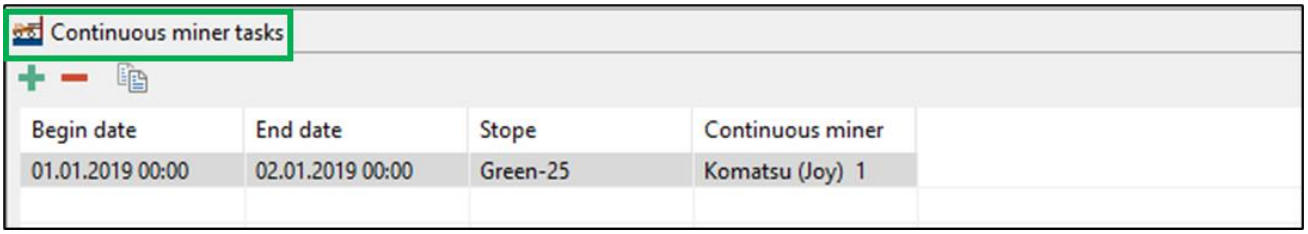
Begin date	End date	Bolts count	Stope	Roofbolter
03.01.2019 00:00	04.01.2019 00:00	360.0	Red-8	Roofbolter 1

Cross-docking tasks

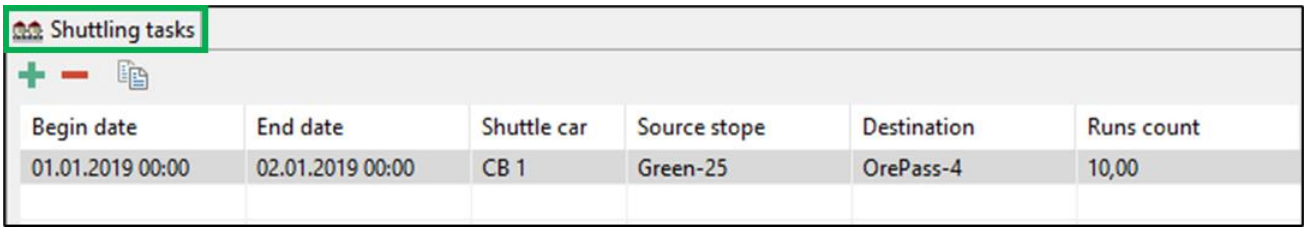
Begin date	End date	Source cross-dock point	Truck	Destination
01.01.2019 00:00	02.01.2019 00:00	CDP-18	Sandvik 10-3	OrePass-12
01.01.2019 00:00	02.01.2019 00:00	CDP-14	Sandvik 1-2	OrePass-4


Skip hoisting tasks

Begin date	End date	Skip hoist
01.01.2019 00:00	02.01.2019 00:00	Skip hoist (west)


Continuous miner tasks

Begin date	End date	Stope	Continuous miner
01.01.2019 00:00	02.01.2019 00:00	Green-25	Komatsu (Joy) 1


Shuttling tasks

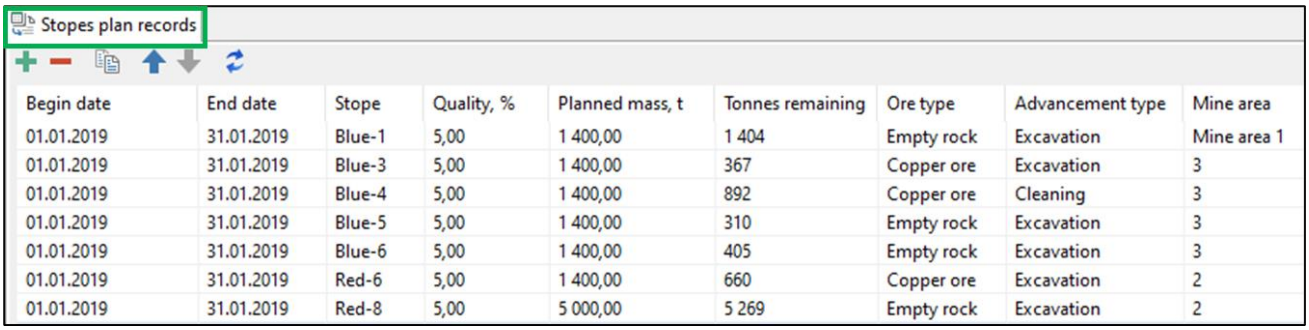
Begin date	End date	Shuttle car	Source stope	Destination	Runs count
01.01.2019 00:00	02.01.2019 00:00	CB 1	Green-25	OrePass-4	10,00

2.9.2. Production plans

MineTwin Underground can automatically form an equipment operation plan based on target plans for mining ore mass or stopes (Clause 2.4).

2.9.2.1 *Stopes plan*

The stopes plan specifies how much ore mass and what quality must be mined in each period in each stope.


Stopes plan records

Begin date	End date	Stope	Quality, %	Planned mass, t	Tonnes remaining	Ore type	Advancement type	Mine area
01.01.2019	31.01.2019	Blue-1	5,00	1 400,00	1 404	Empty rock	Excavation	Mine area 1
01.01.2019	31.01.2019	Blue-3	5,00	1 400,00	367	Copper ore	Excavation	3
01.01.2019	31.01.2019	Blue-4	5,00	1 400,00	892	Copper ore	Cleaning	3
01.01.2019	31.01.2019	Blue-5	5,00	1 400,00	310	Empty rock	Excavation	3
01.01.2019	31.01.2019	Blue-6	5,00	1 400,00	405	Empty rock	Excavation	3
01.01.2019	31.01.2019	Red-6	5,00	1 400,00	660	Copper ore	Excavation	2
01.01.2019	31.01.2019	Red-8	5,00	5 000,00	5 269	Empty rock	Excavation	2

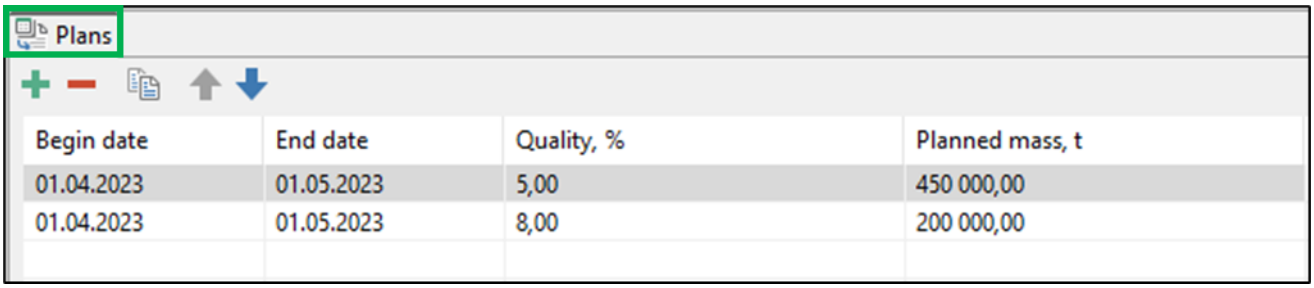
Each stopes plan record is characterized by the following parameters:

- Begin and end dates of the planning period
- Stope
- Planned mass, t.
- Quality of the mined ore mass
- Tones remaining – quantity of remained ore mass in stopes

- Ore type
- Advancement type
- Mine area.

2.9.2.2 *Target plan*

The target plan specifies how much ore mass and what quality must be mined in each target period in total.



Begin date	End date	Quality, %	Planned mass, t
01.04.2023	01.05.2023	5,00	450 000,00
01.04.2023	01.05.2023	8,00	200 000,00

Each target plan record is characterized by the following parameters:

- Begin and end dates of the planning period
- Quality of the mined ore mass
- Planned mass, t.

3. Scheduling and simulation

The scheduler is intended for scheduling equipment operation, taking into account:

- Target values for production volumes and ore quality
- Sequences of the mine technological cycle
- Duration of operations performed by the selected equipment
- Lengths of the hauling distances, geometric distance of the stopes
- Equipment operating schedules
- Scheduled equipment repairs and other routine maintenance
- Blasting schedules.

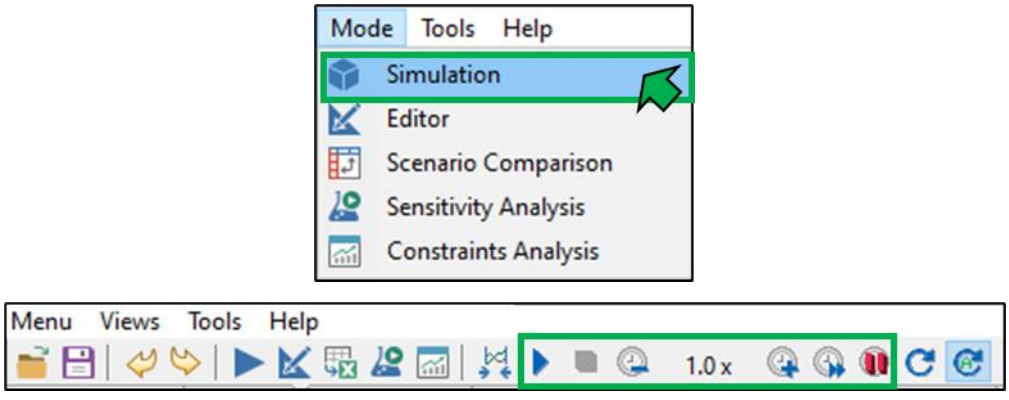
The simulation model checks the feasibility of the scheduler's plan, taking into account:

- Unscheduled repairs (failures)
- Delays due to vehicle passing in busy areas of the mine
- Loading queues
- Unloading queues in front of the ore passes due to erratic loading on them
- Decreased throughput of in-mine haulage due to uneven ore supply

In MineTwin scheduling mode, one shift scheduling and simulation is performed sequentially. At the end of the shift, the scheduler performs scheduling for the next one based on the results of the execution of the previous shift plan by the simulation model.

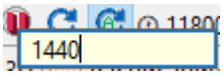
3.1. Simulation management

To switch to the scheduling/simulation mode, you need to select it in the toolbar of the editing mode.

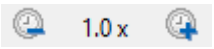


To start the simulation according to the plan, use the button in the upper toolbar of the scheduler window.

To pause the model, use the button .

To pause until the required simulation time, use the button  . When you click on this button, a window will appear in which you need to enter the required stop time in model minutes, for example, 1440 to stop the model one day after the start of the simulation: 

. To close the window for entering simulation time, use the "Esc" key.

To accelerate / slow down the simulation, use the buttons 

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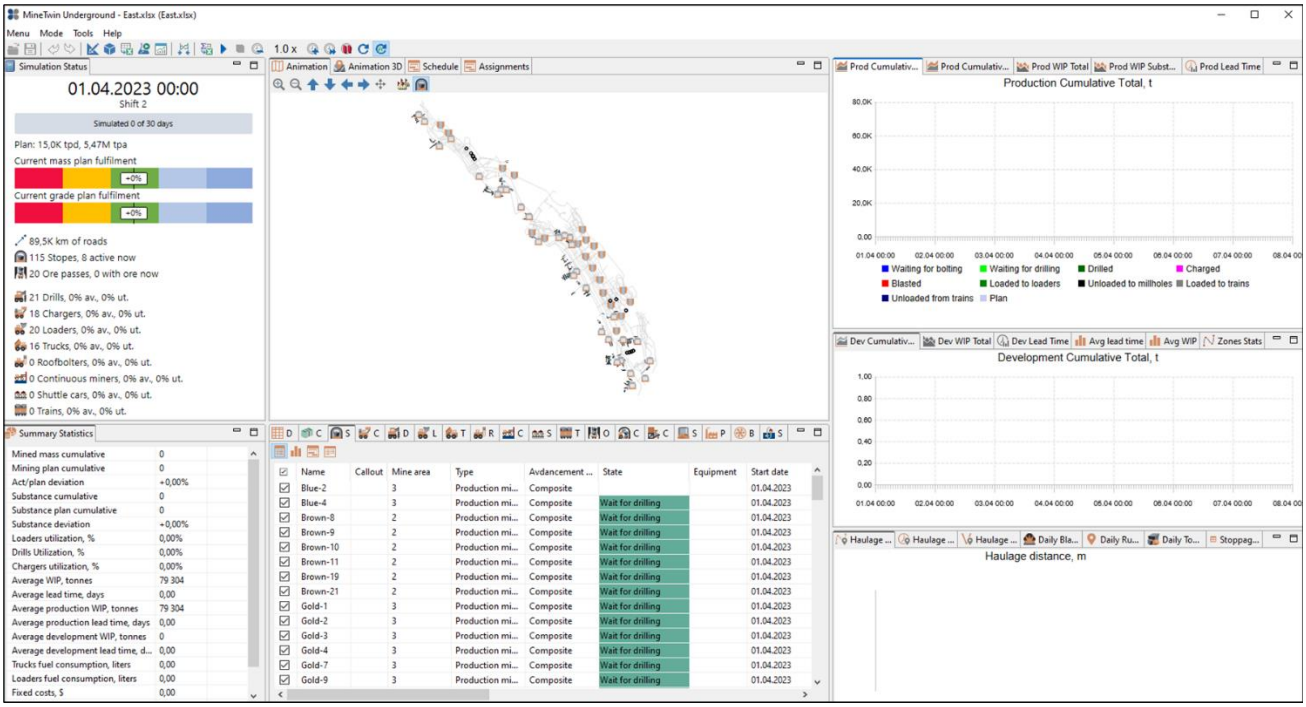
For maximum acceleration, use the button  .

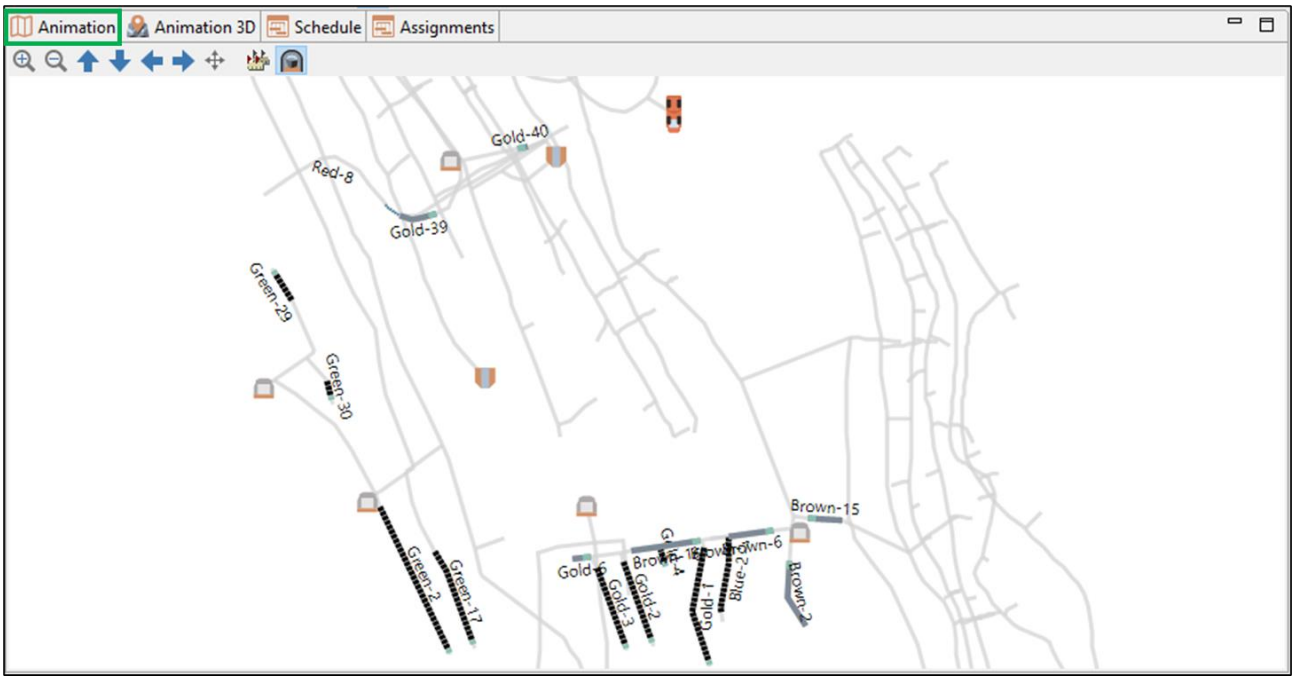
3.2. Visualization of simulation results

The layout of the scheduler window is shown in the figure below.



3.2.1. Animation

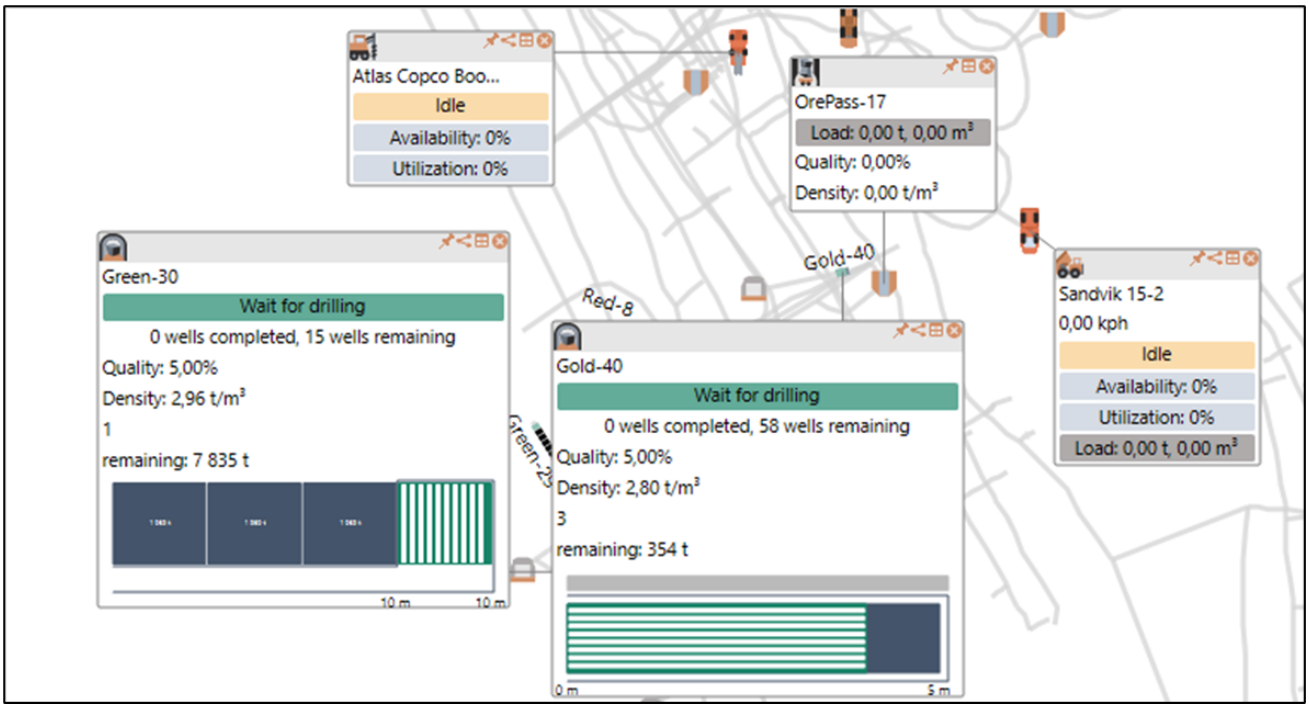
2D animation dynamically displays the simulation process in 2D space: simulation of the movement and equipment/transport operation on the mine map.



The top panel of the animation window contains the buttons that make it easier to work with the map. The buttons  allow to zoom in/ out the map, the buttons  allow to move the map. The button  centers the map so that the entire mine is visible at the same time. The button  turns on the display of the lengths of the mine field segments, the button  displays the names of the stopes on the map.

Clicking on the equipment unit opens a window with information about the status of the equipment unit, its availability and equipment utilization.

Clicking on a stope opens a window with information about the status of the stope, the quality and density of the ore mass in the stope.

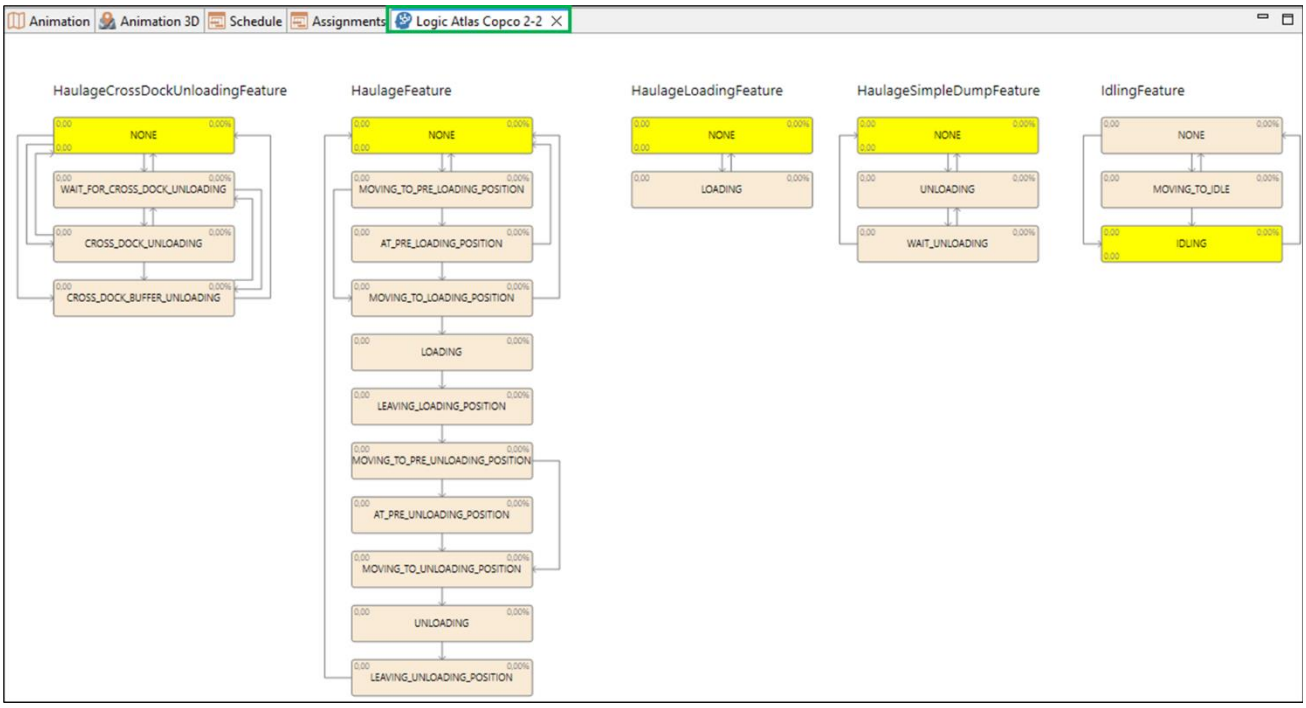


Clicking on the dump area, its loading, quality and density of the ore mass at the dump area are displayed.

The button  in the information window closes the window.

The button  activates the table with the list of equipment units and highlights the selected unit.

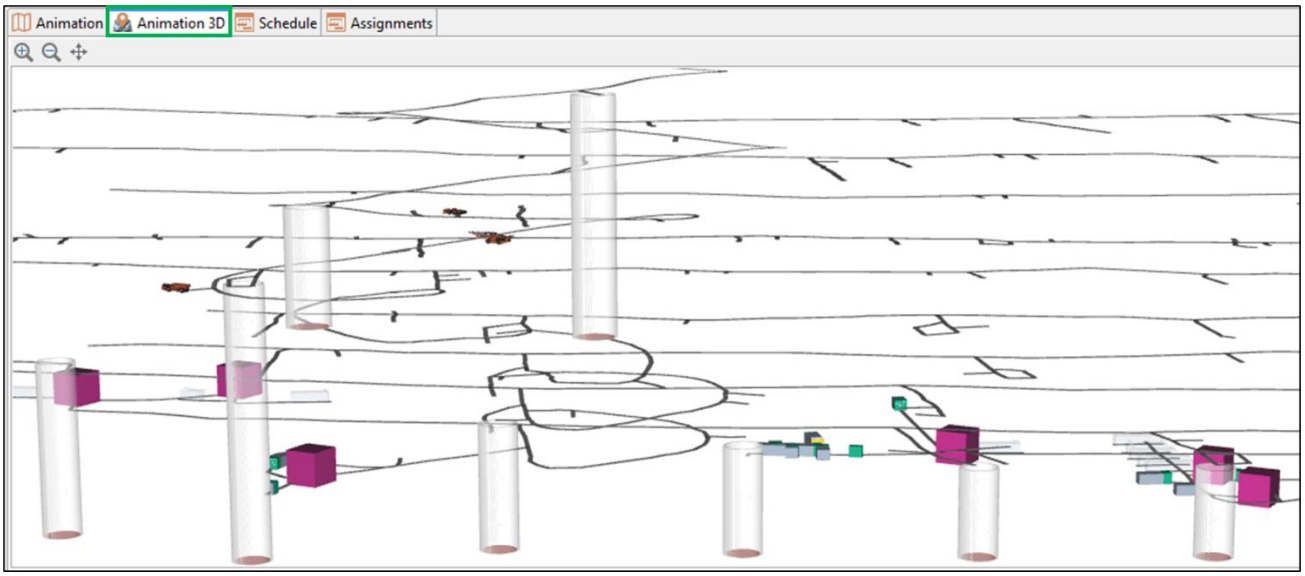
The button  activates the state chart table, which can be used by developers when errors and failures occur during the system operation.



The button  attaches the information window to the map, allowing it to be moved along with the map.

3.2.2. Map 3D

3D animation dynamically displays the simulation process in 3D space: simulation of the movement and equipment/transport operation on the mine 3D map.

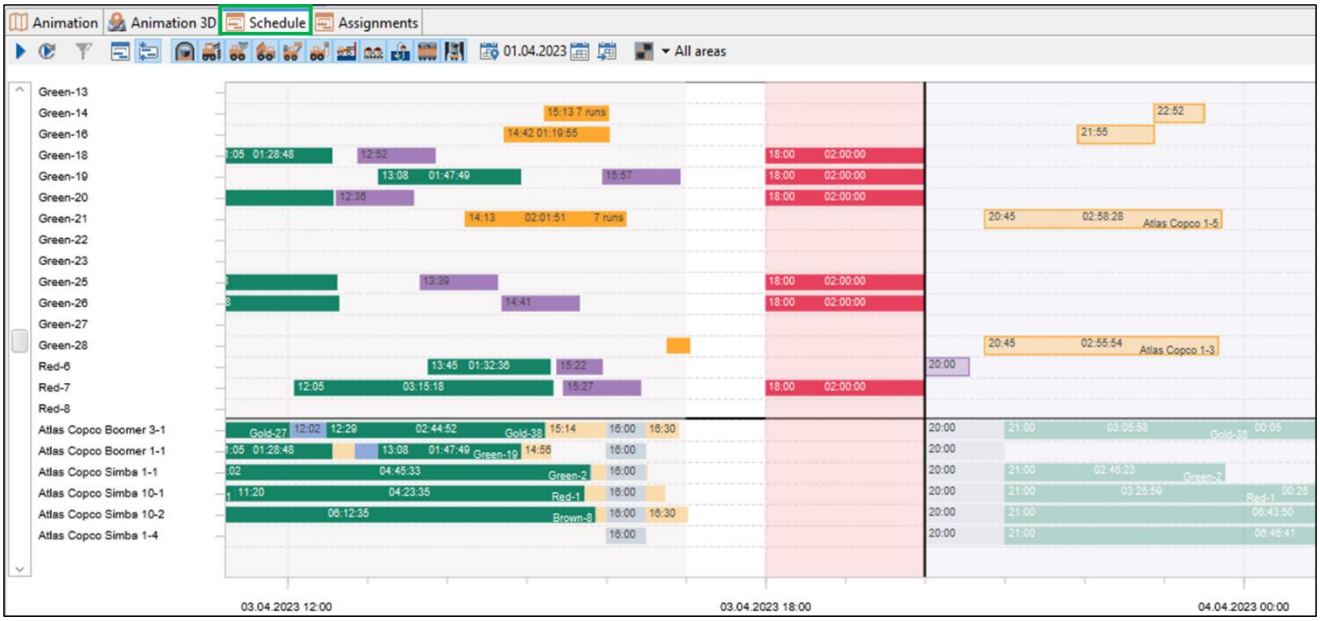


Clicking on the equipment unit opens a window with the name of the equipment unit.

The buttons  allow to zoom in/ out the map, the buttons  centers the map so that the entire mine is visible at the same time.

3.2.3. Schedule

In the "Schedule" window of the scheduling mode, the Gantt chart for the stopes shows the planned states (drilling, charging, blasting, haulage of ore mass, etc.), the planned tasks are displayed for the equipment. In the course of the simulation experiment, the plan fulfilment is dynamically displayed: compliance with the planned schedule and deviations from it.

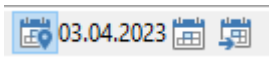


To start the simulation, use the button  in the upper toolbar of the "Schedule" window.

The simulation can be restarted to the required simulation time. To do this, set the vertical line representing the moment in time on the required date and press the button  .

The plan display can be enlarged using the button  ("Normal" mode) or more compact using the button  ("Compact" mode).

When you click on the buttons with the equipment types on the Gantt chart, only equipment of the selected types will be shown. The button  allows to display only the selected mine area on the Gantt chart.

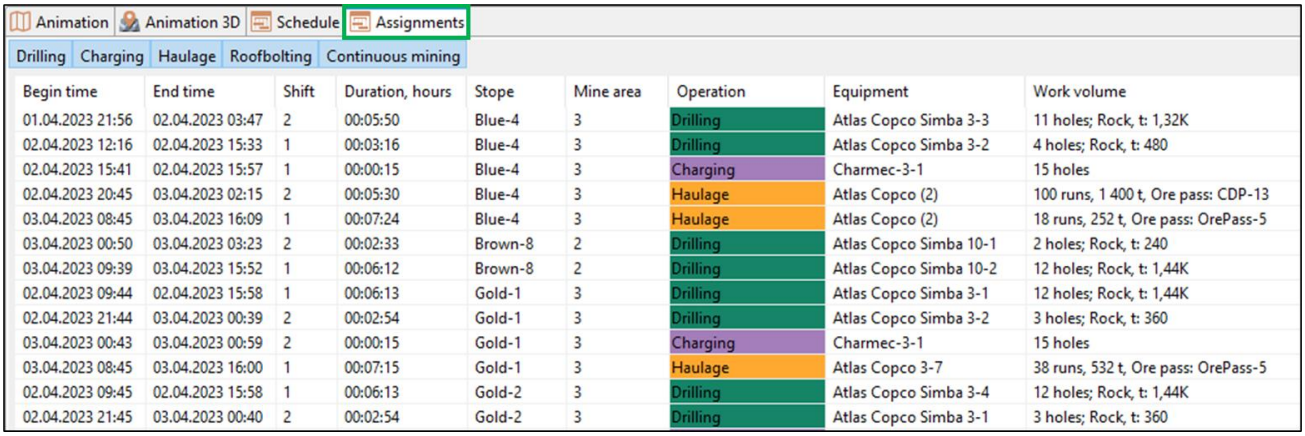
A group of buttons 

allows you to display the schedule for a specific date. The button  turns on the display mode of one day, the button  allows to set the date, the button  turns on the display of the schedule for the selected date.

3.2.4. Assignments

The assignments table contains a list of all operations performed by the equipment with the following information about operations:

- Start and end time of the operation
- Number of the shift on which the operation was completed
- The duration of the operation
- The stope where the operation was performed
- The mine area to which the stope belongs
- Equipment that performed the operation
- Amount of work performed (number of drilled/charged holes/holes, number of trips, amount of transported rock mass, etc.)



Begin time	End time	Shift	Duration, hours	Stope	Mine area	Operation	Equipment	Work volume
01.04.2023 21:56	02.04.2023 03:47	2	00:05:50	Blue-4	3	Drilling	Atlas Copco Simba 3-3	11 holes; Rock, t: 1,32K
02.04.2023 12:16	02.04.2023 15:33	1	00:03:16	Blue-4	3	Drilling	Atlas Copco Simba 3-2	4 holes; Rock, t: 480
02.04.2023 15:41	02.04.2023 15:57	1	00:00:15	Blue-4	3	Charging	Charmec-3-1	15 holes
02.04.2023 20:45	03.04.2023 02:15	2	00:05:30	Blue-4	3	Haulage	Atlas Copco (2)	100 runs, 1 400 t, Ore pass: CDP-13
03.04.2023 08:45	03.04.2023 16:09	1	00:07:24	Blue-4	3	Haulage	Atlas Copco (2)	18 runs, 252 t, Ore pass: OrePass-5
03.04.2023 00:50	03.04.2023 03:23	2	00:02:33	Brown-8	2	Drilling	Atlas Copco Simba 10-1	2 holes; Rock, t: 240
03.04.2023 09:39	03.04.2023 15:52	1	00:06:12	Brown-8	2	Drilling	Atlas Copco Simba 10-2	12 holes; Rock, t: 1,44K
02.04.2023 09:44	02.04.2023 15:58	1	00:06:13	Gold-1	3	Drilling	Atlas Copco Simba 3-1	12 holes; Rock, t: 1,44K
02.04.2023 21:44	03.04.2023 00:39	2	00:02:54	Gold-1	3	Drilling	Atlas Copco Simba 3-2	3 holes; Rock, t: 360
03.04.2023 00:43	03.04.2023 00:59	2	00:00:15	Gold-1	3	Charging	Charmec-3-1	15 holes
03.04.2023 08:45	03.04.2023 16:00	1	00:07:15	Gold-1	3	Haulage	Atlas Copco 3-7	38 runs, 532 t, Ore pass: OrePass-5
02.04.2023 09:45	02.04.2023 15:58	1	00:06:13	Gold-2	3	Drilling	Atlas Copco Simba 3-4	12 holes; Rock, t: 1,44K
02.04.2023 21:45	03.04.2023 00:40	2	00:02:54	Gold-2	3	Drilling	Atlas Copco Simba 3-1	3 holes; Rock, t: 360

The user can choose to display in the table only certain types of tasks by clicking on the button with the appropriate name in the top panel of the "Assignments" window: drilling, charging, haulage, roofbolting, continuous mining.

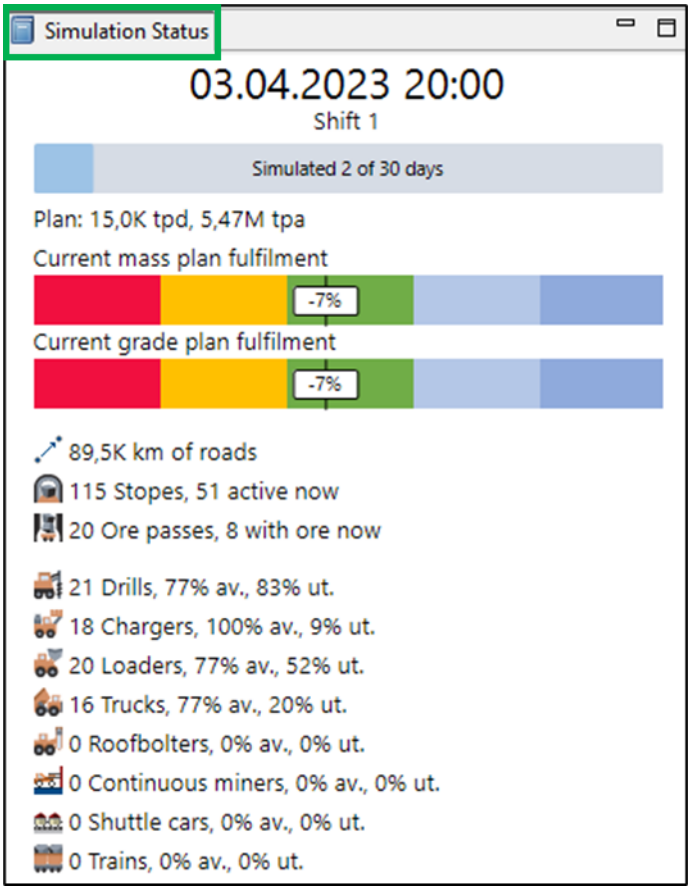
3.3. Statistical information

3.3.1. Simulation status

There is the “Simulation Status” window, which displays general information about the course of the simulation experiment in the left part of the scheduler window:

- how many days are simulated
- current shift number
- daily and annual production plan

- current mass plan fulfilment
- current grade plan fulfilment
- number of kilometers of roads
- the number of stopes in the scenario in total and the number of active now
- number of ore passes, number of ore passes with ore
- number of equipment units, their technical readiness factor and the equipment utilization rate.

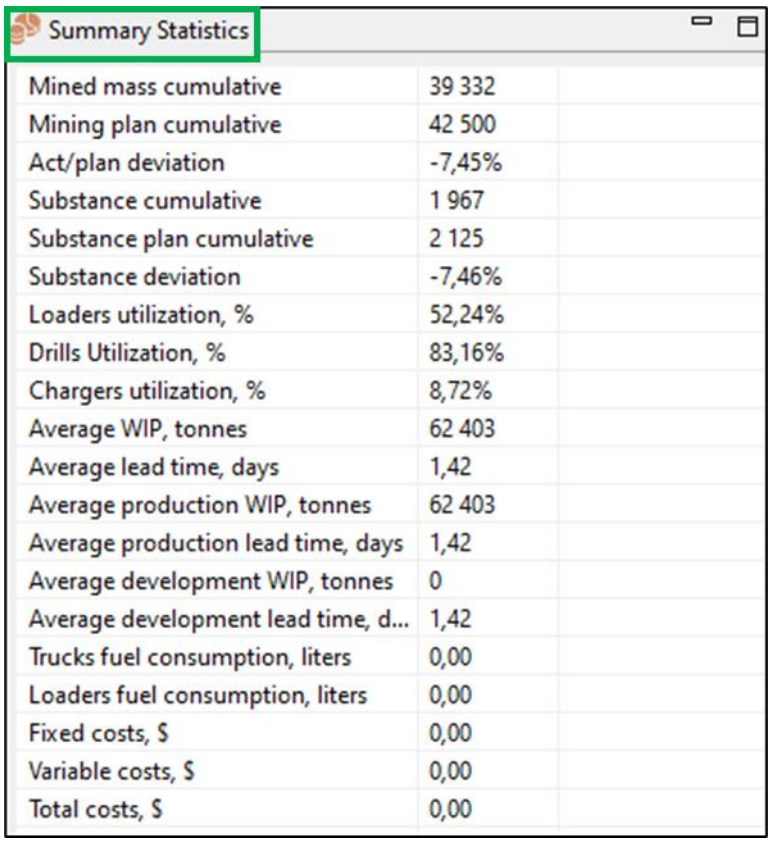


3.3.2. Summary statistics

The "Summary statistics" table displays the main statistical indicators of the simulation experiment results:

- Mined mass cumulative
- Mining plan cumulative
- Ore mass deviation from the plan, in percent
- Substance cumulative
- Substance plan cumulative
- Substance deviation from the plan, in percent

- Average WIP in total and separately for production and development, t: average amount of material (ore, rock, etc.) between some two stages of mining. For example, WIP of drilling is the amount of material for which drilling has started but has not been charged
- Average lead time in total and separately for production and development, days: the time required to mine a conditional ton of ore mass from drilling to haul on top
- Fuel consumption of loaders and trucks, liters
- All costs and separately fixed and variable costs, in USD.



Mined mass cumulative	39 332
Mining plan cumulative	42 500
Act/plan deviation	-7,45%
Substance cumulative	1 967
Substance plan cumulative	2 125
Substance deviation	-7,46%
Loaders utilization, %	52,24%
Drills Utilization, %	83,16%
Chargers utilization, %	8,72%
Average WIP, tonnes	62 403
Average lead time, days	1,42
Average production WIP, tonnes	62 403
Average production lead time, days	1,42
Average development WIP, tonnes	0
Average development lead time, d...	1,42
Trucks fuel consumption, liters	0,00
Loaders fuel consumption, liters	0,00
Fixed costs, $	0,00
Variable costs, $	0,00
Total costs, $	0,00

3.3.3. Daily volume stats

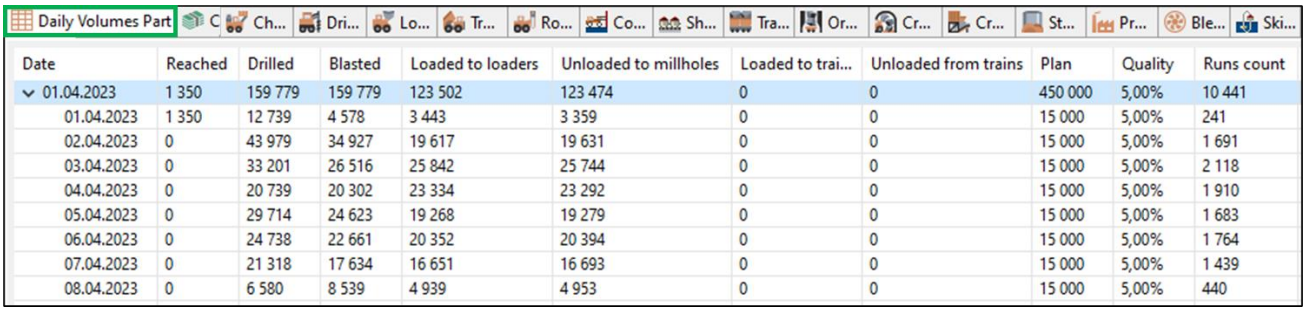
The "Daily Volume Stats" table shows the daily volumes of ore mass at different stages of its production:

- reached ore mass (ore mass in stopes, access to which is open)
- drilled ore mass
- blasted ore mass
- ore mass loaded to loaders
- ore mass unloaded by loaders and trucks to the ore passes
- ore mass loaded to trains

- ore mass unloaded from trains to the ore passes

The following also displayed:

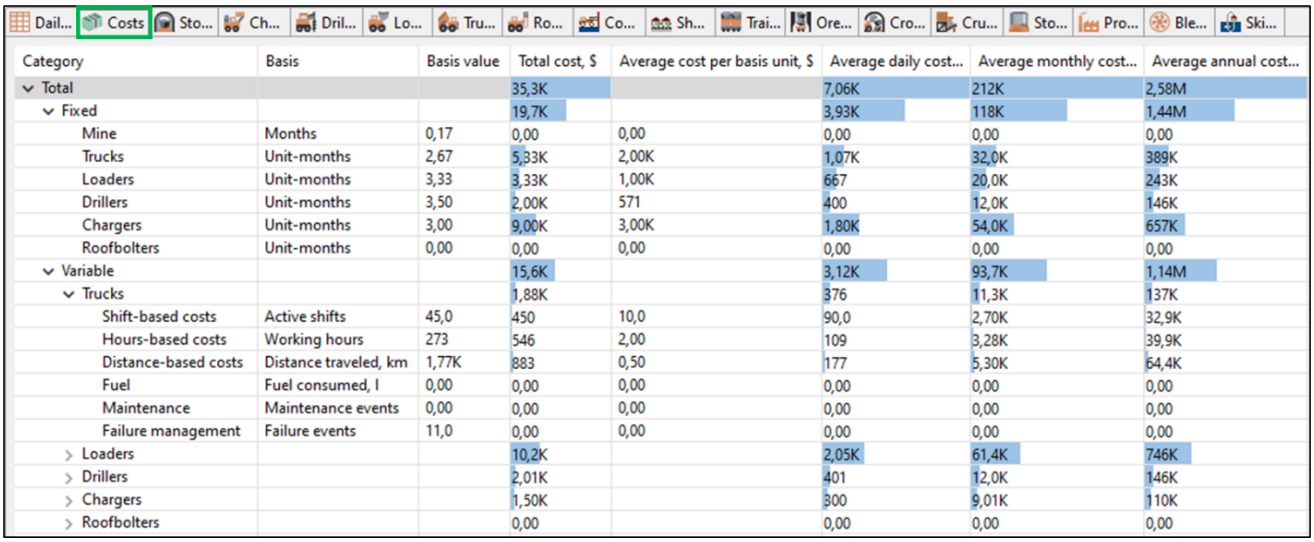
- daily planned volume of ore mass production
- simulated daily quality of ore mass (percentage of substance)
- planned daily quality of ore mass (percentage of substance)
- number of drilled holes per day
- number of drilled hole meters per day
- number of runs of loaders/ trucks per day
- daily volume of ore mass transported in ton-kilometers
- daily simulated volume of mining of rock mass with a cumulative total
- daily planned volume of mining of rock mass with a cumulative total
- daily deviation from the mining plan
- daily simulated volume of extraction of useful substance with a cumulative total
- daily planned volume of extraction of useful substance on a cumulative basis
- substance daily deviation from the plan.



Date	Reached	Drilled	Blasted	Loaded to loaders	Unloaded to millholes	Loaded to trai...	Unloaded from trains	Plan	Quality	Runs count
01.04.2023	1 350	159 779	159 779	123 502	123 474	0	0	450 000	5,00%	10 441
01.04.2023	1 350	12 739	4 578	3 443	3 359	0	0	15 000	5,00%	241
02.04.2023	0	43 979	34 927	19 617	19 631	0	0	15 000	5,00%	1 691
03.04.2023	0	33 201	26 516	25 842	25 744	0	0	15 000	5,00%	2 118
04.04.2023	0	20 739	20 302	23 334	23 292	0	0	15 000	5,00%	1 910
05.04.2023	0	29 714	24 623	19 268	19 279	0	0	15 000	5,00%	1 683
06.04.2023	0	24 738	22 661	20 352	20 394	0	0	15 000	5,00%	1 764
07.04.2023	0	21 318	17 634	16 651	16 693	0	0	15 000	5,00%	1 439
08.04.2023	0	6 580	8 539	4 939	4 953	0	0	15 000	5,00%	440

3.3.4. Costs

The «Costs» table contains information about costs by types of costs and types of equipment.



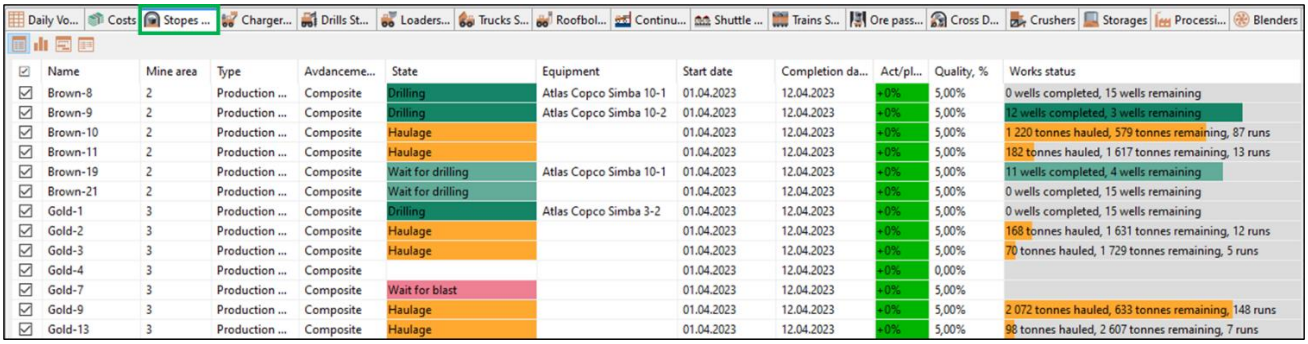
Category	Basis	Basis value	Total cost, $	Average cost per basis unit, $	Average daily cost...	Average monthly cost...	Average annual cost...
Total			35,3K		7,06K	212K	2,58M
Fixed			19,7K		3,93K	118K	1,44M
Mine	Months	0,17	0,00	0,00	0,00	0,00	0,00
Trucks	Unit-months	2,67	5,33K	2,00K	1,07K	32,0K	389K
Loaders	Unit-months	3,33	3,33K	1,00K	667	20,0K	243K
Drillers	Unit-months	3,50	2,00K	571	400	12,0K	146K
Chargers	Unit-months	3,00	9,00K	3,00K	1,80K	54,0K	657K
Roofbolters	Unit-months	0,00	0,00	0,00	0,00	0,00	0,00
Variable			15,6K		3,12K	93,7K	1,14M
Trucks			1,88K		376	11,3K	137K
Shift-based costs	Active shifts	45,0	450	10,0	90,0	2,70K	32,9K
Hours-based costs	Working hours	273	546	2,00	109	3,28K	39,9K
Distance-based costs	Distance traveled, km	1,77K	883	0,50	177	5,30K	64,4K
Fuel	Fuel consumed, l	0,00	0,00	0,00	0,00	0,00	0,00
Maintenance	Maintenance events	0,00	0,00	0,00	0,00	0,00	0,00
Failure management	Failure events	11,0	0,00	0,00	0,00	0,00	0,00
Loaders			10,2K		2,05K	61,4K	746K
Drillers			2,01K		401	12,0K	146K
Chargers			1,50K		300	9,01K	110K
Roofbolters			0,00		0,00	0,00	0,00

The table displays:

- Capital (fixed costs) total and by type of equipment
- Number of used equipment-months by types of equipment
- Average costs per equipment unit by type for the entire simulation period/ average per day, average monthly/ average annual
- Variable costs by types of equipment and types of cost accrual:
    - Shift-based costs
    - Hours-based costs
    - Distance-based costs
    - Fuel
    - Maintenance
    - Failure management.

3.3.5. Stopes stats

The " Stopes stats" table shows data on the state of stopes at each moment of time.



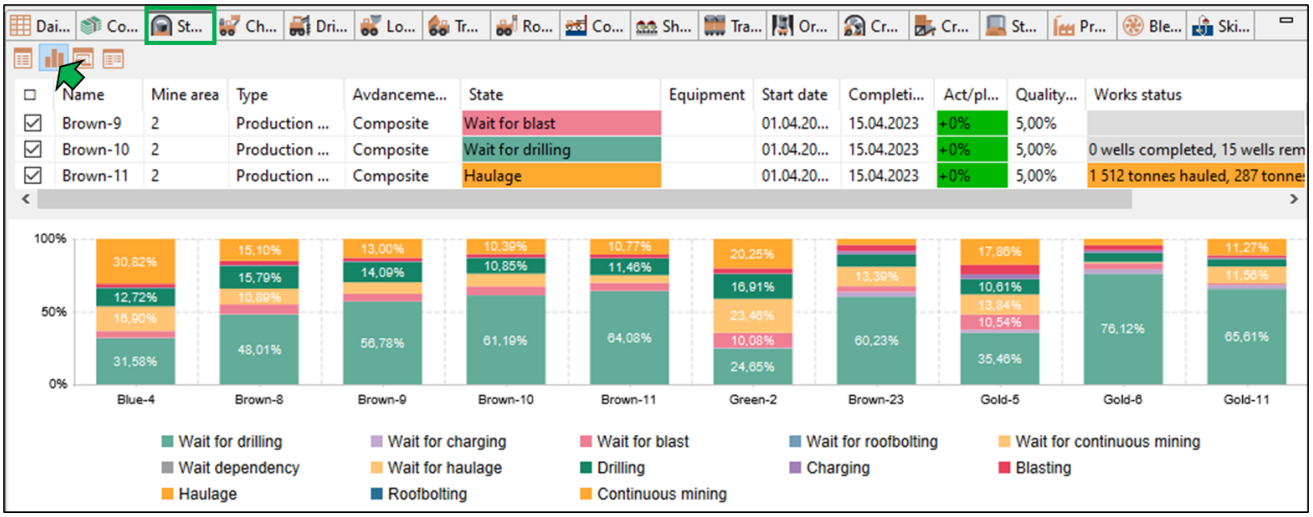
Name	Mine area	Type	Avdanceme...	State	Equipment	Start date	Completion da...	Act/pl...	Quality, %	Works status
Brown-8	2	Production ...	Composite	Drilling	Atlas Copco Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Brown-9	2	Production ...	Composite	Drilling	Atlas Copco Simba 10-2	01.04.2023	12.04.2023	+0%	5,00%	12 wells completed, 3 wells remaining
Brown-10	2	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	1 220 tonnes hauled, 579 tonnes remaining, 87 runs
Brown-11	2	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	182 tonnes hauled, 1 617 tonnes remaining, 13 runs
Brown-19	2	Production ...	Composite	Wait for drilling	Atlas Copco Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	11 wells completed, 4 wells remaining
Brown-21	2	Production ...	Composite	Wait for drilling		01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Gold-1	3	Production ...	Composite	Drilling	Atlas Copco Simba 3-2	01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Gold-2	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	168 tonnes hauled, 1 631 tonnes remaining, 12 runs
Gold-3	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	70 tonnes hauled, 1 729 tonnes remaining, 5 runs
Gold-4	3	Production ...	Composite			01.04.2023	12.04.2023	+0%	0,00%	
Gold-7	3	Production ...	Composite	Wait for blast		01.04.2023	12.04.2023	+0%	5,00%	
Gold-9	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	2 072 tonnes hauled, 633 tonnes remaining, 148 runs
Gold-13	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	98 tonnes hauled, 2 607 tonnes remaining, 7 runs

The following is shown for each stope:

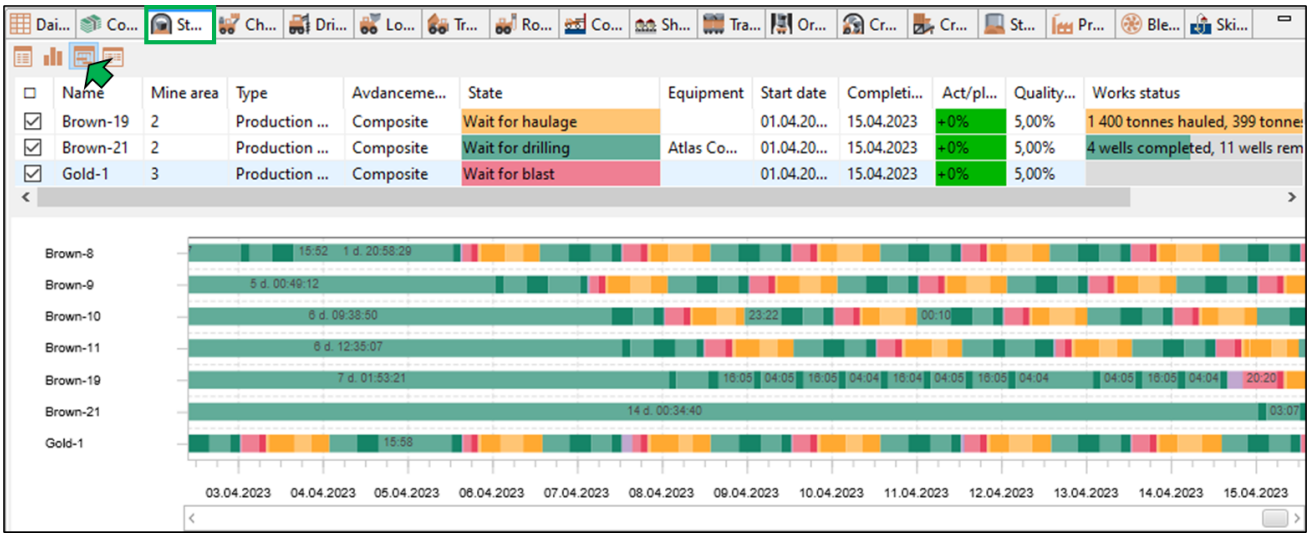
- Mine area to which the stope belongs

- Type (production or development)
- Advancement Type (excavation, cleaning, etc.)
- Current state of the stope (wait for drilling, drilling, wait for charging, charging, etc.)
- Start and completion date
- Duration of state
- Simulated amount of removed ore mass in tons and m3
- Planned amount of removed ore mass in tons
- Percentage deviation from the plan
- The quality of the ore mass in the stope (content of useful substance)
- Density of the ore mass in the stope
- Works status: volume of completed and remaining work in the stope (the number of drilled wells/holes and the number of wells/holes left for drilling, the number of hauled and remaining tonnes of ore mass, etc.).

The button  in the upper right corner of the table opens the bar chart of stopes stats.



The button  in the upper right corner of the table opens the Gantt chart of stopes statistics.

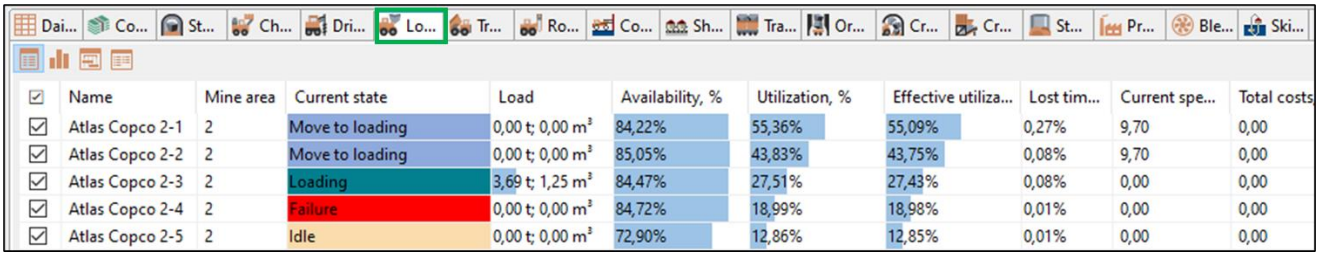


3.3.6. Equipment stats

The status and general information about equipment units are displayed in separate tables for each equipment type, such as:

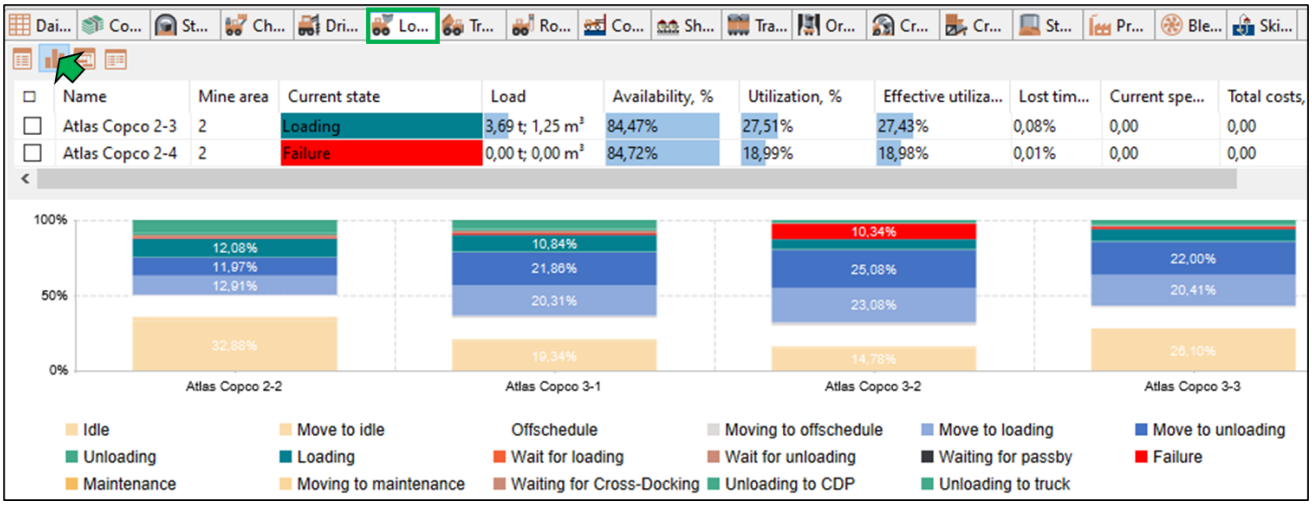
- Mine area to which the equipment unit is assigned
- Current state (movement, work performance, no tasks, etc.)
- Availability, % - the ratio of the time when the equipment was available for operation (in accordance with the schedule and periods of unavailability) to the entire simulation period
- Utilization, % - the ratio of the time when the equipment performed tasks to the entire simulation period
- Effective utilization, % - equipment utilization factor minus lost time
- Lost time, % - the ratio of the time when the equipment was in the "No task" state to the entire simulation period
- Current movement speed, km/h
- All costs per equipment unit, in USD.

The data table on the operation of the equipment on the example of loaders is shown in the figure.

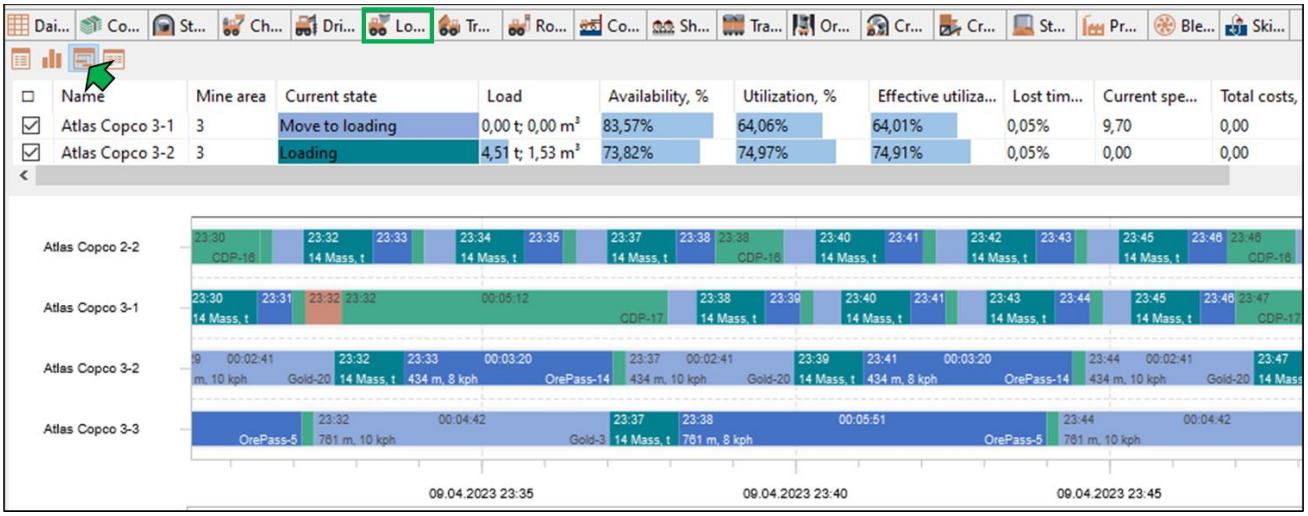


Besides, additional specific statistics are displayed for certain types of equipment, such as the number of runs for trucks, the number of drilled holes for drilling machines, etc.

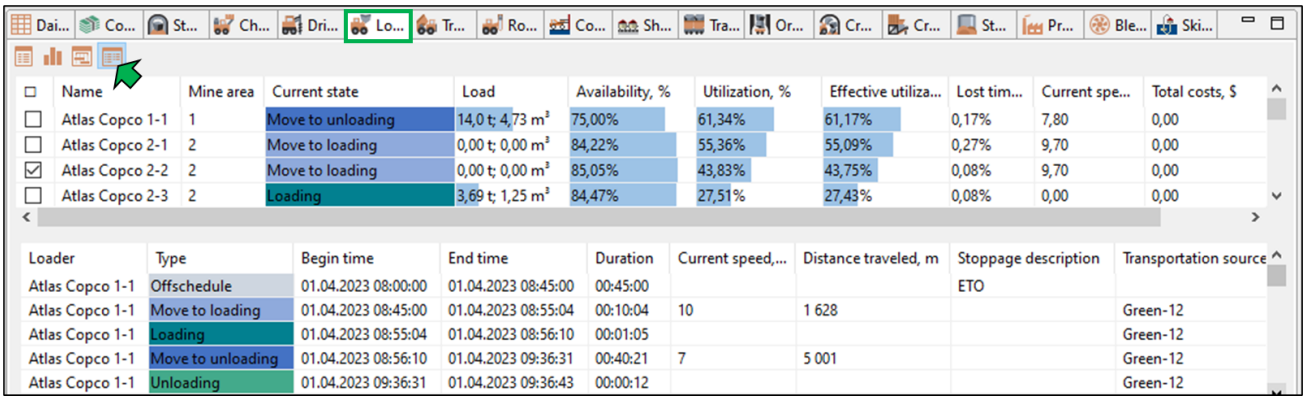
The button  in the upper right corner of the table opens the display of equipment operation stats in the form of a bar chart.



The button  in the upper right corner of the table opens the Gantt chart of equipment operation stats.



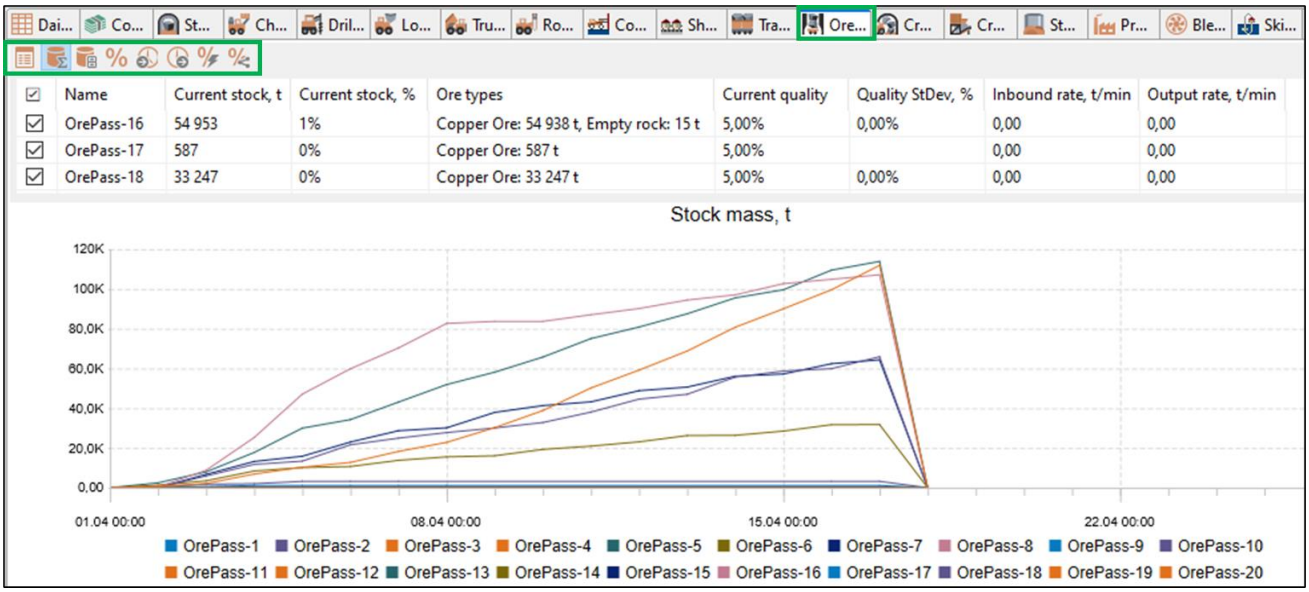
The button  in the upper right corner of the table opens a table with detailed information about the equipment states for the entire simulation period.



3.3.7. Ore storage places

Separate tables for ore passes, cross-dock points and storages display information about their current status, such as occupancy, types and quality of ore, etc.

The data table of the states of ore passes is shown in the figure.



The following information is displayed for each ore pass:

- Capacity, t
- Occupancy, in tons and % of capacity
- Current amount of ore mass contained in the ore pass by type
- Current content of useful substance in the ore mass of the ore pass, in %
- Standard deviation of quality (RMS) of ore mass, %
- Rate of ore mass entering the ore pass, t/min
- Output rate of ore mass from the ore pass, t/min.

The buttons in the upper toolbar of the "Ore passes" window open separate charts that display:

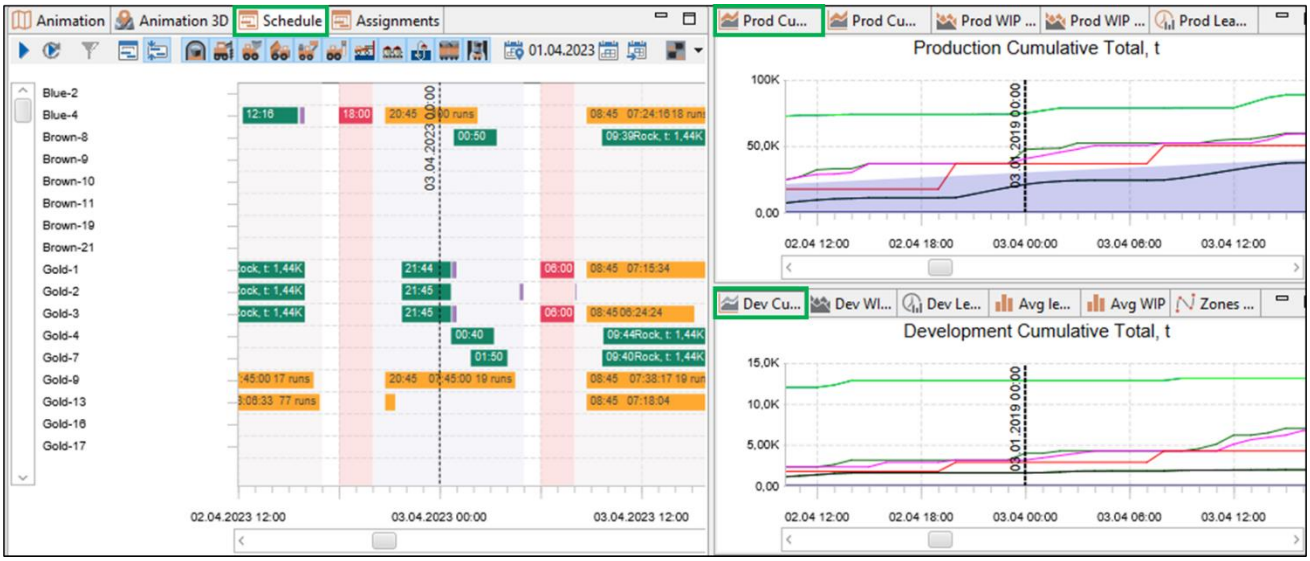
- Ore mass stock in ore passes, in tons
- Volume of ore mass stock in ore passes, in m3
- Change in the quality of the ore mass, in %
- Rate of ore mass entering the ore pass, t/min
- Output rate of ore mass from the ore pass, t/min.
- Changes in the quality of ore fragments, %
- Variability of the content of useful substances by processing stages, %.

3.4. Graphs and charts

The MineTwin Underground visualization contains various graphs and charts for analyzing simulation results.

1. Graphs for analysis of production
    - Production cumulative total graph
    - Production cumulative substance graph
    - Production WIP total
    - Production WIP substance
    - Production lead time
2. Graphs for the analysis of development
    - Development cumulative total graph
    - Development WIP total
    - Development lead time
3. Graphs stats for production and development
    - Average lead time
    - Average WIP
    - Zones stats
4. Graphs for the analysis of ore mass transportation
    - Haulage distance
    - Haulage time
    - Haulage speed
    - Daily blasts count
    - Daily runs count
    - Daily tonnes mined
    - Stoppages stats.

By pressing the button  in the top toolbar, cumulative graphs are synchronized with the schedule.


Animation
Animation 3D
Schedule
Assignments
01.04.2023
Blue-2
Blue-4
Brown-8
Brown-9
Brown-10
Brown-11
Brown-19
Brown-21
Gold-1
Gold-2
Gold-3
Gold-4
Gold-7
Gold-9
Gold-13
Gold-16
Gold-17
02.04.2023 12:00
03.04.2023 00:00
03.04.2023 12:00
Prod Cu...
Prod Cu...
Prod WIP ...
Prod WIP ...
Prod Lea...
Production Cumulative Total, t
100K
50,0K
0,00
03.01.2019 00:00
02.04 12:00
02.04 18:00
03.04 00:00
03.04 06:00
03.04 12:00
Dev Cu...
Dev WI...
Dev Le...
Avg le...
Avg WIP
Zones ...
Development Cumulative Total, t
15,0K
10,0K
5,00K
0,00

4. Scenario comparison

Scenario comparison mode allows you to simulate multiple scenarios at the same time and then compare the results.

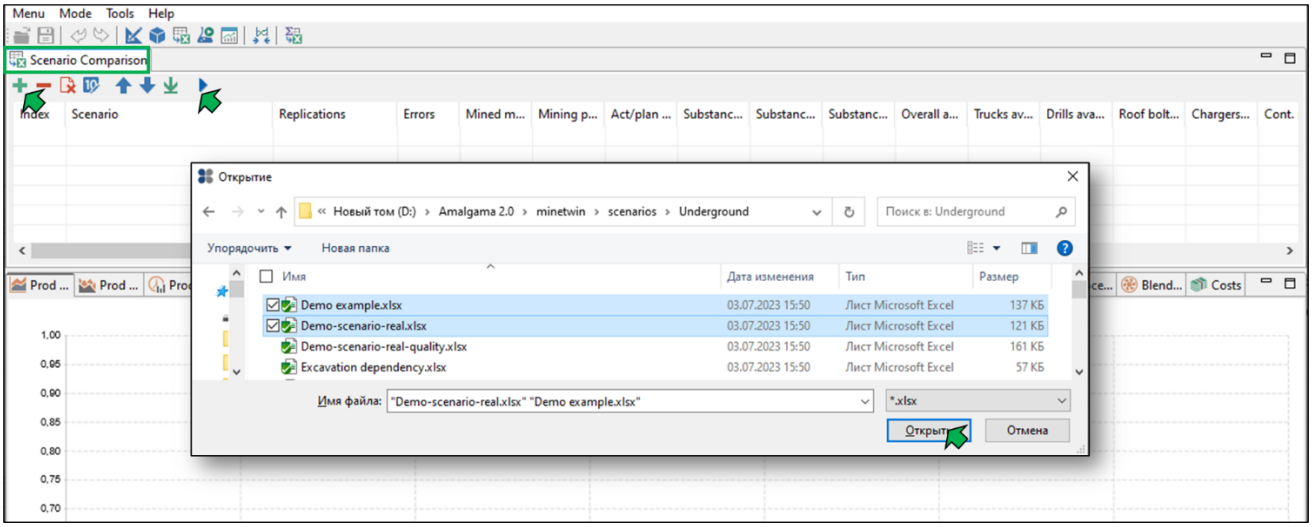
In the opened scenario comparison mode window, you can select several scenarios with the button  in the upper toolbar, and exclude unnecessary scenarios with the button . The button  clears the list of scenarios.

In the scenario comparison mode, simulation of each scenario can be run several times with different values of random variables. The button  is used to set the number of launches (replications).

The buttons  allow to move scenarios up and down in the list. The button  allows to reload scenarios, for example, if they have been changed since they were added to the list for comparison.

In the scenario comparison mode, it is possible to run scenario simulation several times with different values of random variables. To set the number of launches, use the button (number of replications).

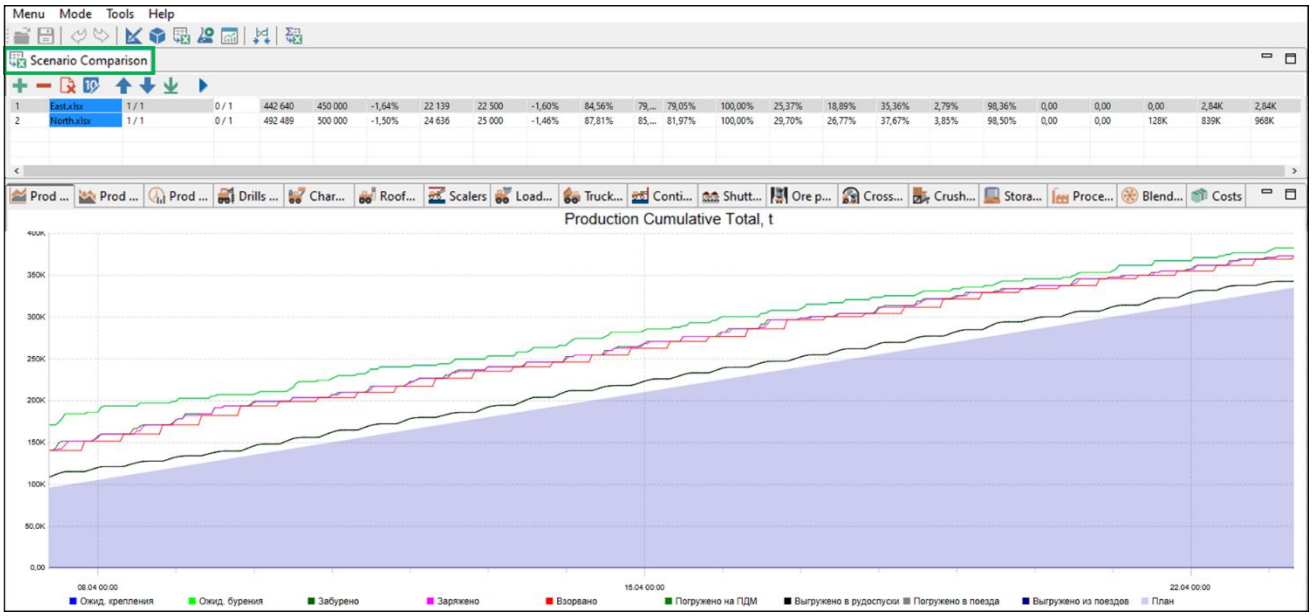
Scenario comparison is launched using the button  .



After the completion of the modeling, the selected scenarios can be compared based on several key indicators in the table.

The graphs display the indicators for the scenario selected in the table.

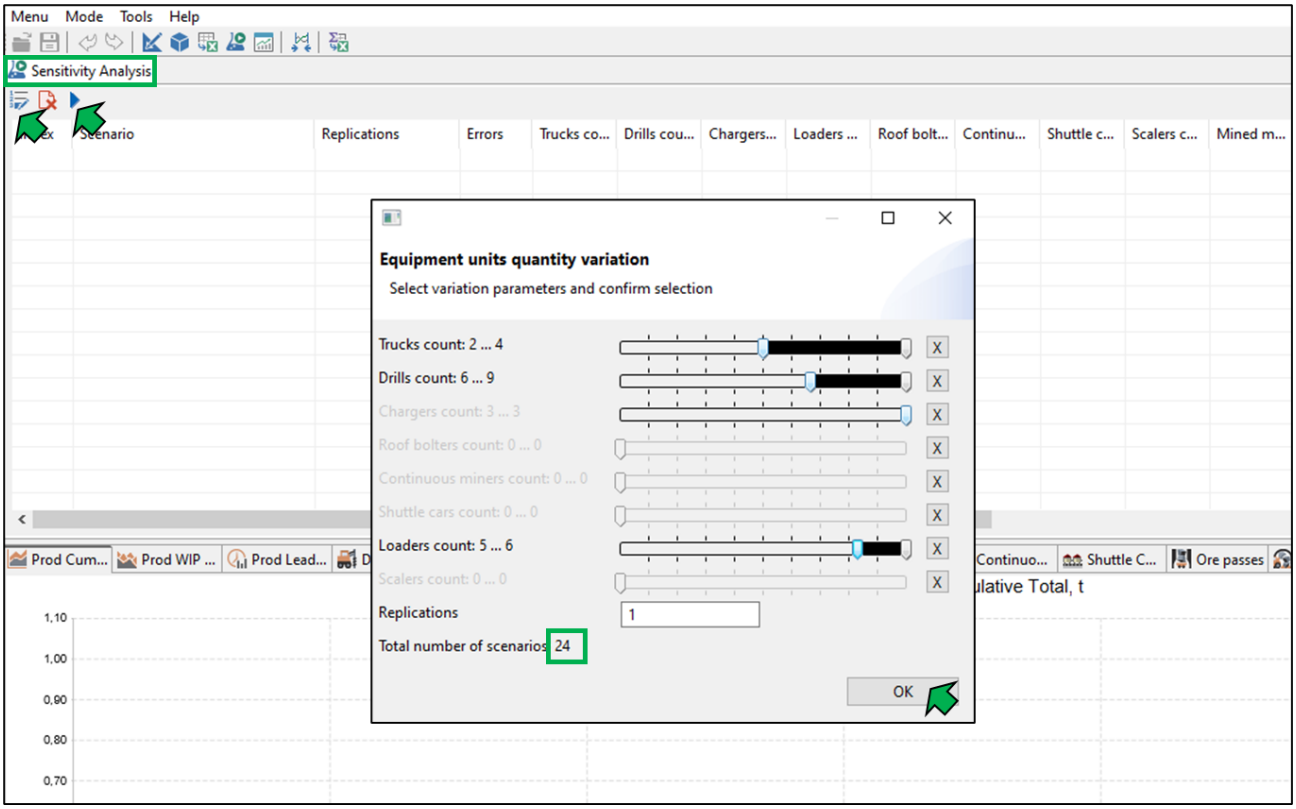
If the scenarios were simulated several times with different values of random variables, then the table will display the average indicators for each scenario, and the graph will show the data of the first replication.



5. Sensitivity analysis

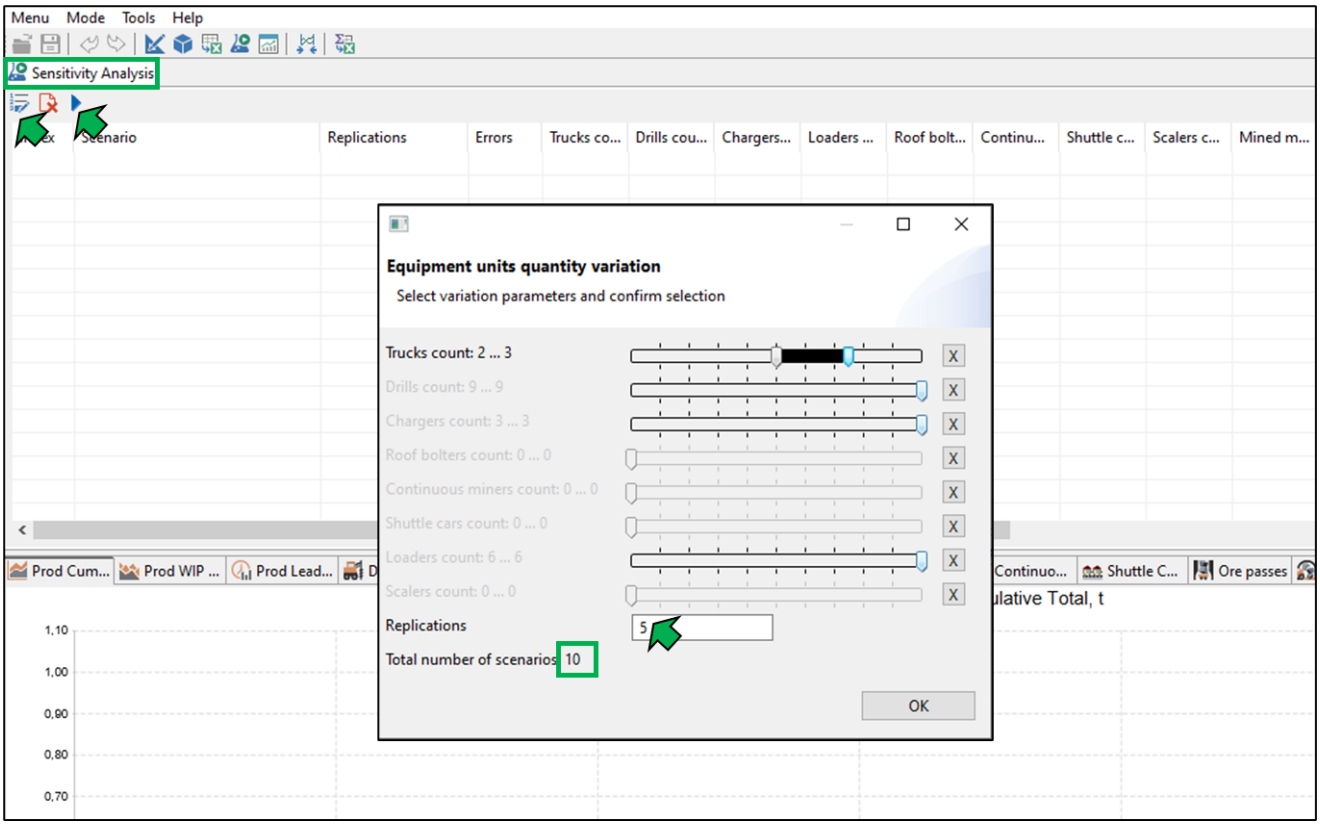
The sensitivity analysis mode allows you to run simultaneous simulations of the same scenario with different equipment quantities.

In the opened window of the sensitivity analysis mode, you need to set the ranges for changing the equipment quantity of each type using the button  .



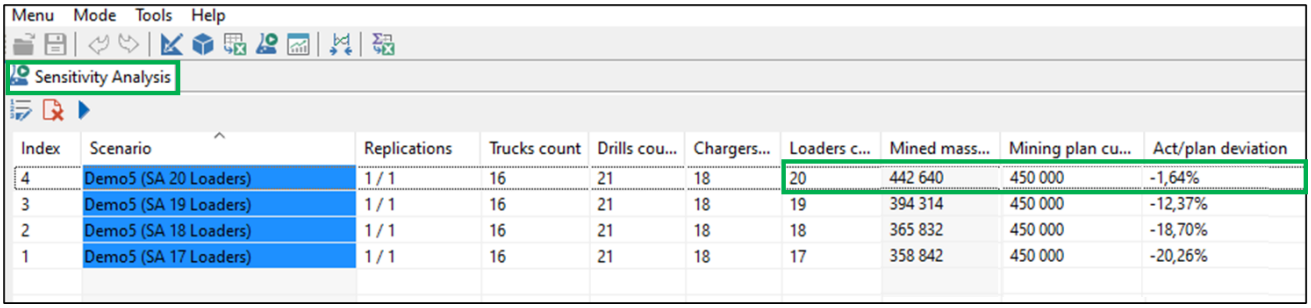
After that, a complete set of simulation scenarios with various combinations of the equipment quantity will appear in the interface of the sensitivity analysis mode. For example, 24 combinations are possible with the parameters shown in the figure above.

In the sensitivity analysis mode, you can run the simulation of each scenario several times with different values of the random variables. To do this, use the "Replications" parameter. For example, in the figure below, the range for the trucks count is set from 2 to 3 and 5 replications. This means that the simulation with 2 trucks will be performed five times, simulation with 3 trucks will be performed five times, and so on, for a total of 10 scenarios.



If you need to set other ranges and number of replications, you can clear the table with the button and set new variation parameters. You can delete individual scenarios from the list using the button. Sensitivity analysis is launched using the button .

After running and completing a series of simulation experiments, you can quickly compare the simulation results and select a combination of the equipment quantity to best meet your production plan.



Index	Scenario	Replications	Trucks count	Drills cou...	Chargers...	Loaders c...	Mined mass...	Mining plan cu...	Act/plan deviation
4	Demo5 (SA 20 Loaders)	1 / 1	16	21	18	20	442 640	450 000	-1,64%
3	Demo5 (SA 19 Loaders)	1 / 1	16	21	18	19	394 314	450 000	-12,37%
2	Demo5 (SA 18 Loaders)	1 / 1	16	21	18	18	365 832	450 000	-18,70%
1	Demo5 (SA 17 Loaders)	1 / 1	16	21	18	17	358 842	450 000	-20,26%

The given example shows the sensitivity of the scenario to the number of loaders. The best result is achieved with a maximum of 20 units.

6. Constraints analysis

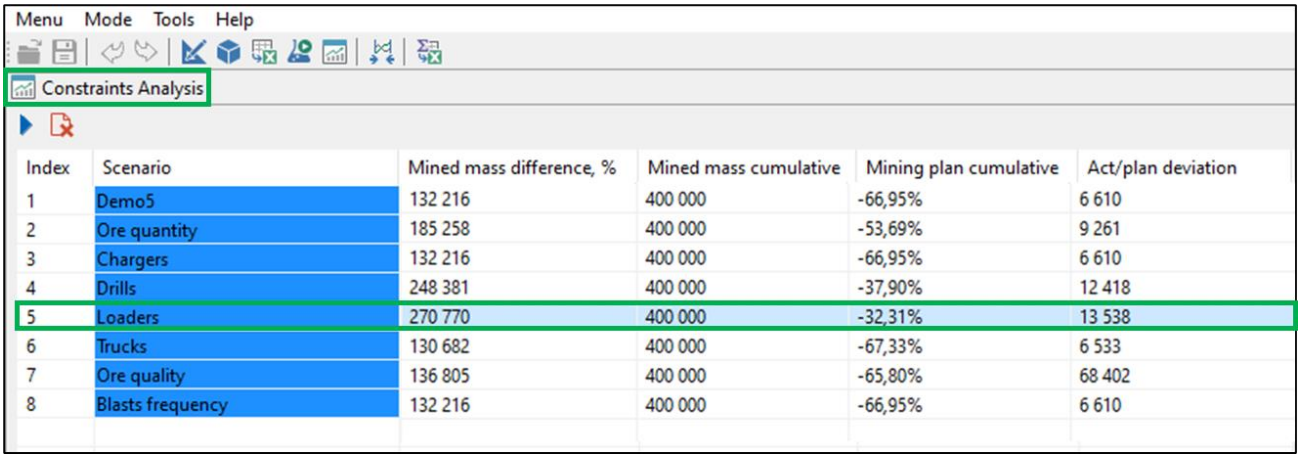
Constraints analysis mode is designed to identify bottlenecks in the scenario. When performing a constraints analysis, MineTwin Underground automatically runs scenario simulations several times, removing each of the major constraints in turn, and shows how much the percentage of the production plan fulfilment would have improved if this constraint were not present.

The following constraints are consistently removed during constraints analysis:

1. Ore quantity in stopes
2. Number of chargers
3. Number of drilling machines
4. Number of loaders
5. Number of trucks
6. Ore mass quality
7. Blasts frequency

The constraint analysis is started using the button . The button clears the list before a new launch.

An example of the constraints analysis result is shown in the figure below.



Index	Scenario	Mined mass difference, %	Mined mass cumulative	Mining plan cumulative	Act/plan deviation
1	Demo5	132 216	400 000	-66,95%	6 610
2	Ore quantity	185 258	400 000	-53,69%	9 261
3	Chargers	132 216	400 000	-66,95%	6 610
4	Drills	248 381	400 000	-37,90%	12 418
5	Loaders	270 770	400 000	-32,31%	13 538
6	Trucks	130 682	400 000	-67,33%	6 533
7	Ore quality	136 805	400 000	-65,80%	68 402
8	Blasts frequency	132 216	400 000	-66,95%	6 610

In the example above, the scenario lacks loaders. With the addition of enough loaders to operate the mine, production will more than double its current value: 270 kt vs. 132 kt.