MineTwin OpenPit Documentation

2026-07-10

Table of Contents

Introduction

Purpose of this Document

This document describes the MineTwin tool for planning and simulating mining operations. It serves as a reference for MineTwin users seeking to understand the tool's capabilities and workflow.

System Overview

MineTwin OpenPit enables users to schedule and simulate open-pit mining operations. It is composed of the following modules:

1. **Editor**
   - The **Editor** allows creating and editing scenarios via the MineTwin OpenPit UI or Excel files.
2. **Integration module**
   - The **Integration Module** enables importing data on the road network, block locations and properties, and equipment maintenance from external systems. Supported formats include *.xlsx*, *.txt*, *.dxf*, *.str*, *.obj*, and *.dtm*.
3. **Scheduler**
   - In MineTwin's scheduling mode, each shift is planned and then simulated one at a time. After completing a shift, the **Scheduler** plans the next one based on simulation results from the previous shift.
4. **Simulation model**

   Operations follow two sequential stages:

   - Equipment scheduling by the **Scheduler**.
   - **Simulation** of equipment and transportation based on that schedule.

System requirements

Operating System: Windows 7 (32- or 64-bit) or newer.

Dependencies: Microsoft Excel 2007 or newer must be installed.

1. Editing scenario

1.1. Preparing the input file

A MineTwin OpenPit scenario is defined in an Excel file containing all required input data.

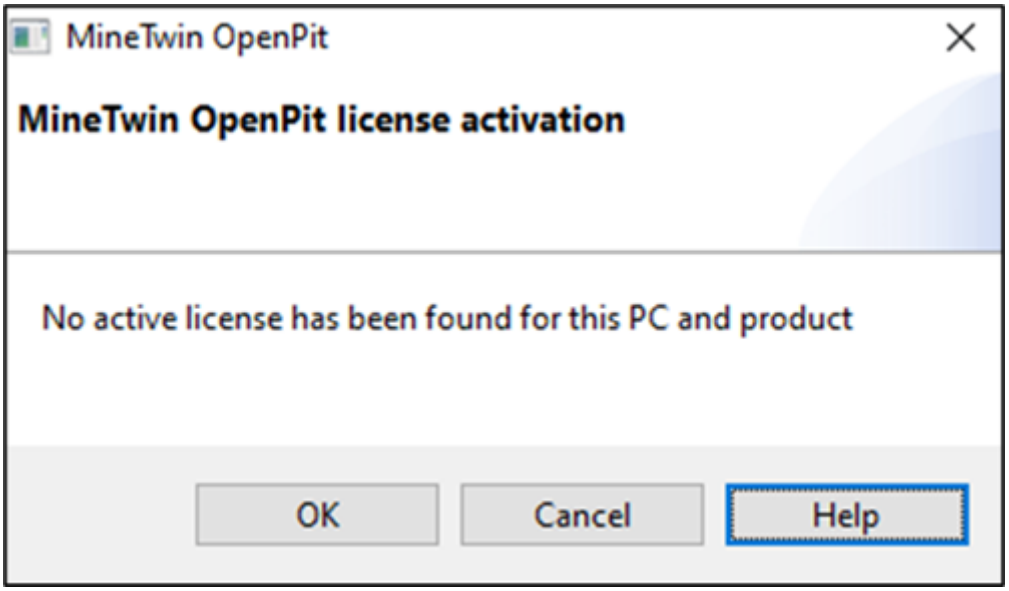
Creating a scenario in MineTwin OpenPit is possible in two ways:

1. In the application interface – all source data, such as haul road network elements, equipment types and units, equipment and haul truck schedules, assignment of equipment and trucks to mining areas, etc., are added/deleted manually directly in the application. The enterprise's haul road network topology can be added to a scenario by importing road centerlines in .dxf format.
2. By importing a template with source data – when creating a new scenario, the application allows the user to import the core data from a pre-filled Excel template.

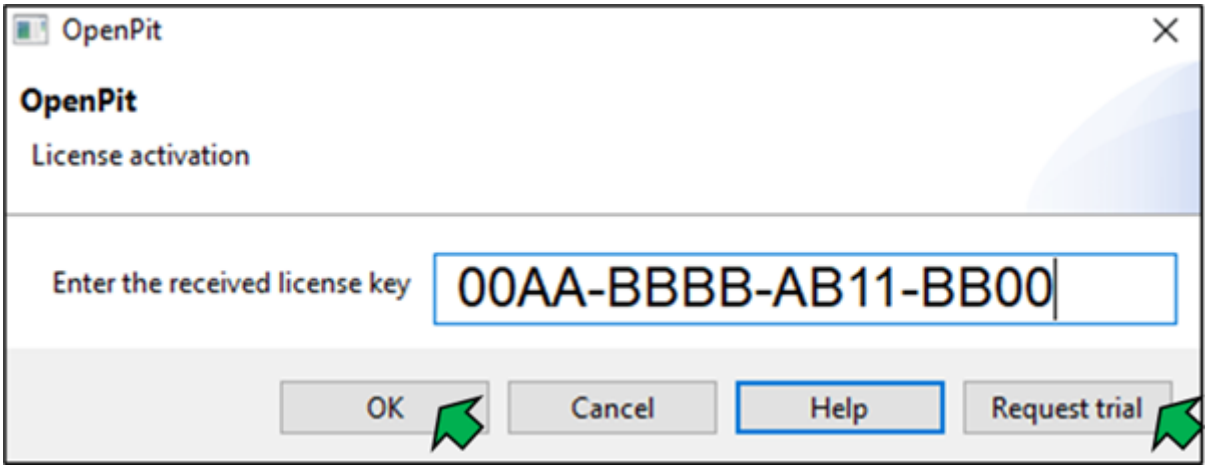
1.2. Launching the application, loading the editing mode

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

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



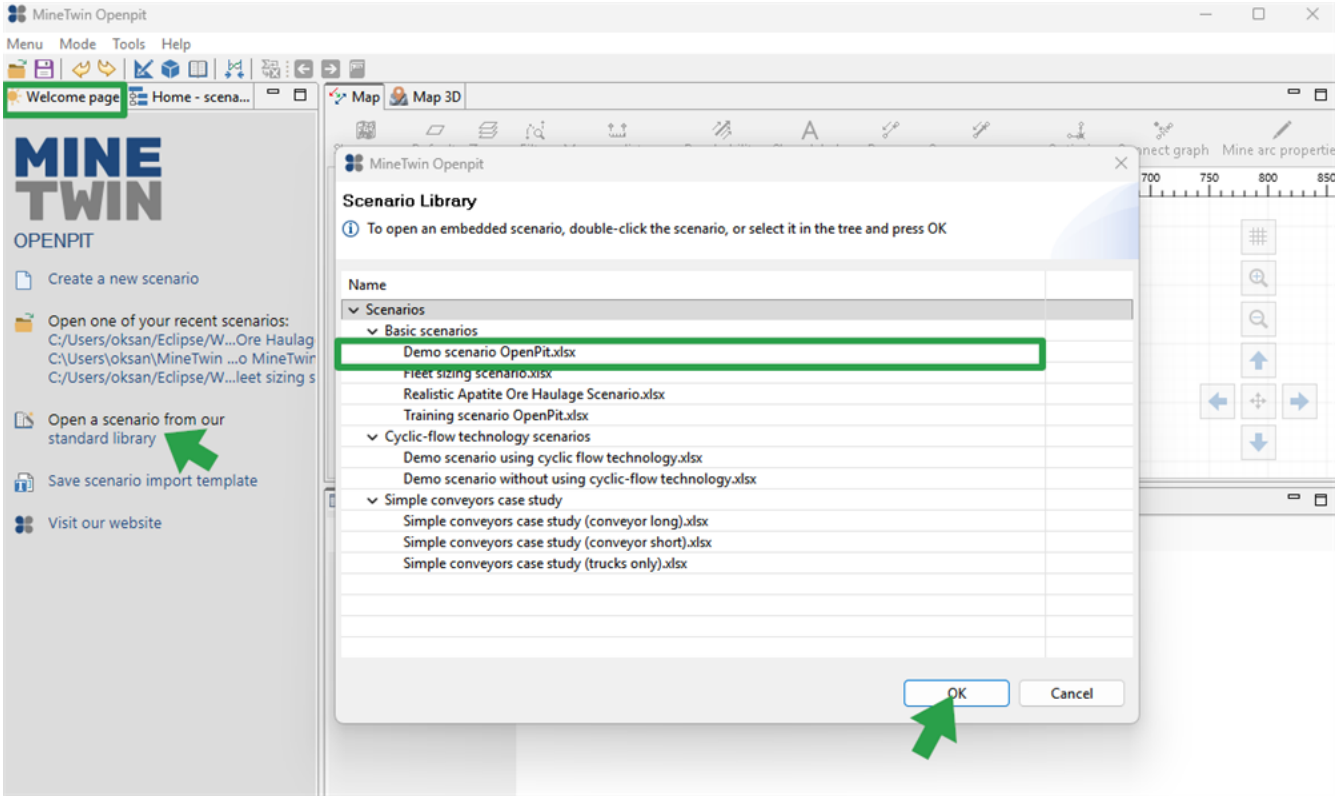
3. After clicking on the "OK" button, a license entry window will open, where you need to enter the received license key.



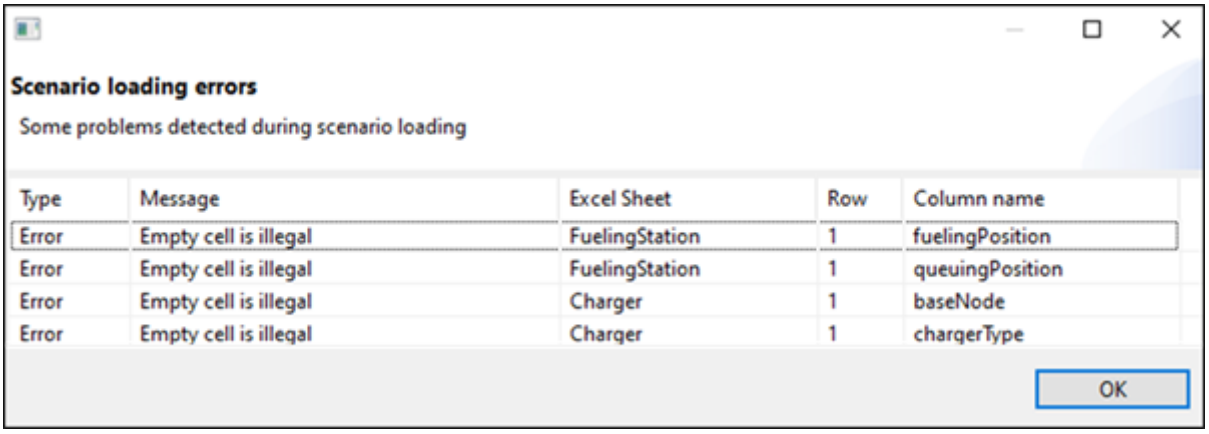
If the key is correct and is not activated on another PC, MineTwin OpenPit will be launched.

4. If there is no commercial license, you 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, presenting a unique PC ID, which opens when you click on Help.

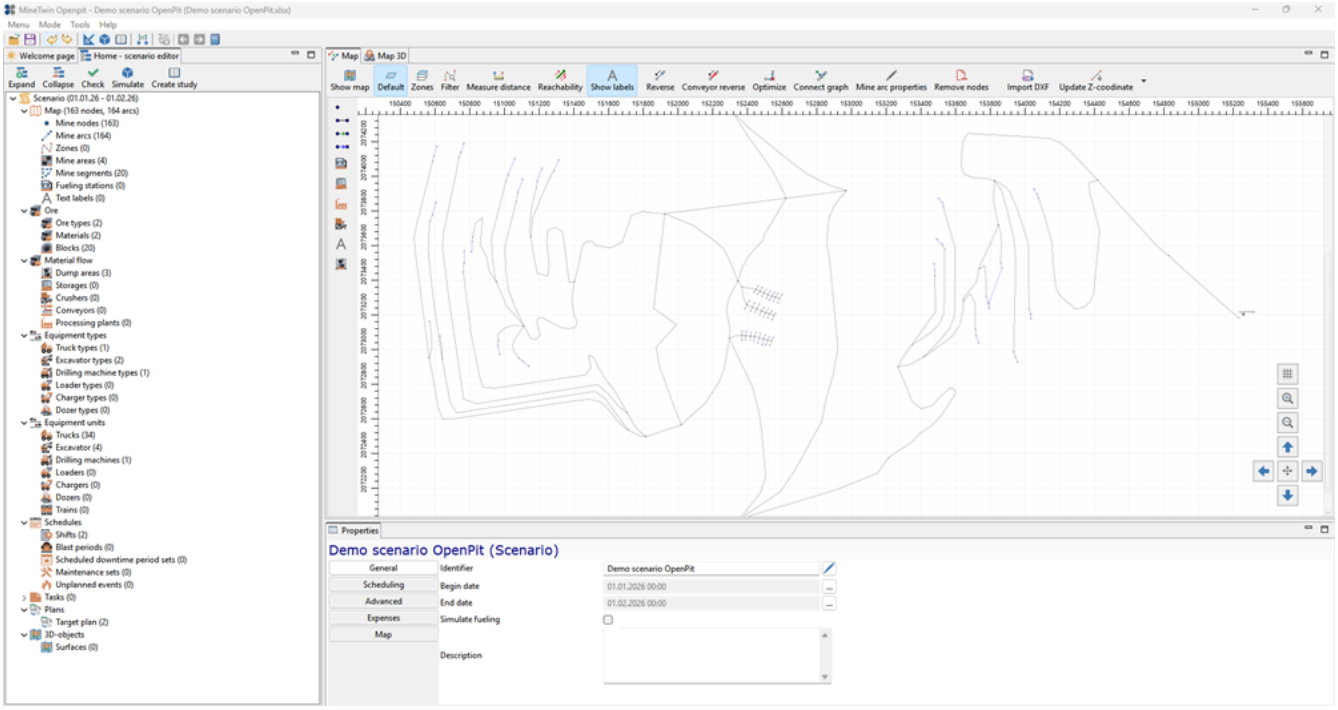
6. After launching MineTwin OpenPit the application's working window will open. On the left side of the window, on the **Welcome page** tab, the following functions are located:
   - **Create a new scenario** – this function creates a new scenario file that requires manual data entry and/or data import
   - **Open one of your resent scenarios** – this function displays a list of recently opened scenarios on the panel for quick switching between them
   - Open a scenario from our standart library* – this function opens a window with a set of demonstration scenarios
   - **Save scenario import template** – clicking this function downloads an Excel file of the established format to your PC, which is used to fill in the core data and subsequently create a scenario by importing it.
   - **Visit our website** – this function redirects to the website of Amalgama LLC.



If the file contains errors, a list will appear showing the relevant sheet, row, and column—fix them either directly in Excel or using the tool's interface.



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



In the editor interface, windows can be resized by dragging their borders and relocated by dragging the title bars.

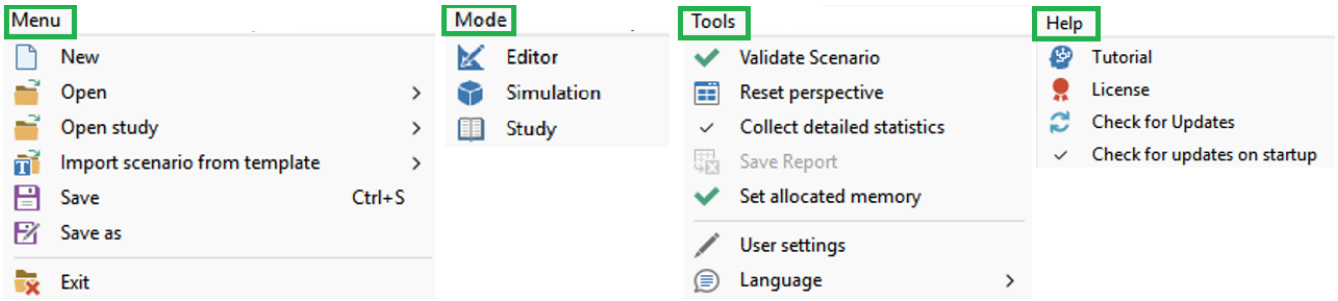
Double-click a window tab to maximize it; double-click again or use **Reset perspective** in **Tools** menu to revert it.

1.3. Tools and windows in the scenario editor

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

1.3.1. Toolbar

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



The **Menu** element of menu bar contains the following items:

- Create a new scenario ( )
- Open scenario ( )
- Open study ( )

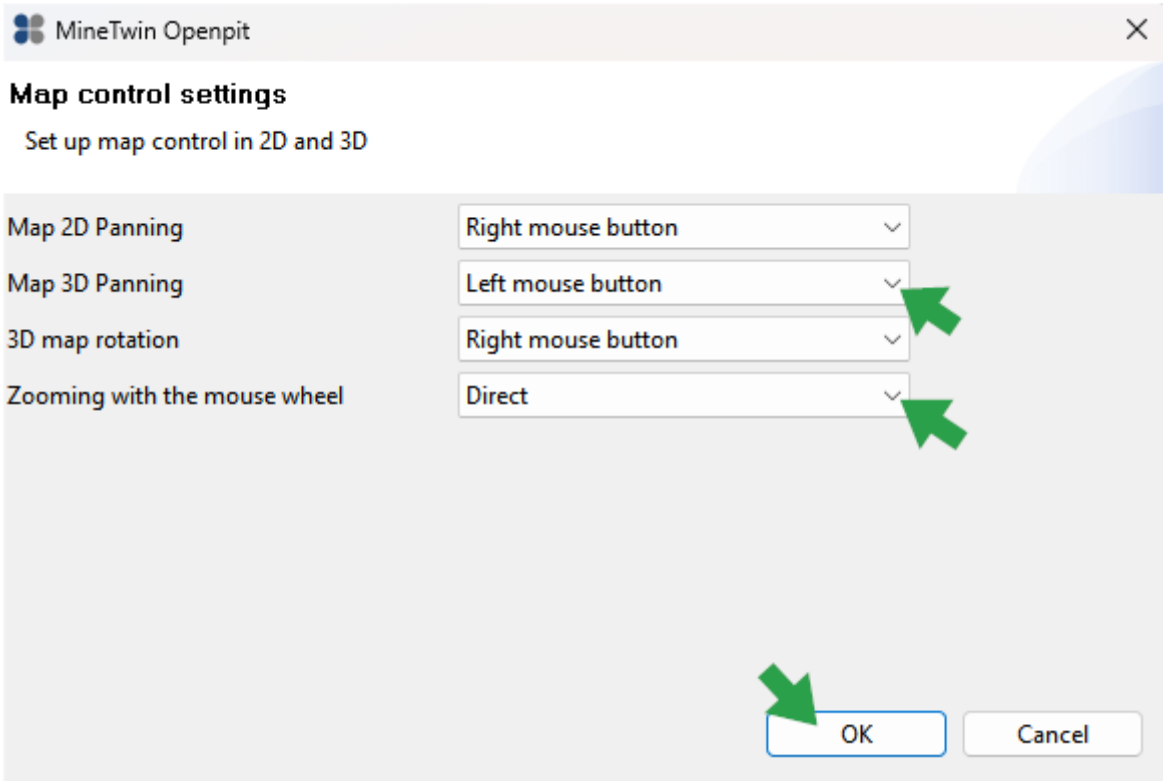
- Import scenario from template ( ) – this function creates a new scenario by importing the filled-in source data template
- Save scenario ( )
- The "Save As" function ( )
- Exit ( ).

The **Mode** menu is used to switch between the modes:

- Editor ( );
- Simulation ( );
- Study ( );

The **Tools** menu contains the following items:

- Validate scenario after its creation/editing ( )
- Reset perspective ( )
- Collect detailed statistics ( )
- Save Report ( )
- Set allocated memory ( ) - the function allows you to set the amount of RAM used during simulation
- User settings ( ). The user can choose the map panning/rotation method that suits them best in 2D and 3D modes



- Language switch (Russian and English are available) ( )

The **Help** menu contains:

- Link to the tutorial and documentation site ( )
- Information about the license under which the system is open ( )
- Manual update check ( )
- Automatic check for updates on startup ( )

If it is necessary to undo/redo a canceled action, use the buttons .

The button synchronizes graphs in the simulation mode.

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

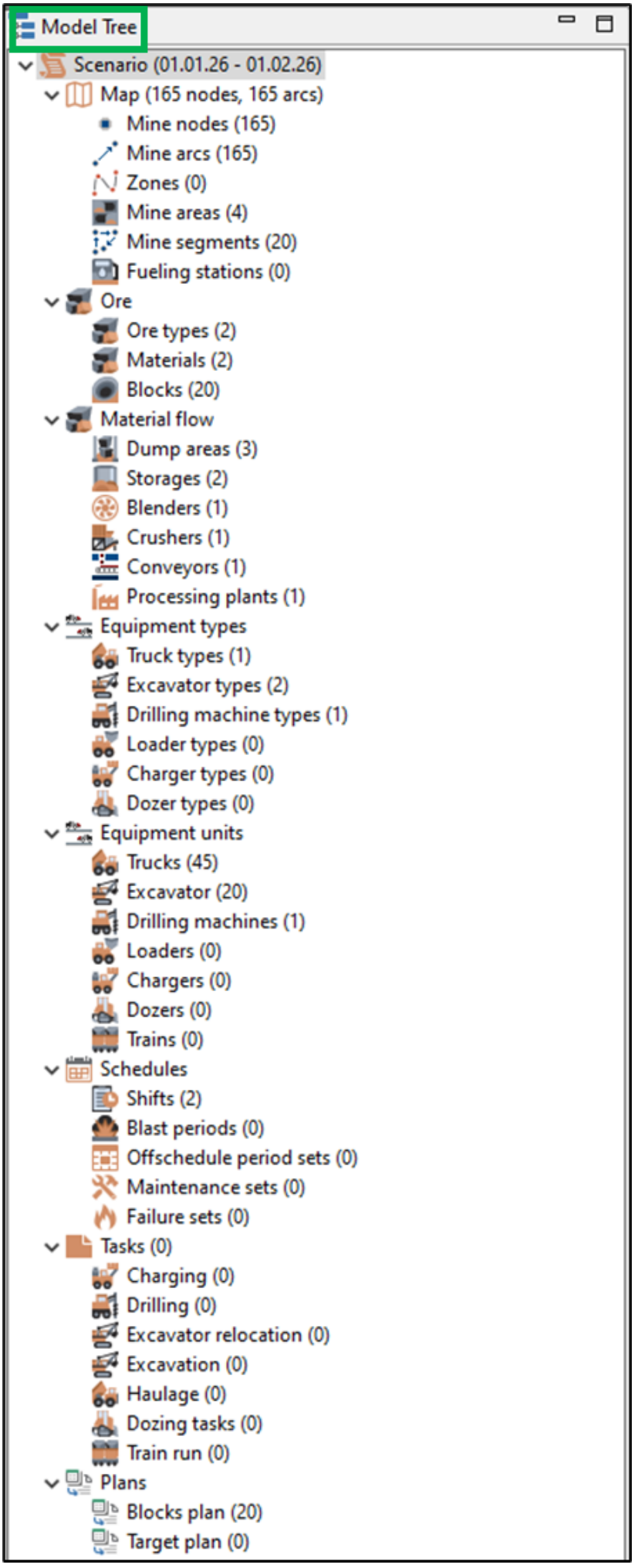
The buttons moves to previous/next object in the scenario.

The button searches any scenario element by its name.

1.3.2. Model tree

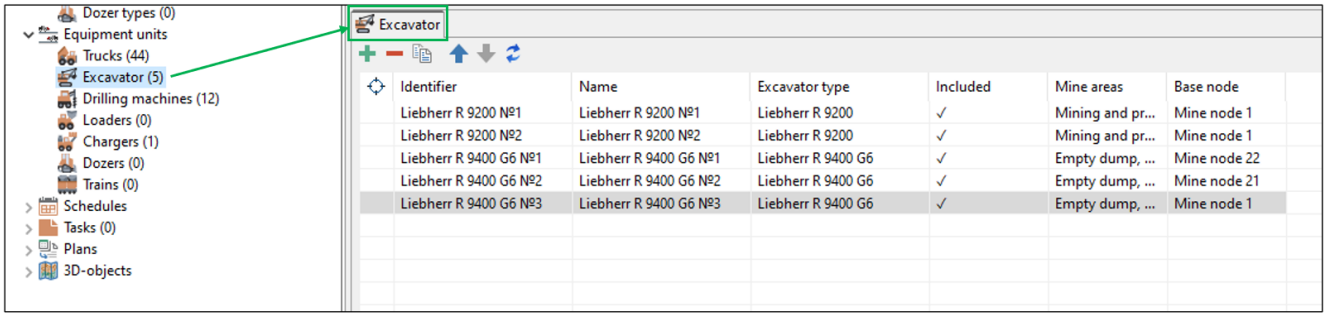
All scenario objects and entities data (parameters of blocks, dump areas, equipment units, equipment operation schedules, etc.) are displayed in the form of a tree and are grouped by types. For each type of object/entity, the number of units of the object/entity is shown.

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


Model Tree
Scenario (01.01.26 - 01.02.26)
Map (165 nodes, 165 arcs)
Mine nodes (165)
Mine arcs (165)
Zones (0)
Mine areas (4)
Mine segments (20)
Fueling stations (0)
Ore
Ore types (2)
Materials (2)
Blocks (20)
Material flow
Dump areas (3)
Storages (2)
Blenders (1)
Crushers (1)
Conveyors (1)
Processing plants (1)
Equipment types
Truck types (1)
Excavator types (2)
Drilling machine types (1)
Loader types (0)
Charger types (0)
Dozer types (0)
Equipment units
Trucks (45)
Excavator (20)
Drilling machines (1)
Loaders (0)
Chargers (0)
Dozers (0)
Trains (0)
Schedules
Shifts (2)
Blast periods (0)
Offschedule period sets (0)
Maintenance sets (0)
Failure sets (0)
Tasks (0)
Charging (0)
Drilling (0)
Excavator relocation (0)
Excavation (0)
Haulage (0)
Dozing tasks (0)
Train run (0)
Plans
Blocks plan (20)
Target plan (0)

1.3.3. 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, excavators, blocks, etc.

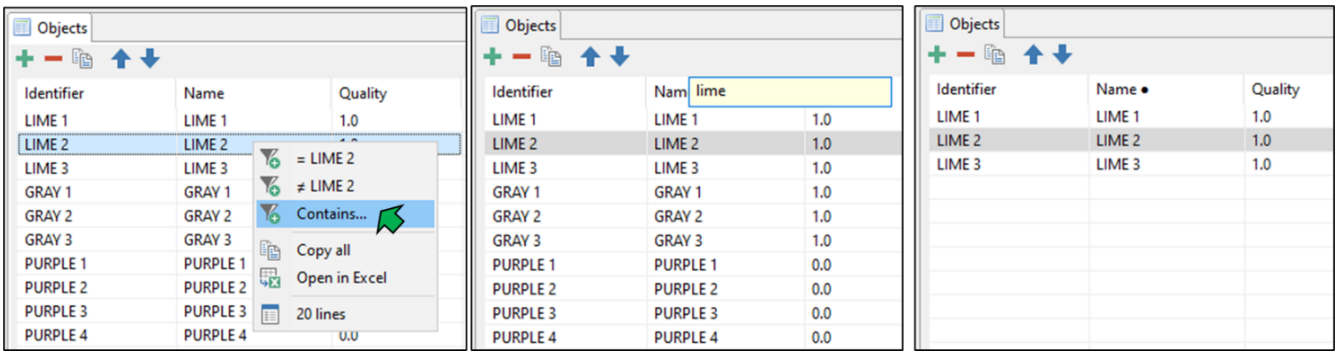


At the top of the "Objects" window, there is a toolbar with functions for adding, deleting, copying objects, and moving objects up and down.

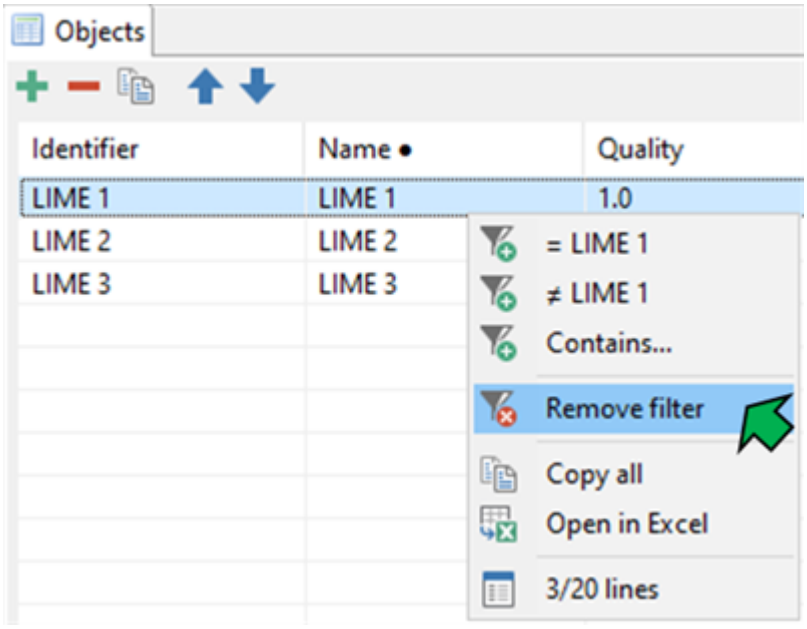
When you hover the mouse over the icon, the name of the function performed by the corresponding button will be displayed.

The column with the  icon allows you to highlight a locatable object on the map by double-clicking its row.

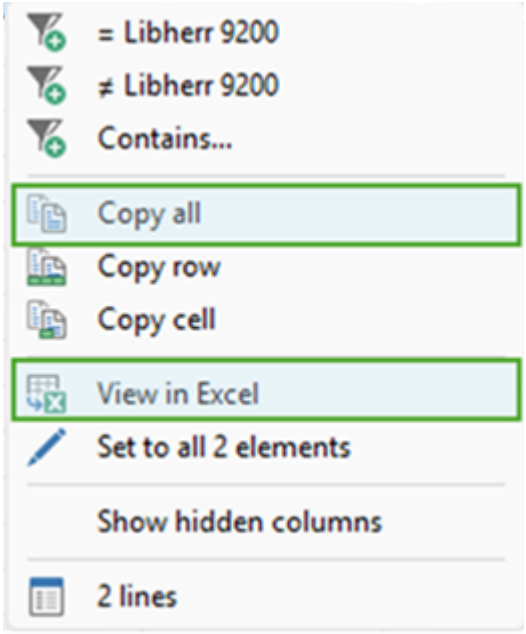
Sorting of all columns of the data table is available in the table, as well as filters. To apply a filter, right-click on a line in the required column and set the required filter.



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



You can copy or export the contents of the entire table, or selected rows/cells, to Excel for further analysis.

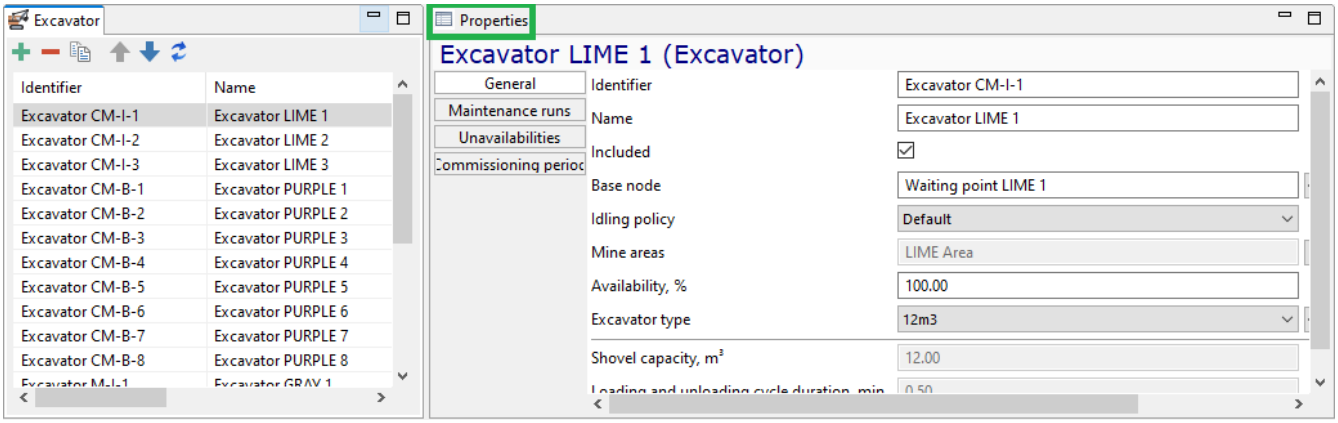


Most columns in the table are editable. To edit the value in a single cell, left-click it.

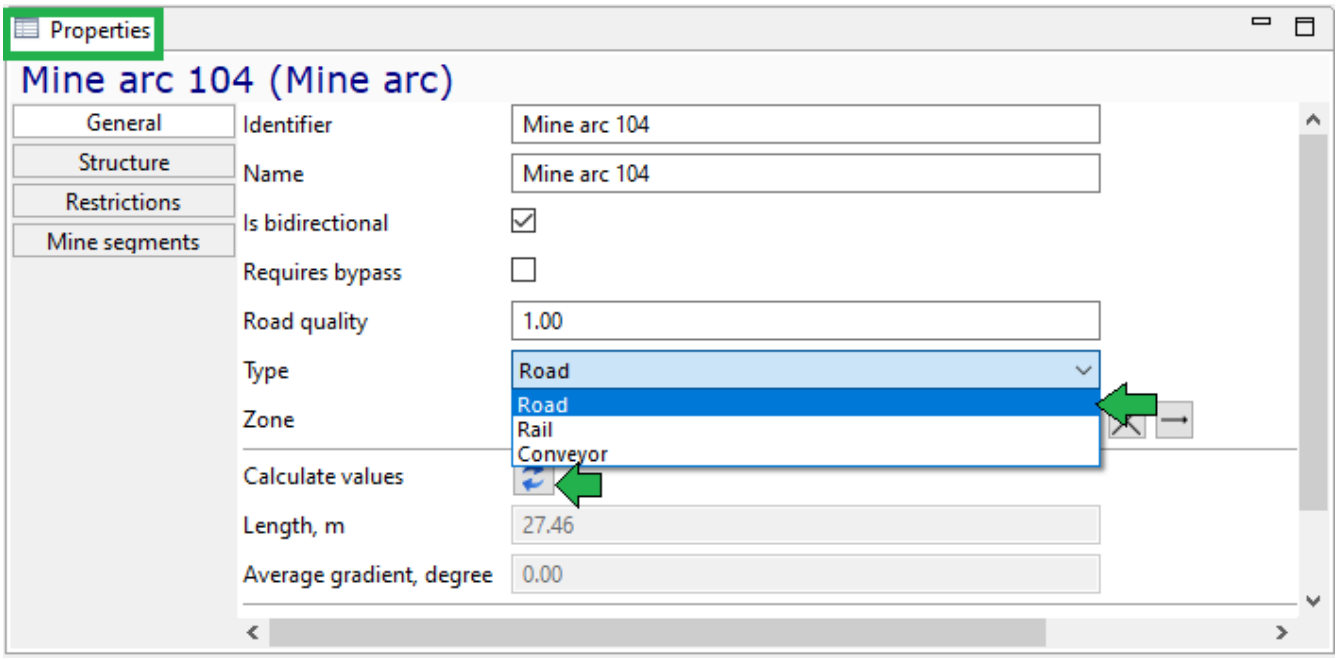
To set the selected value to all other elements in a column, right-click it and select the **Set to XX elements** menu item — for example, to set the same explosives magazine for all chargers. You can also filter the rows beforehand (e.g., by equipment type) and then the selected value will be assigned only to the filtered cells — for instance, to set the same work area for all excavators of the same type.

1.3.4. 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.

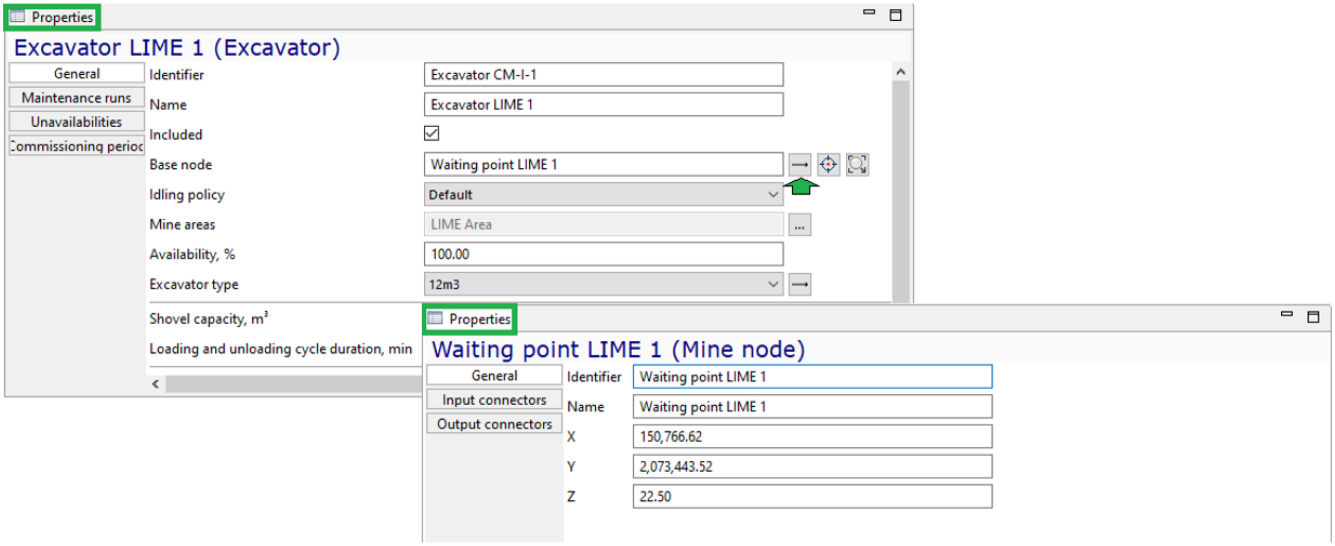


To change the parameters, the values of which are limited by the enumeration, the required value is selected from the drop-down list and removed by clicking the ☒ button to the right of the field.

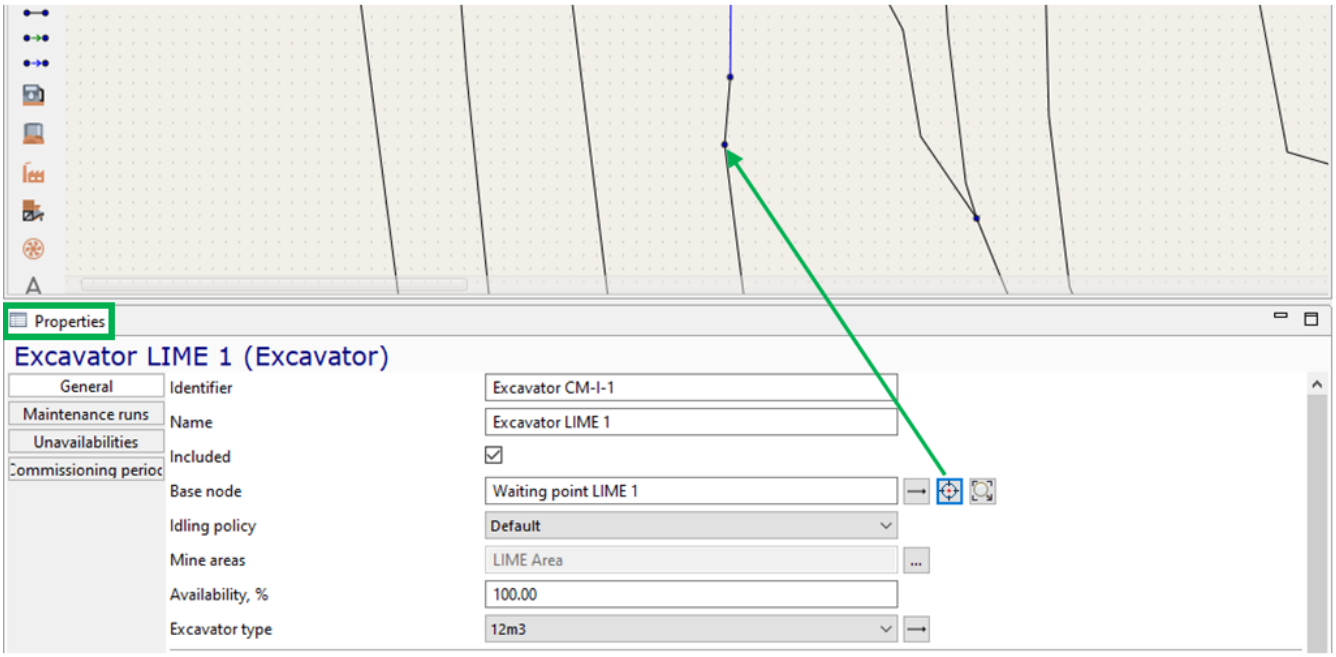


To update the data, use the button 🔄.

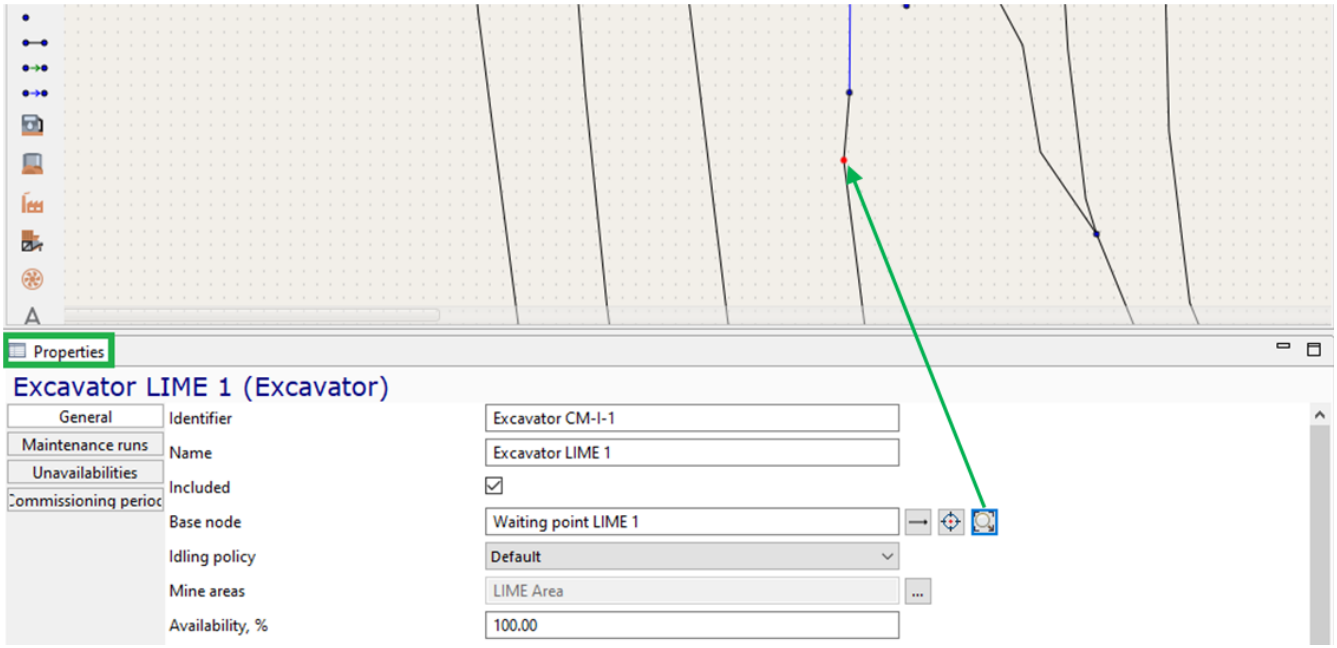
From the properties of the object unit, you can go to the properties of related objects, for example, from the properties of the equipment unit to the properties of the type of this equipment unit or the properties of its base node. To do this, click on the arrow to the right of the field.



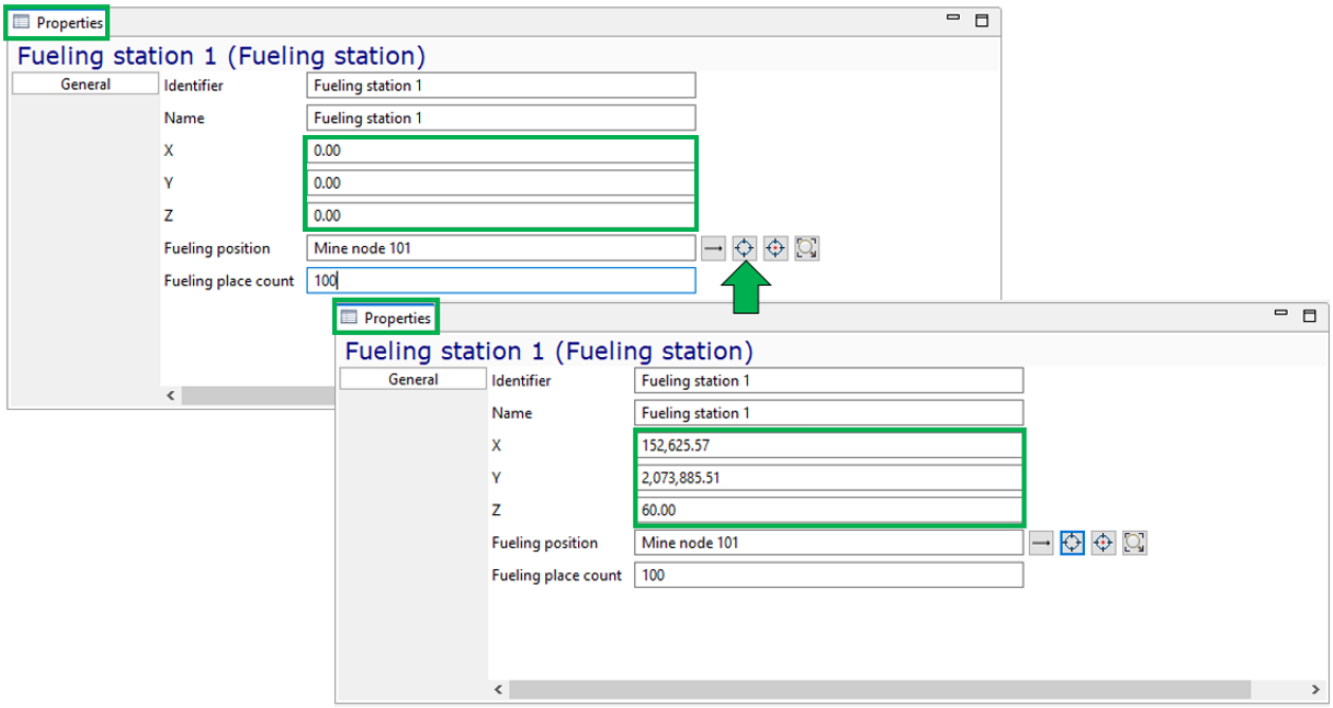
The button  allows you to define a different base node by selecting it on the map in 2D mode.



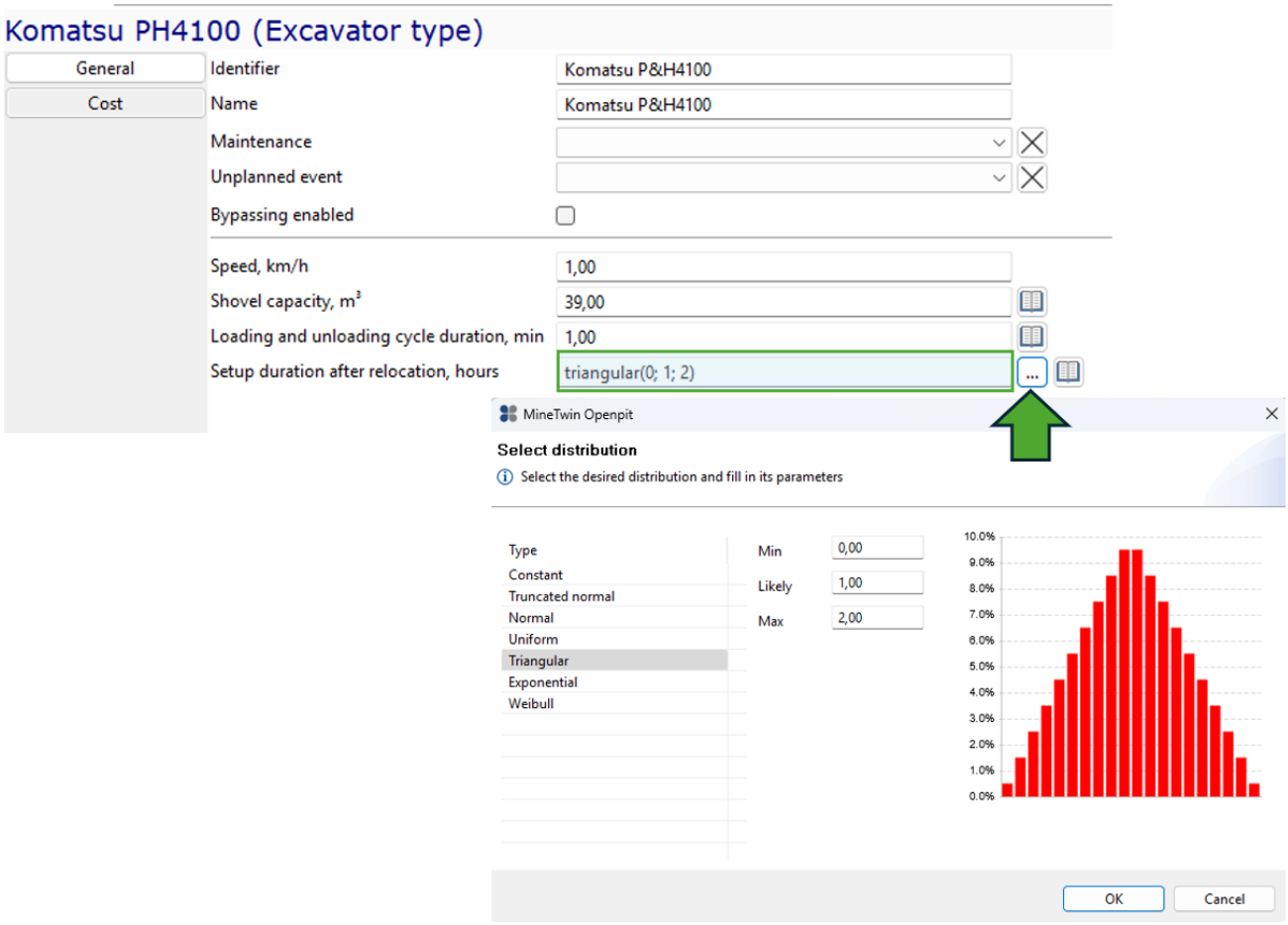
The button  highlights the selected node in the graphical editor (on a 2D map).



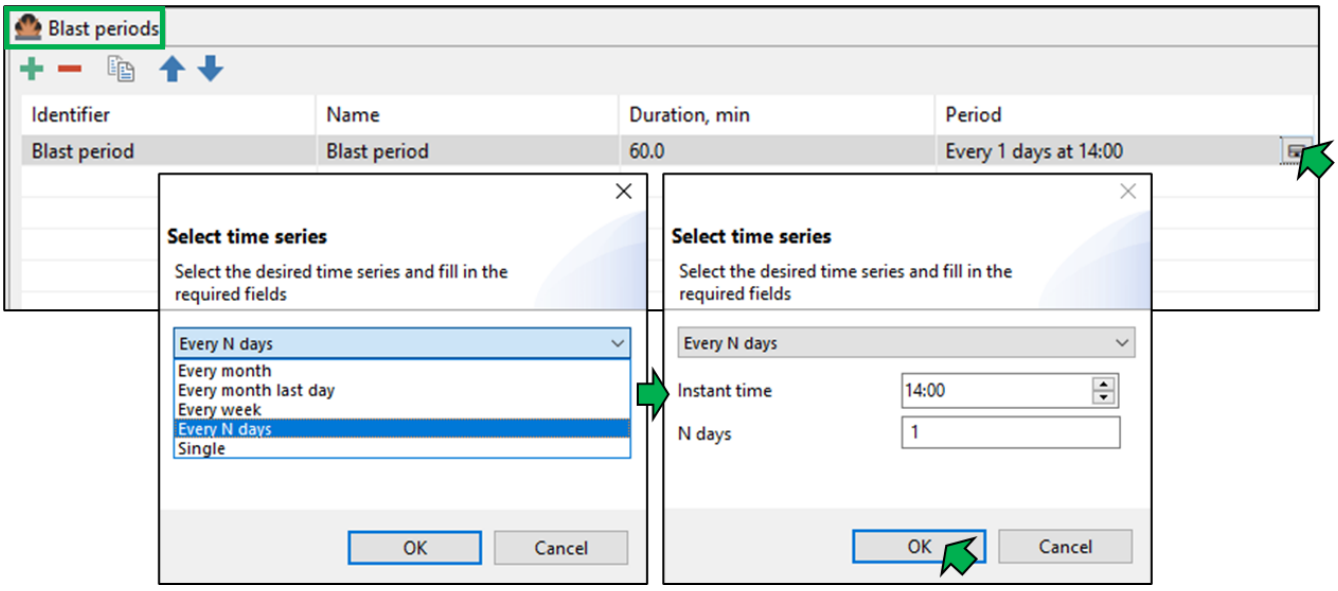
To move the object unit on the mine map to the point of its base node, use the button  .



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

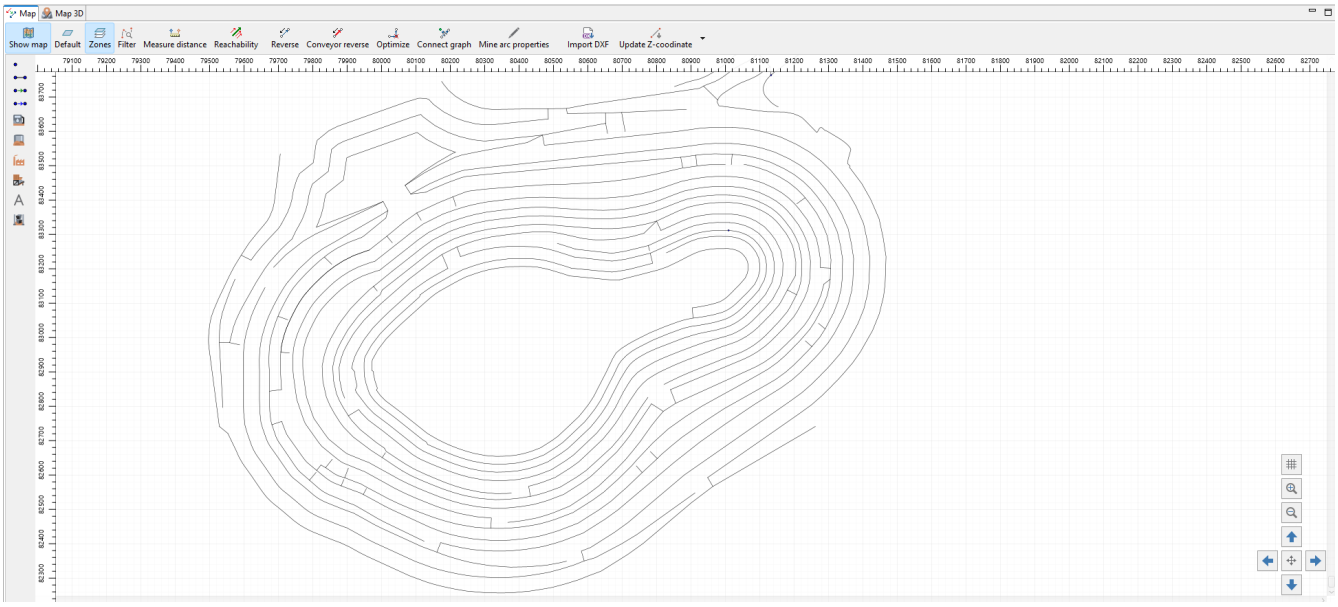


The time of occurrence of all periodic events in MineTwin can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days).



1.3.5. Map

The **Map** window displays a mine plan in two dimensions. You can edit the plan in this mode directly.



View controls

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

The buttons  in the bottom right corner allow you to zoom in and out on the map.

The buttons  allow to move the map.

The button  allows you to center the map.

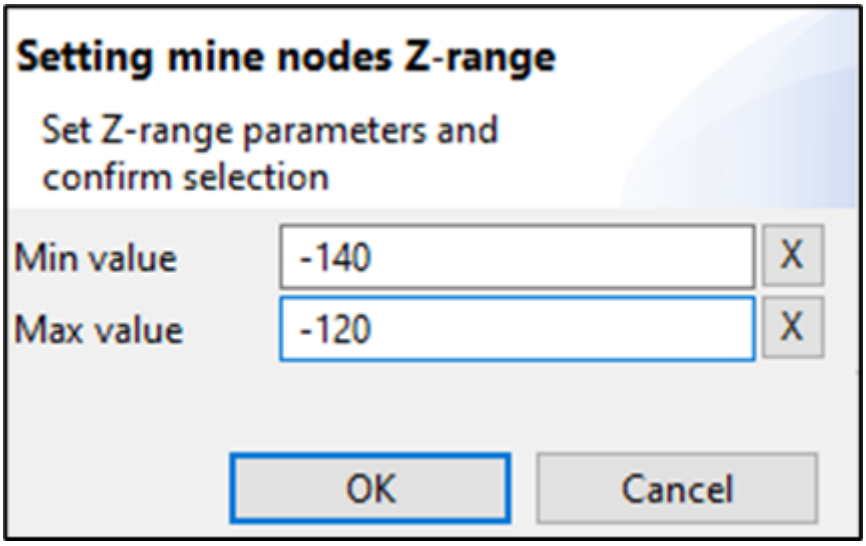
The button  allows you to toggle grid on the map and rulers at the sides.

Map Upper Toolbar

The button  allows you to enable/disable the display of a geographical map of the area.

The button  activates the default highlight of the mine arcs, and the button  activates the mine zones highlight of the arcs.

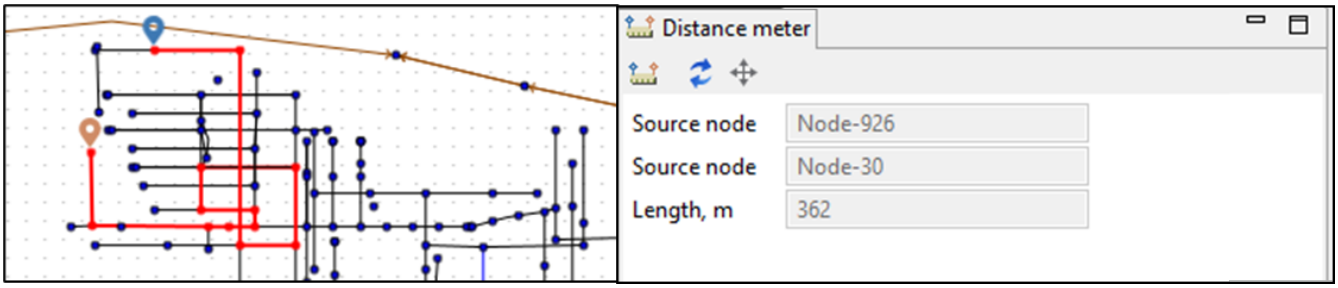
In the graphic editor MineTwin OpenPit, the viewing of individual sections of the mine field located at a given depth is available. The button  is used to set the range in the Z-coordinate of the mine nodes for viewing, for example, from -140 to -120.



After you've set the Z-coordinates, only objects with the Z-coordinates in the set range will be shown. Clicking the button again will remove the filter.

The button allows you 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.

The button toggles highlight of the isolated (not connected) sections of the map with different colors.

Quick map editing controls

Some quick map editing controls are also placed on the upper toolbar:

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

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

The button optimizes arc bending points - removes bending points that are on the same line between two consecutive bending points of selected mine arcs or all arcs of the scenario if no arc is

selected.

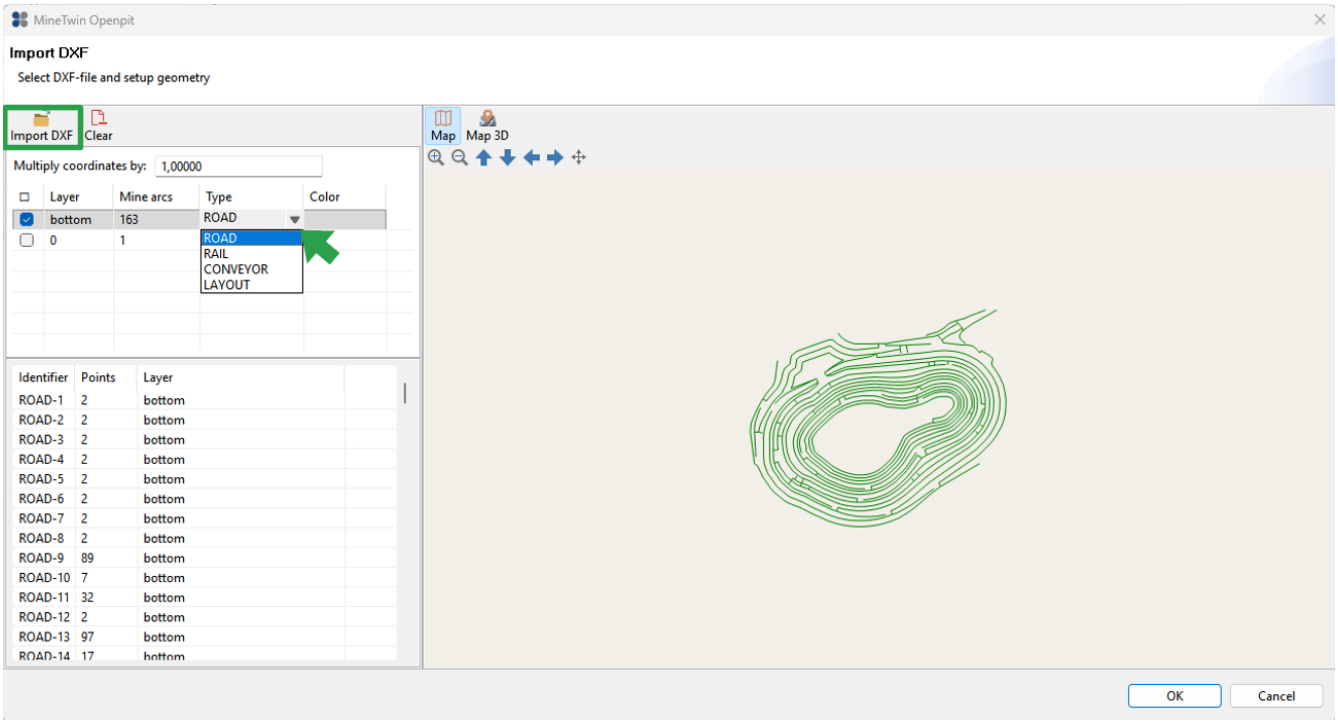
The button  divides mine segments by mine nodes that are in vicinity (2.5 m distance or less) and then connects them to that nodes. The action is taken only for selected segments. If no segments are selected, then the action is performed for entire map.

DXF file import

MineTwin OpenPit supports importing graphical data from third-party IT systems in DXF (.dxf) format. Clicking the  button opens a dialog where you can select the DXF file, choose the required layers, and import them into the scenario. If the parameters of the imported topology are specified in a non-metric system (e.g., feet), you need to multiply the coordinates by the appropriate conversion factor to convert them to metric units. When importing geometry, the following line types can be assigned:

- **ROAD** — road axis for the movement of self-propelled mobile equipment
- **RAIL** — railroad track axis
- **CONVEYOR** — conveyor line axis
- **LAYOUT** — polylines of the layout layer used as auxiliary elements when working with the Map; they are not involved in simulation

By default, all imported lines are assigned the ROAD type.



Left toolbar (palette)

The left panel of the editor window (palette) contains objects that can be added to the plan: mine nodes, arcs, block and mine segments, fueling/ recharging stations, storage, processing plants, crushers, dump areas and text labels.

A mine polyline arc and a layout polyline are created by successively placing vertices/points of the

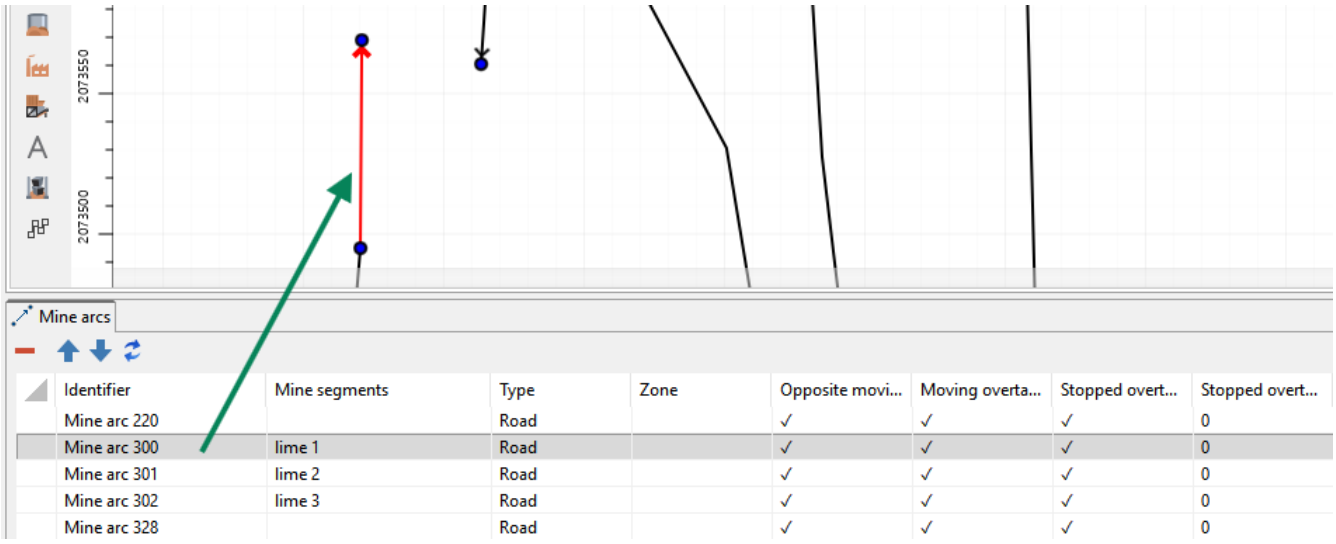
polyline with the mouse. Drawing is completed by double-clicking the left mouse button. If you start drawing a polyline arc from a transport network node and/or finish on an existing similar node, the line connects to these nodes and edges, forming a single network.

To add an block or a mine segment, left-click the corresponding object on the palette, then left-click the desired edge on the map.

To add other objects from the palette, left-click the object on the palette, then click at the location on the map where you want to place the object.

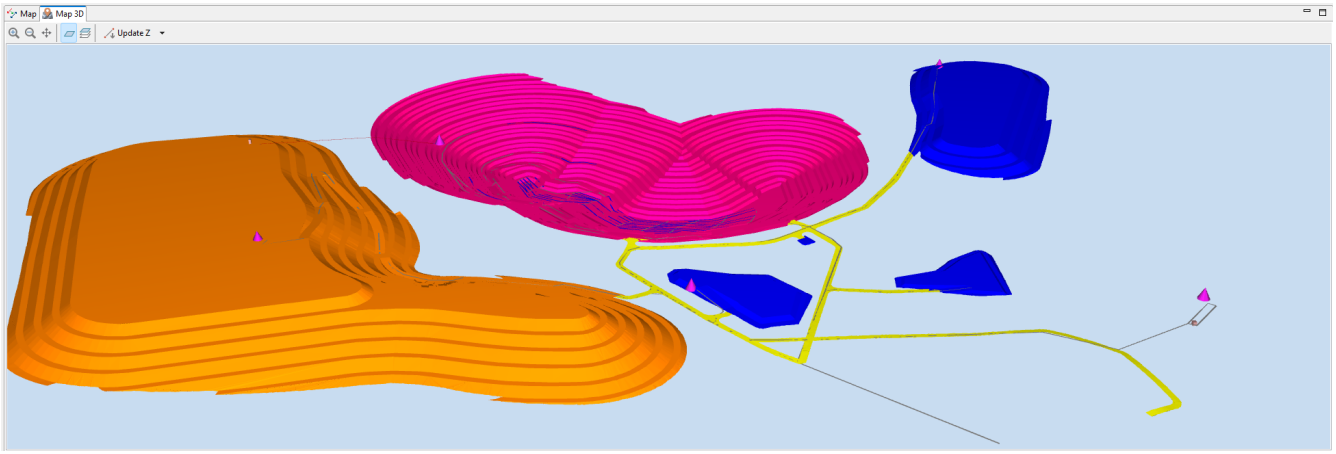
In the Map window, multiple selection and moving of objects is available. To do this, select the objects with the mouse and move them using the keyboard arrow keys.

When you select the object unit in the list of objects window, the corresponding object is highlighted on the map.



1.3.6. Map 3D

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



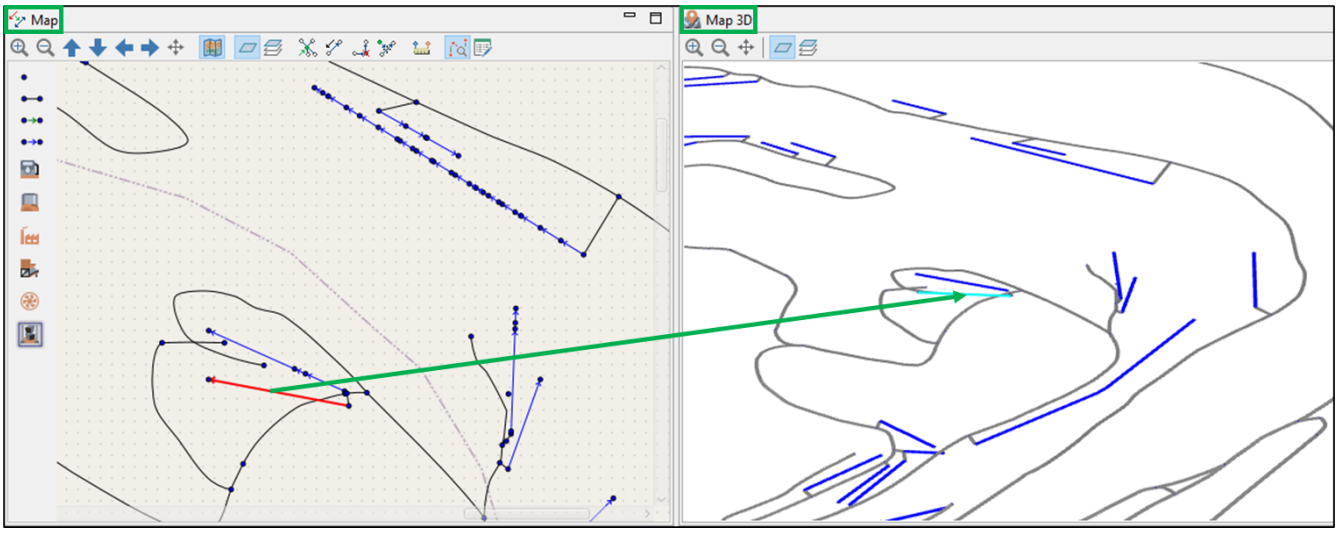
The plan is moved with the mouse while holding down the left mouse button, rotated - while holding down the right mouse button.

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

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

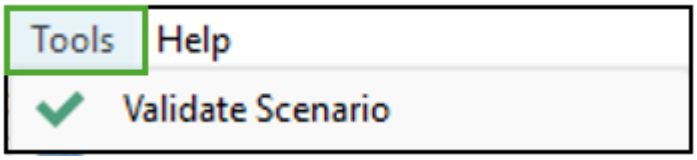
The button activates the illumination of the mine arcs by default, and the button activates the illumination of the arcs by mine zones.

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

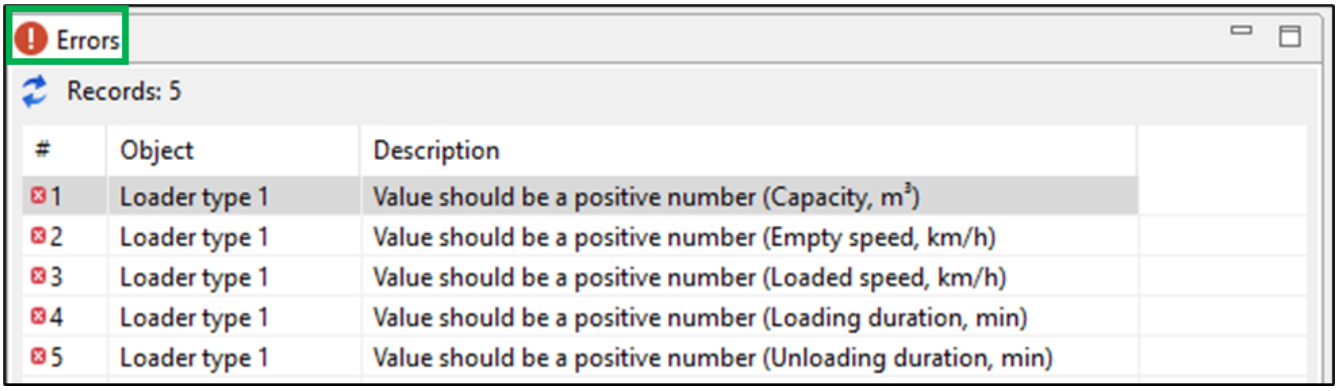


1.3.7. Errors

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 you can quickly fix it.

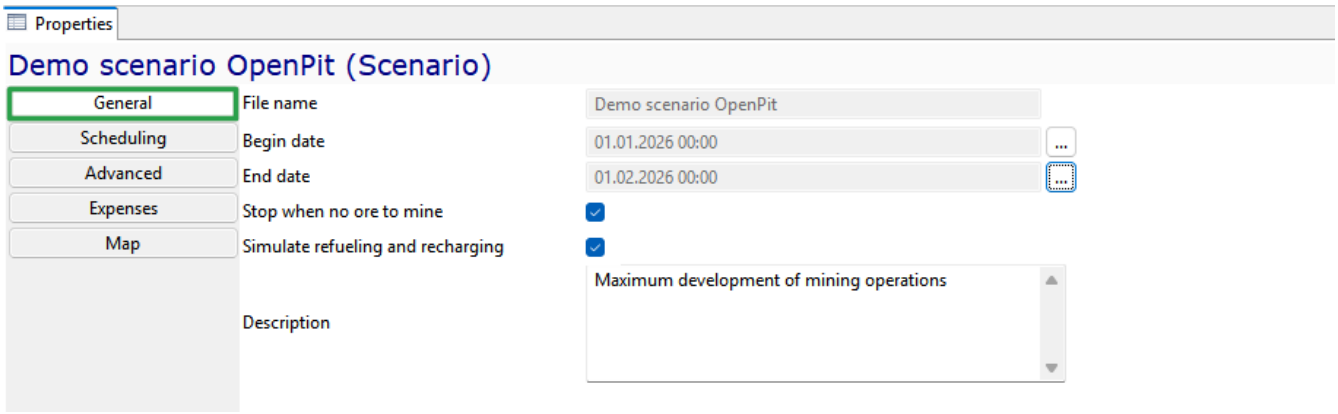
The button in the upper right corner of the "Errors" window serves to update the error list after they have been fixed.

1.4. Scenario

Scenario - the root object of the model. The Scenario object tree element contains global parameters related to the scheduling and simulation of an open-pit mine.

On the **General** tab, you will find:

- **File name**
- **Begin and end date** - date and time for planning and simulation
- **Simulate refueling and recharging** - when checked, refueling and recharging are simulated; when unchecked, fuel and energy demand is calculated but the movement to the station and the refueling/recharging process are not simulated
- **Stop when no ore mine** - stop the simulation if there is no ore remaining in the mining fronts, even if specified end date has not yet been reached
- **Description** — comments on the scenario (optional).

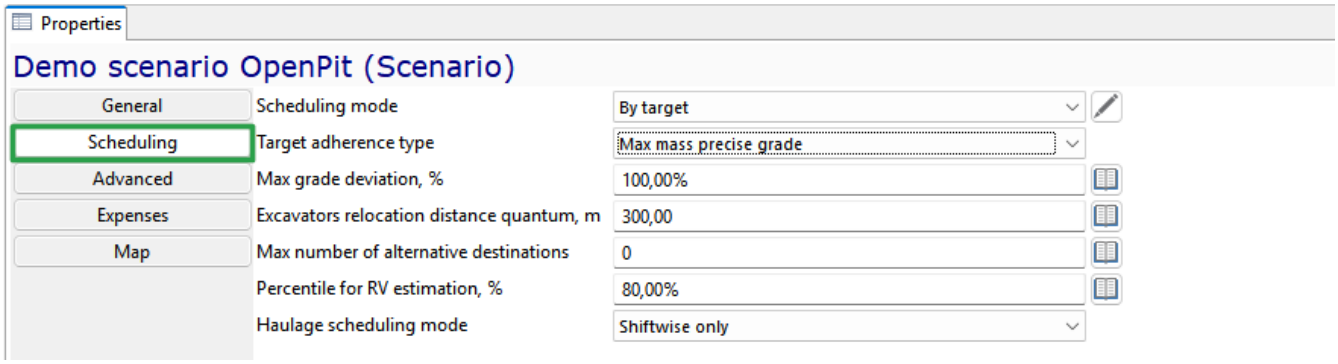


The **Scheduling** tab contains parameters that define the planning rules:

- **Scheduling mode** — in MineTwin OpenPit currently only one planning mode is available – the Target value plan, which defines how much ore mass and of what quality must be extracted in each planning period for the entire pit/mine
- **Target adherence type** — one of two options for target adherence policy:
  - *Maximize mass with exact match to grade* — the scheduler tries to meet the planned ore quality and volumes. It does not exceed planned production volumes even if there are free work faces and equipment. If work faces, equipment, or ore of the required quality are insufficient, the scheduler prioritizes achieving the target ore quality, even at the cost of reducing tonnage
  - *Maximize mass regardless of grade* — the scheduler maximizes production regardless of

quality. It seeks to reach target volumes for both ore and waste and to avoid situations where one target is missed while the other is greatly exceeded. After hitting both targets, equipment is distributed approximately evenly between ore and waste to maximize both

- **Excavator relocation distance quantum, m** — this parameter defines the search radius for an excavator's next work location. After an excavator completes work in a block, its next work location is searched for within the specified radius. When all blocks within this radius have been processed, the radius is doubled, and the search for a work location is conducted within the new, doubled radius. If no work is found there either, the search is performed across any range
- **Percentile for RV estimation, %** – a technical parameter that defines the fluctuation range of random variables. The result of the calculation is a number that does not vary during the planning process. For example, with a uniform distribution of operation duration from 5 to 10:
  - If the percentile is set to 0 % – the minimum possible value of 5 will be used in planning
  - If the percentile is set to 100 % – the maximum possible value of 10 will be used in planning
  - If the percentile is set to 20 % – the value 6 will be used in planning, because with 20% probability in a uniform distribution from 5 to 10, the value will be between 5 and 6
  - If the percentile is set to 40 % – the value 7 will be used
- **Haulage scheduling mode**:
  - *Shiftwise only* – tasks are generated only at the start of each shift and are not updated during the shift
  - *Dynamic only* – a new task is assigned to each haul truck immediately upon completion of its previous trip
  - *Shiftwise and dynamic* – tasks are generated on a shift basis but are supplemented dynamically if a truck becomes idle (e.g., due to excavator breakdown or early completion of work).

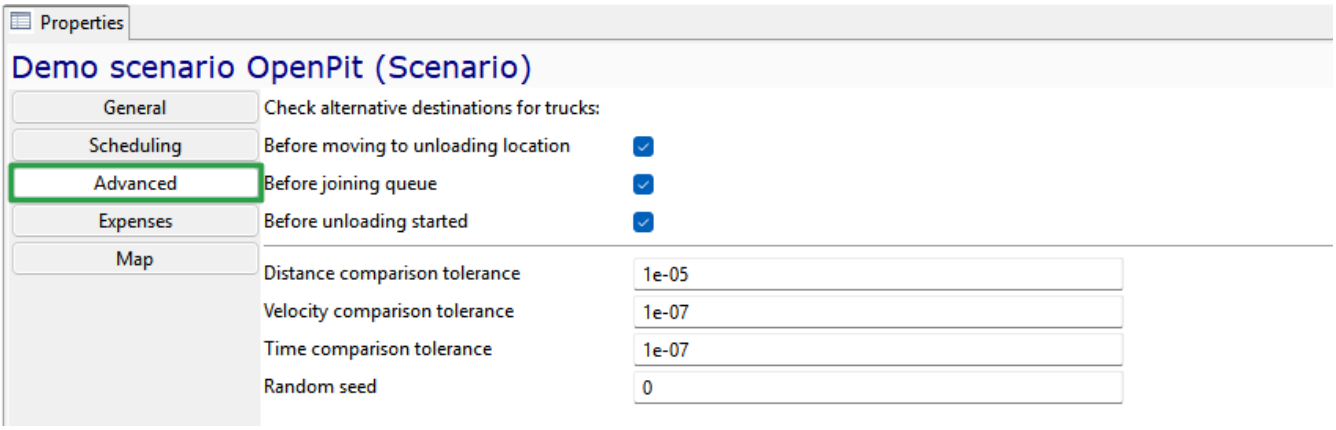


The **Advanced** tab contains additional technical settings

When to check the fill level of the planned dump location and choose alternative dump locations for trucks:

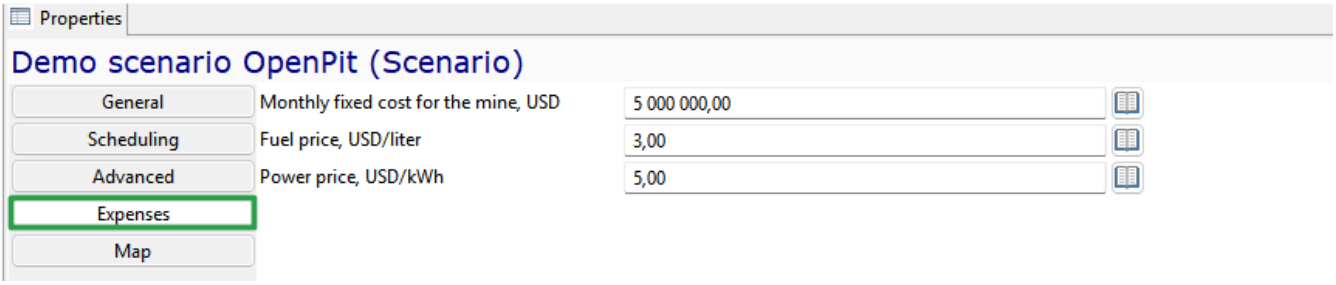
- **Before moving to unloading location** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before beginning to unloadw
- **Before joining queue** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before joining the queue for unloading

- **Before unloading started** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before starting to travel to the dump area/ ore pass
- Precision settings for comparing **Distance**, **Velocity**, and **Time** during simulation
- **Random seed** — an initial value used in random number generators to create a sequence of random numbers. It serves as a "starting point" that determines which numbers will be generated. Using the same random seed ensures that the simulation results for a scenario are identical on every simulation run. Running the same scenario with a different random seed may produce different simulation results.



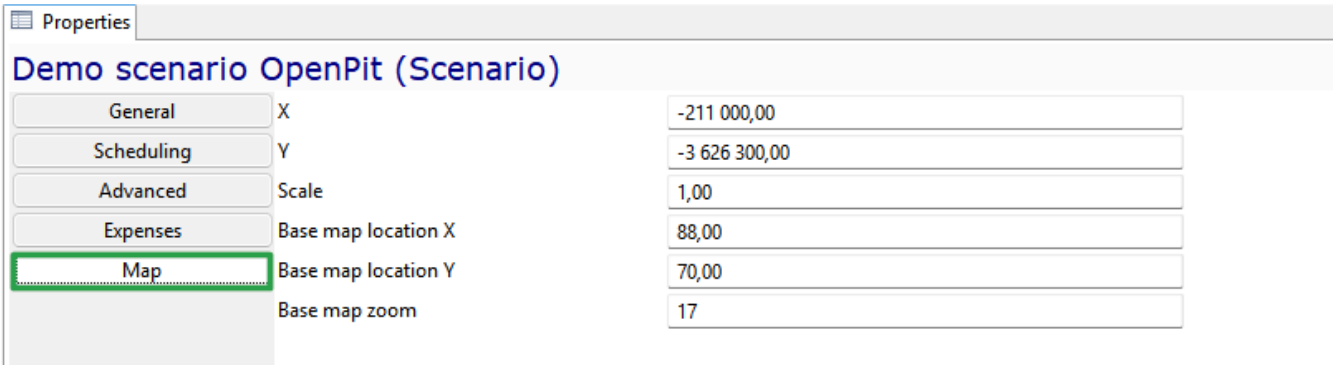
On the **Expenses** tab, you specify:

- **Monthly fixed costs of the pit/mine, USD**
- **Fuel price, USD/liter** to be used when calculating fuel costs
- **Power price, USD/kWh** - for charging self-propelled equipment with electric motors (rechargeable batteries).



The **Map** tab also contains technical parameters related to map settings:

- Absolute coordinates **X** and **Y**
- Map **Scale**
- **Base map location X and Y** — offset coordinates of the origin on the geographic map
- **Base map zoom** — base scale on the geographic map: an integer from 2 to 18. Recommended value: 14. 2 is the smallest scale (entire world visible), 18 is the largest (maximum zoom-in).



1.5. Map

The Map model tree group contains the following elements of an open-pit mine:

- Mine nodes
- Mine arcs
- Zones
- Mine areas
- Mine segments
- Layout layers

1.5.1. Mine node

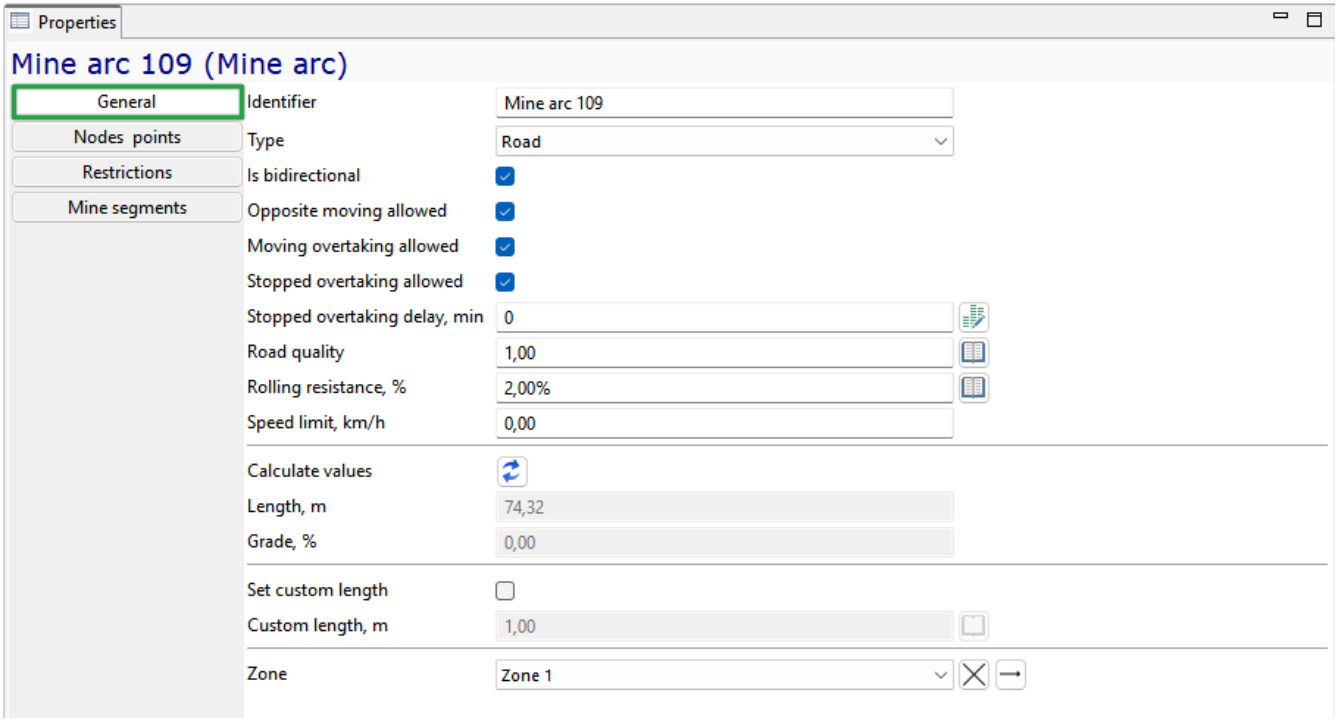
Mine node - an element of the mine transport network graph, which corresponds to one point in three-dimensional space.

The **mine node** is characterized by the following parameters:

- Unique **Identifier**
- **X**-, **Y**- and **Z**-coordinates

1.5.2. Mine arc

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

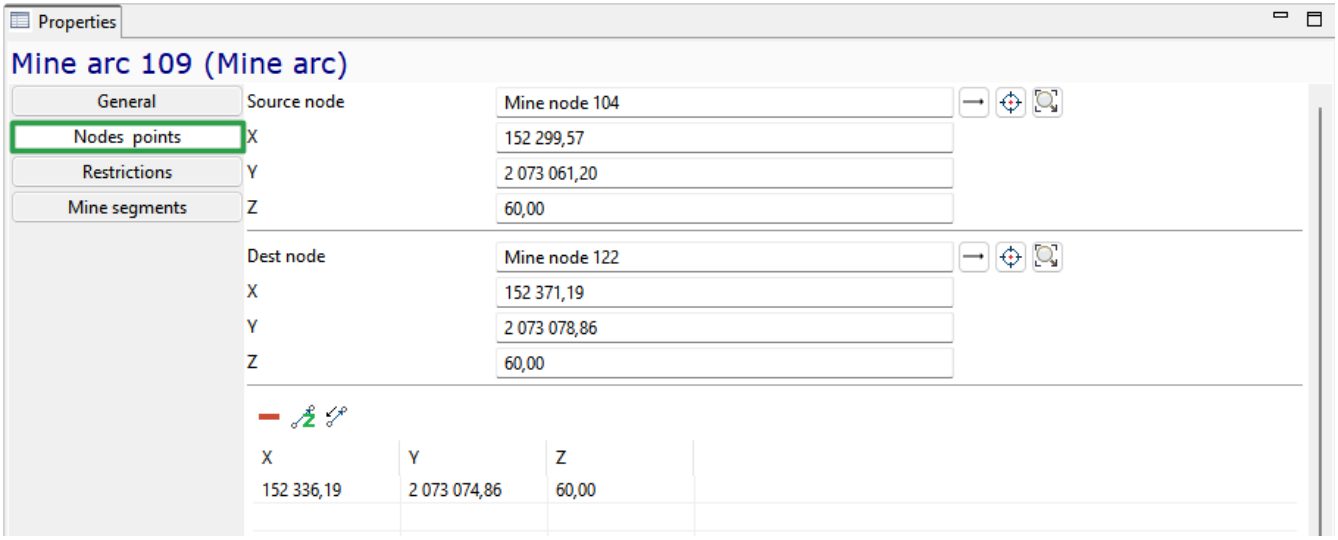


The mine arc is characterized by the following parameters:

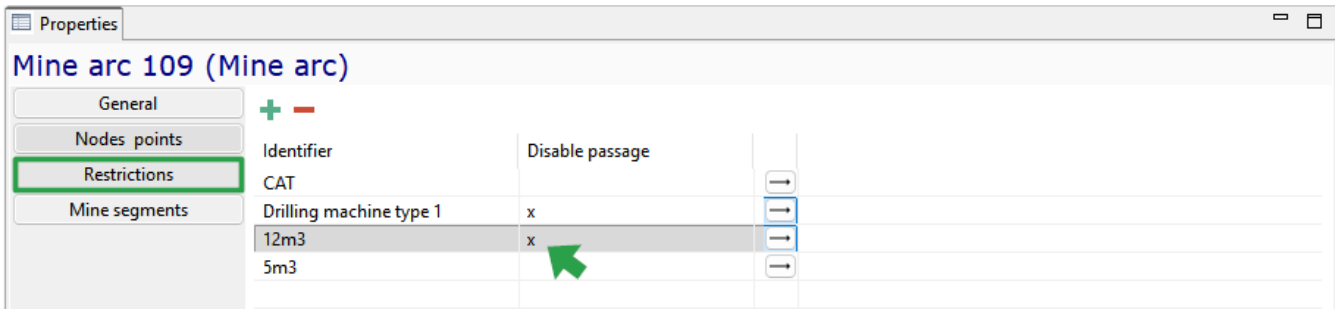
- Unique **Identifier**
- **Type** — one of the following types: Road (non-rail), Rail or Conveyor
- **Is bidirectional** — parameter indicating whether travel along this mine arc is possible in both directions (two-way road)
- **Opposite moving allowed** — a parameter specifies whether simultaneous movement in the opposite direction is allowed. If not, the equipment will stop in front of the arc to allow those traveling in the opposite direction to pass
- **Moving overtaking allowed** — a parameter specifies whether passing of slower vehicles traveling in the same direction is permitted on this arc
- **Stopped overtaking allowed** — a parameter specifies whether a moving vehicle may overtake or bypass a stopped vehicle on this arc
- **Stopped overtaking delay, min** — a parameter defines the additional delay required for a vehicle to overtake or bypass a stopped vehicle on this arc
- **Road quality** — a factor that adjusts the base speed of equipment when traveling along this mine arc
- **Rolling resistance, %** — the resistance that occurs when tires of self-propelled wheeled equipment roll on the road surface. This parameter affects the equipment's travel speed when the speed calculation rule "Rimpull curve based" is applied
- **Speed limit, km/h** — maximum speed of movement for all moveable equipment on this arc. The actual speed can be lower due to individual equipment settings
- **Length** — system-calculated length of the segment, taking into account the mine arcs it comprises
- **Grade, %** — arc gradient (slope) is automatically calculated by the system as the ratio of the vertical rise (difference in z-coordinates) to the arc length, expressed as a percentage

- **Set custom length** — parameter allowing to set an arbitrary length for the mine arc, disregarding actual coordinates and scaling
- **Custom length,m** — conditional/override length of the mine arc
- **Zone** — zones serve for color-coding mine arcs. For example, a user can create a transport network zone indicating roads requiring clearing and then apply this zone (color) to all arcs that need clearing

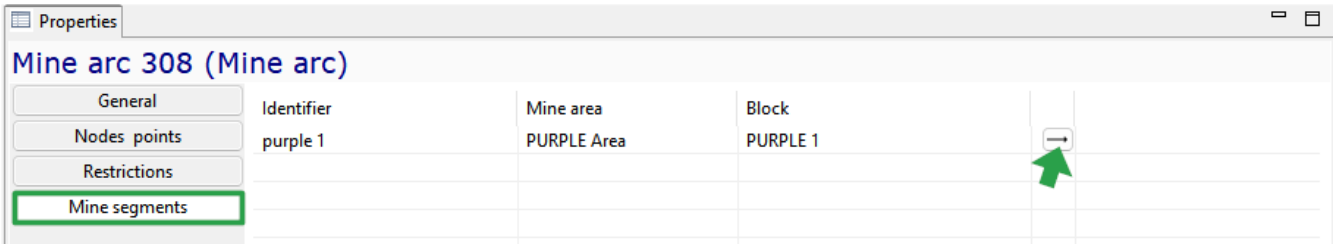
On a separate **Nodes points** tab of the arc properties, the arc structure is shown: links to the start and end nodes and the list arc bend points.



In the **Restrictions** tab, you can prevent certain equipment types from moving along the arc by checking them.



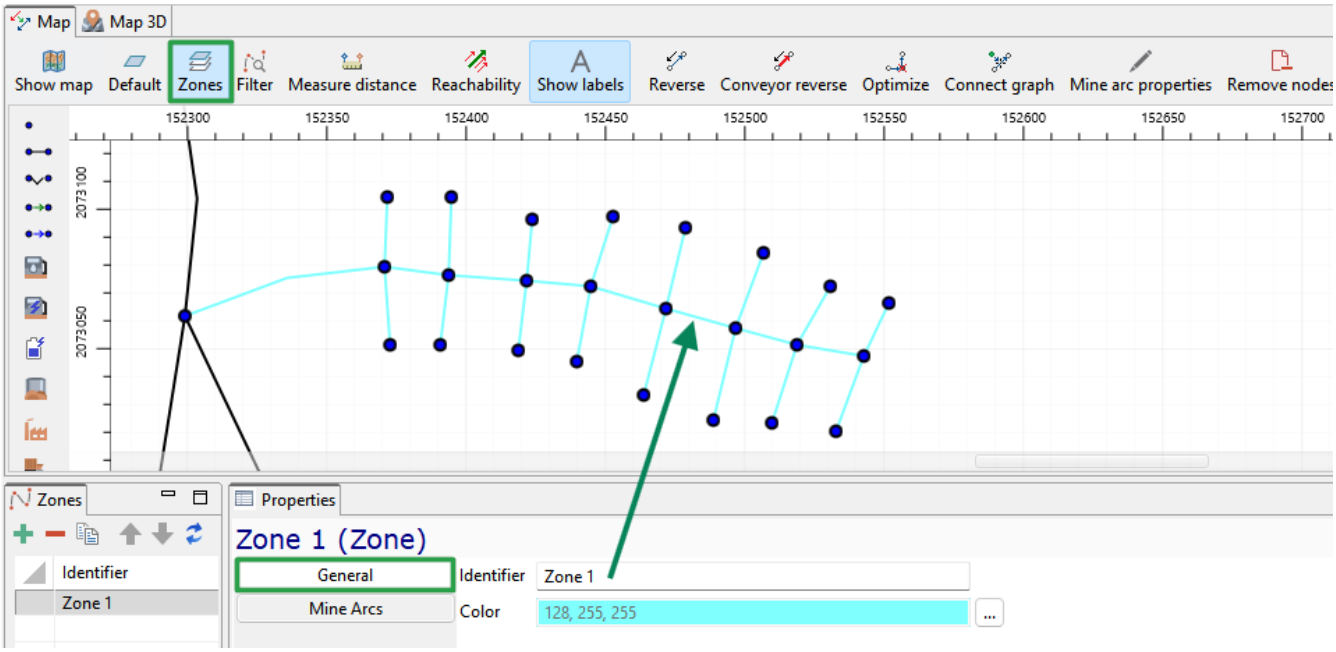
On the **Mine segments** tab of the arc properties, there is a link to the mine segment of which this arc is a part.



1.5.3. Zones

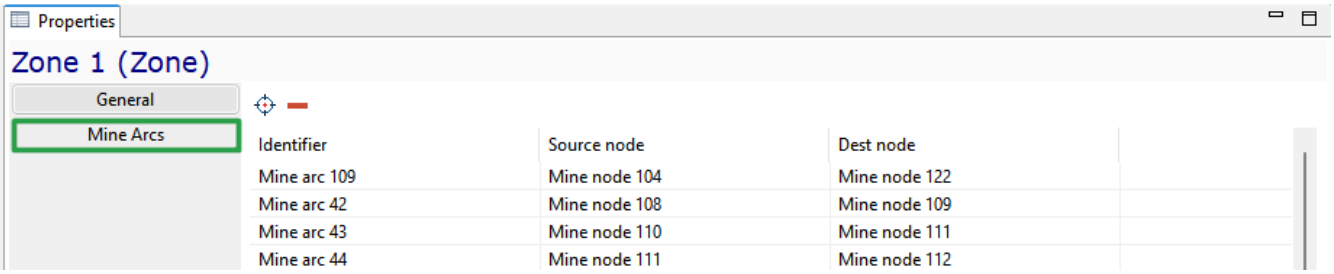
In the Zones object, a list of options for the color marking of arcs on the map is specified. For example, you can create a zone of the mine field, indicating the roads to be cleaned, and then apply

this zone (color) to all arcs that require cleaning.



A zone is characterized by a unique **identifier** and **color**.

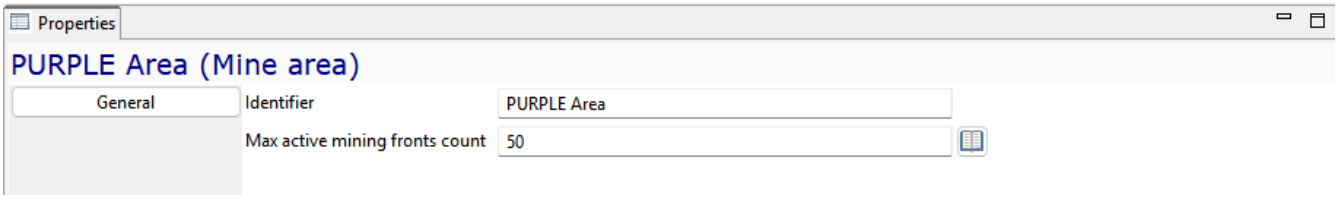
The **Mine arcs** tab of the zone properties contains a list of the mine arcs included in this zone.



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

1.5.4. Mine areas

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



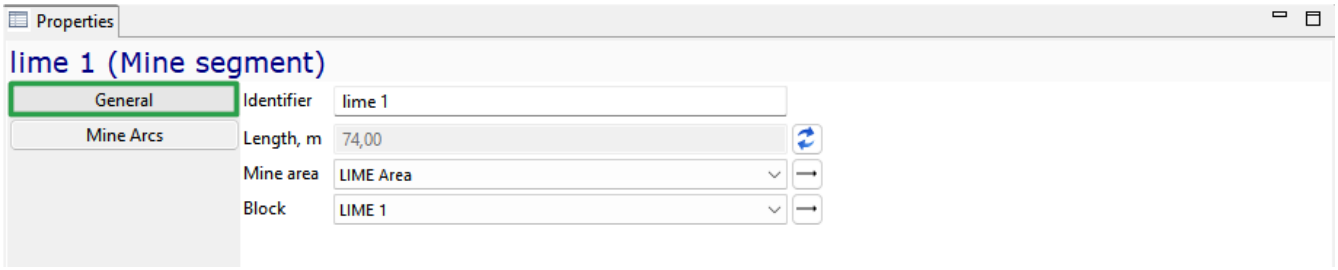
A mine area in MineTwin OpenPit has following parameters:

- A unique **Identifier**
- **Max active mining fronts count** - a parameter that limits the number of concurrent active blocks within a mine area, even when sufficient equipment is available. For example, if 10 blocks are available for extraction, but the user sets the limit to 5, only 5 blocks will be worked

on simultaneously. Work on the sixth block will only begin once operations in one of the first five are completed, and so on

1.5.5. Mine segments

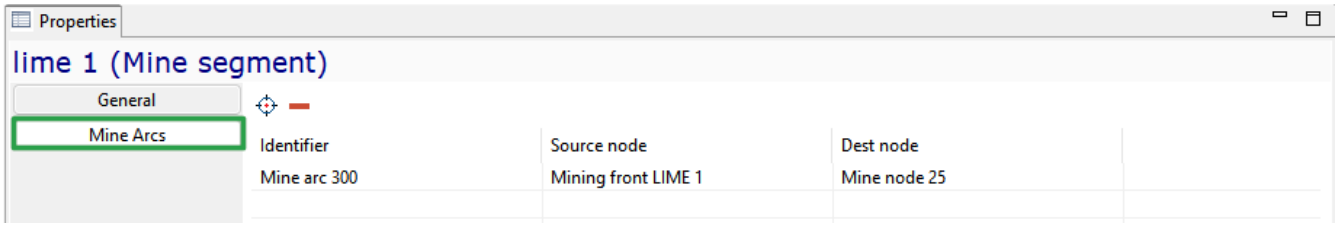
Mine segment - an ordered set of mine arcs used to define the location of a block. A mine segment is represented by a directed polyline in three-dimensional space.



The mine segment has following **General** parameters:

- Unique **Identifier**
- **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
- **Block** - a link to a block located within this mine segment

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 an arc by selecting it on a mine field using the button  or remove an arc from the mine segment ().

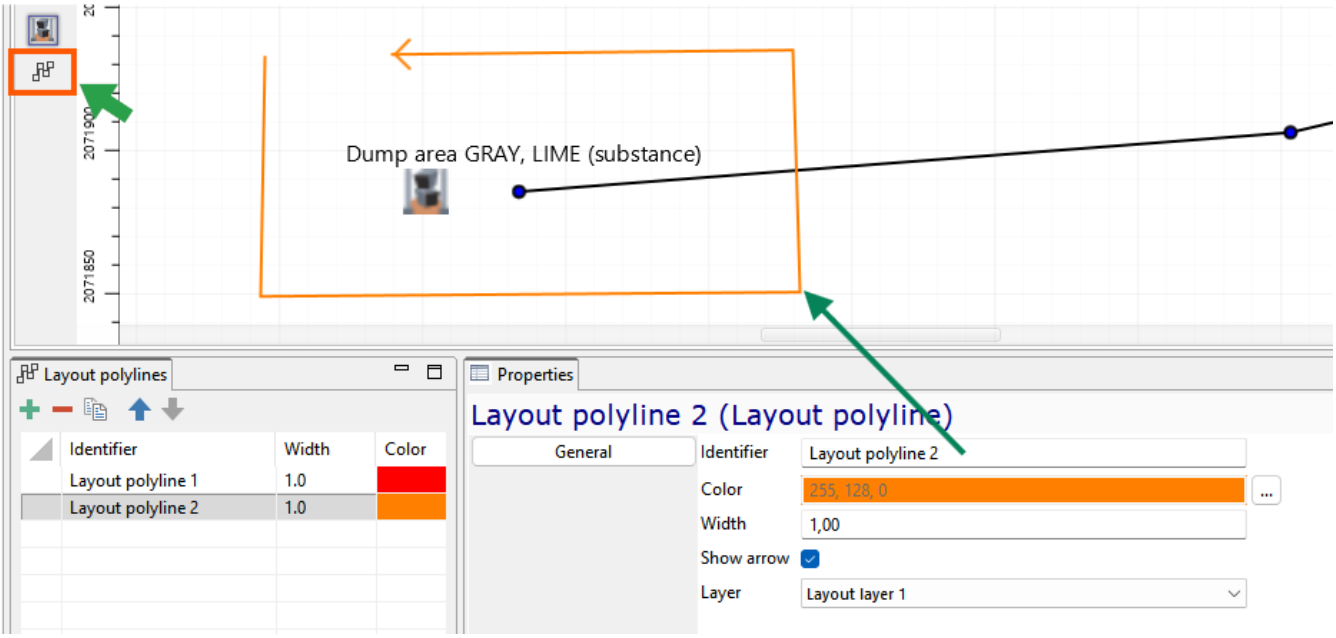
1.5.6. Layout layers

The **Layout layers** element of the object tree contains a list of layers, each of which includes two groups of objects: **Layout polylines** and **Text labels**. Layout layer objects serve as supplementary information when working with the map and are not involved in modeling. Layer properties allow enabling/disabling its visibility and editability.

Layout polylines

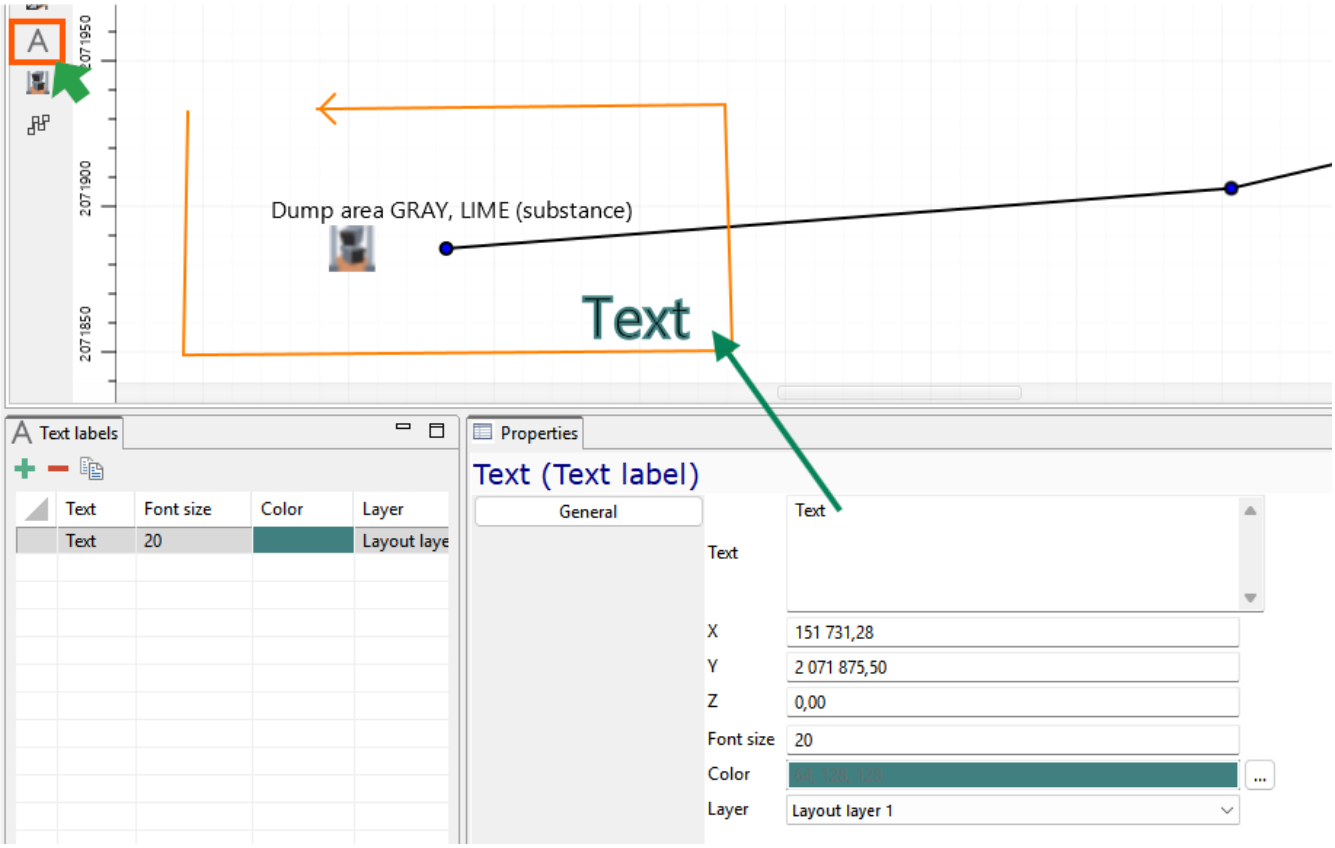
The **Layout polylines** group of the selected **Layout layer** contains a set of polylines created in the application or imported from a .dxf file. Adding a new element to the map is possible using the button from the palette located on the left side of the 2D map window. Polyline properties include:

- Unique **Identifier**
- **Color** — ability to set the color by selecting from a palette
- **Width** — line thickness in pixels
- **Show arrow** — function to enable/disable the display of an arrow at the last point of the polyline
- **Layer** — move the layout polyline to the desired layer by selecting from the list of available layout layers



Text labels

The **Text Labels** element lists the text labels added to the map. You can add a new item to the map using the button from the toolbar on the left side of the 2D map window. In the properties window you can enter the label text and set the font size and color, assignment to a layout layer from the list of those available in the scenario.



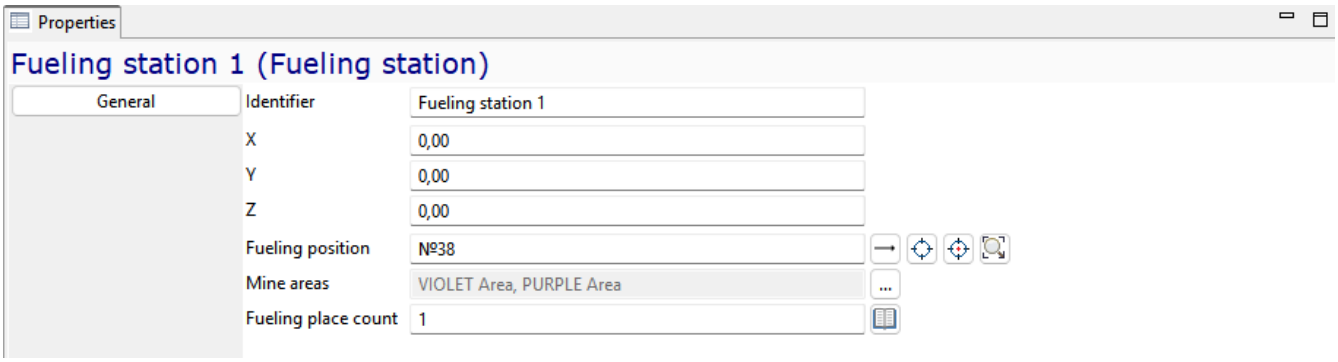
1.6. Energy

Energy object tree group contains the following mine/pit elements:

- Fueling stations
- Recharging stations
- Recharging bays
- Fixed battery types
- Swappable battery types

1.6.1. Fueling stations

A fueling stations is a transport infrastructure element designed for refuelling equipment with fuel.



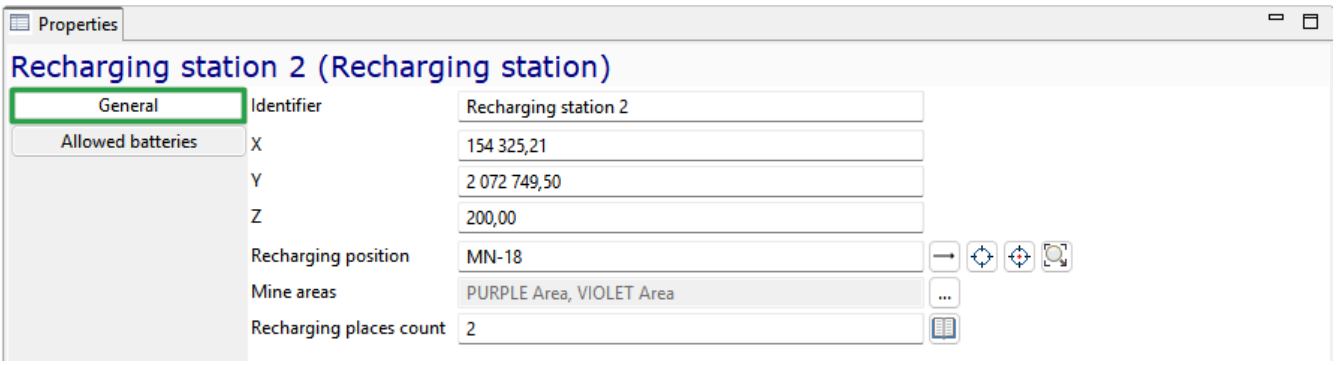
The fueling station has the following parameters:

- Unique **Identifier**

- **X-**, **Y-** and **Z**— coordinates
- **Fueling position** — link to the mine node where the equipment unit is located while refueling at the fueling station
- **Mine areas** - when specifying areas, this fueling station will only serve self-propelled equipment that belong to those areas
- **Fueling place count** - number of simultaneous refueling positions

1.6.2. Recharging stations

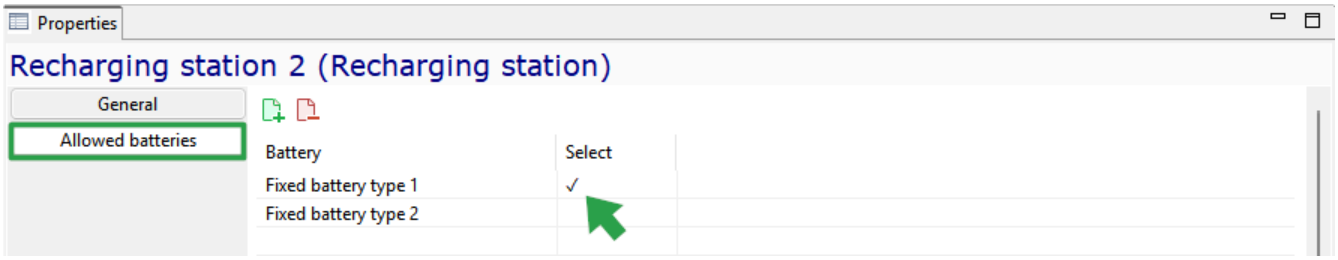
Recharging stations — a transport infrastructure element designed for recharging batteries that are structurally integrated into the equipment and cannot be removed from it.



The **General** properties of a recharging stations include:

- Unique **Identifier**
- **X**, **Y**, and **Z**— coordinates of the transport network node at which the station is located
- **Recharging position** — identifier of the transport network node at which the equipment unit is positioned during battery recharging
- **Mine areas** — mine areas whose equipment may be recharged at this station
- **Recharging places count** — number of equipment units that can be recharged simultaneously at this station.

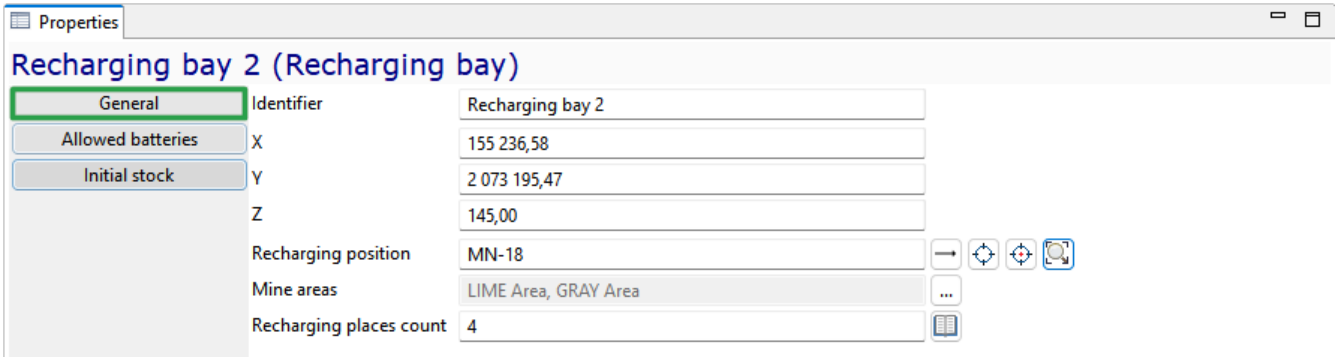
On the **Allowed batteries** tab, you may select from the list the types of fixed batteries that can be recharged at this station. The types and specifications of fixed batteries are populated in the **Fixed battery types** object group.



To select the permitted types, tick the **Select** field. The button allows you to select the entire list of fixed battery types, while the button clears all selections.

1.6.3. Recharging bays

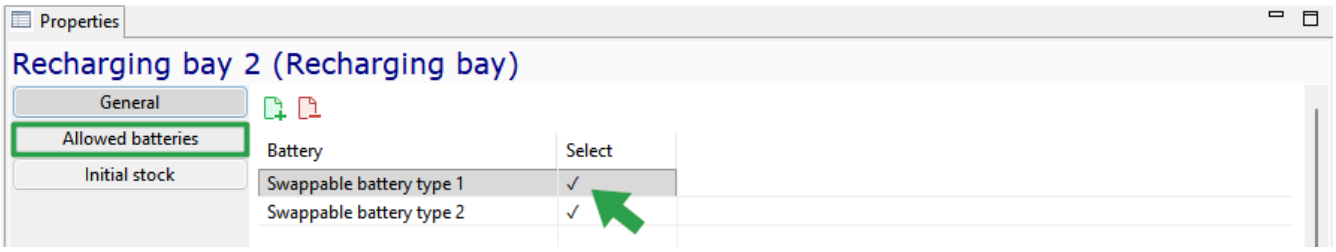
Recharging bays — a transport infrastructure element designed for exchanging depleted batteries with fully charged ones and for recharging discharged batteries.



The **General** properties of a recharging bays include:

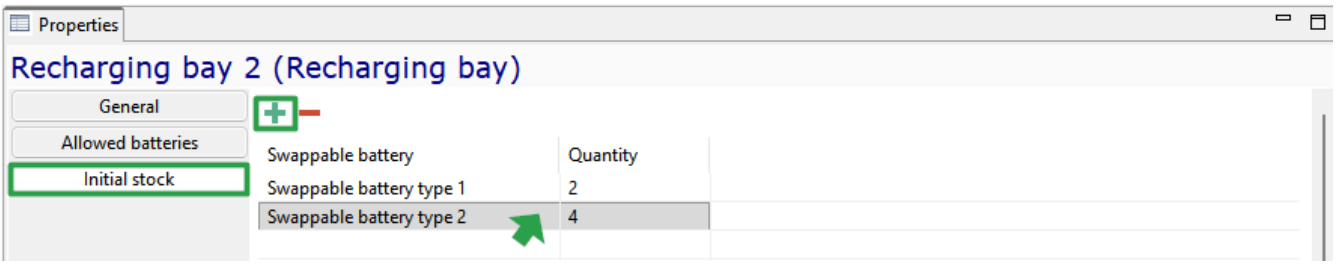
- Unique **Identifier**
- **X**, **Y**, and **Z**— coordinates of the transport network node at which the station is located
- **Recharging position** — identifier of the transport network node at which the equipment unit is positioned during battery recharging
- **Mine areas** — mine areas whose equipment may be recharged at this station
- **Recharging places count** — number of equipment units that can be recharged simultaneously at this station.

On the **Allowed batteries** tab, you may select from the list the types of swappable batteries that can be recharged at this station. The types and specifications of swappable batteries are populated in the **Swappable battery types** object group. To select the permitted types, tick the **Select** field.

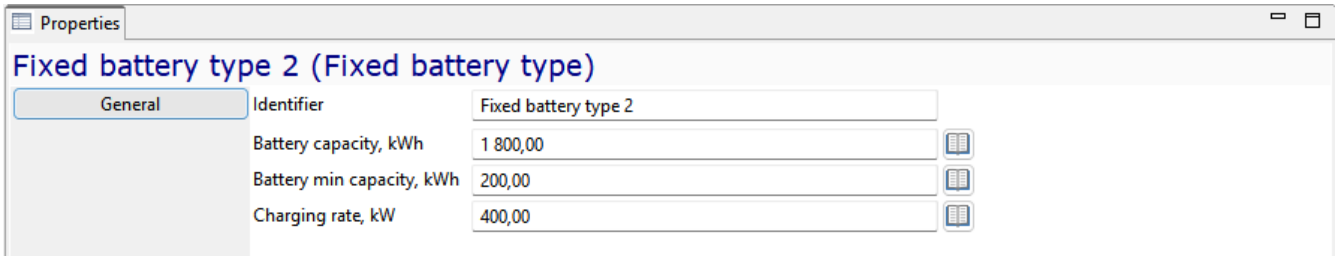


The button allows you to select the entire list of swappable battery types, while the button clears all selections.

On the **Initial stock** tab, specify the quantity of fully charged batteries of each type (if any) available at the start of the simulation. If the station has no stock of charged batteries, this tab is left blank.



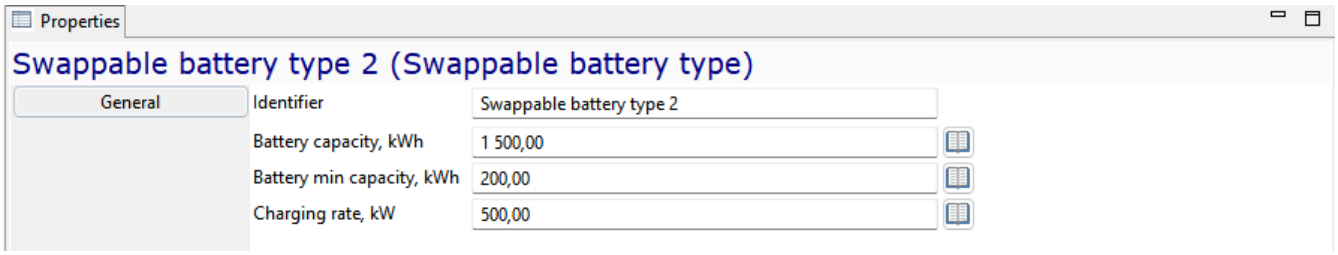
1.6.4. Fixed battery types



Fixed battery types are characterised by the following **General** properties:

- unique **Identifier**
- **Battery capacity, kWh** — the capacity of a fully charged battery
- **Battery min capacity, kWh** — the capacity value at which the equipment unit begins travelling to the recharging station
- **Charging rate, kW** — the charging power rate at which energy is transferred from the station to the battery per hour.

1.6.5. Swappable battery types



Swappable battery types are characterised by the following **General** properties:

- unique **Identifier**
- **Battery capacity, kWh** — the capacity of a fully charged battery
- **Battery min capacity, kWh** — the capacity value at which the equipment unit begins travelling to the recharging station
- **Charging rate, kW** — the charging power rate at which energy is transferred from the station to the battery per hour.

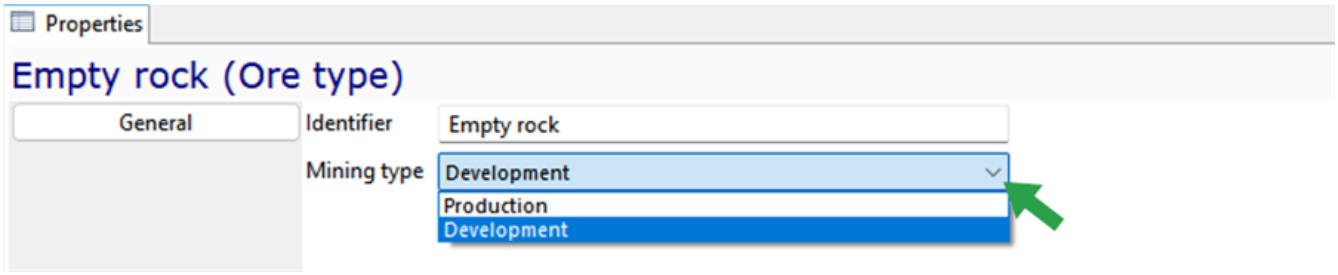
1.7. Ore

The Ore model tree group contains the following elements of an open-pit mine:

- Ore types
- Materials
- Blocks.

1.7.1. Ore type

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



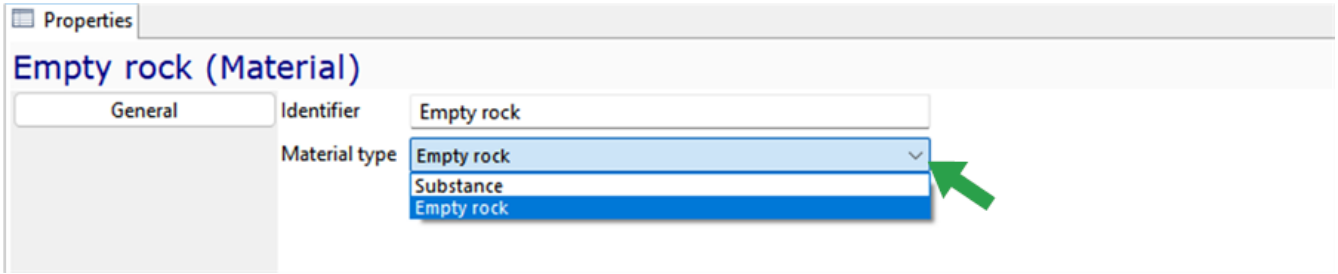
Ore types are used to determine haulage destinations for ore from blocks. For example, ore from a block containing the "Oxidized" type will be hauled only to dump locations that accept ore of this type.

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

- Unique **identifier** and **name**
- **Mining type**: production or development.

1.7.2. Material

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



The following properties must be set for each material:

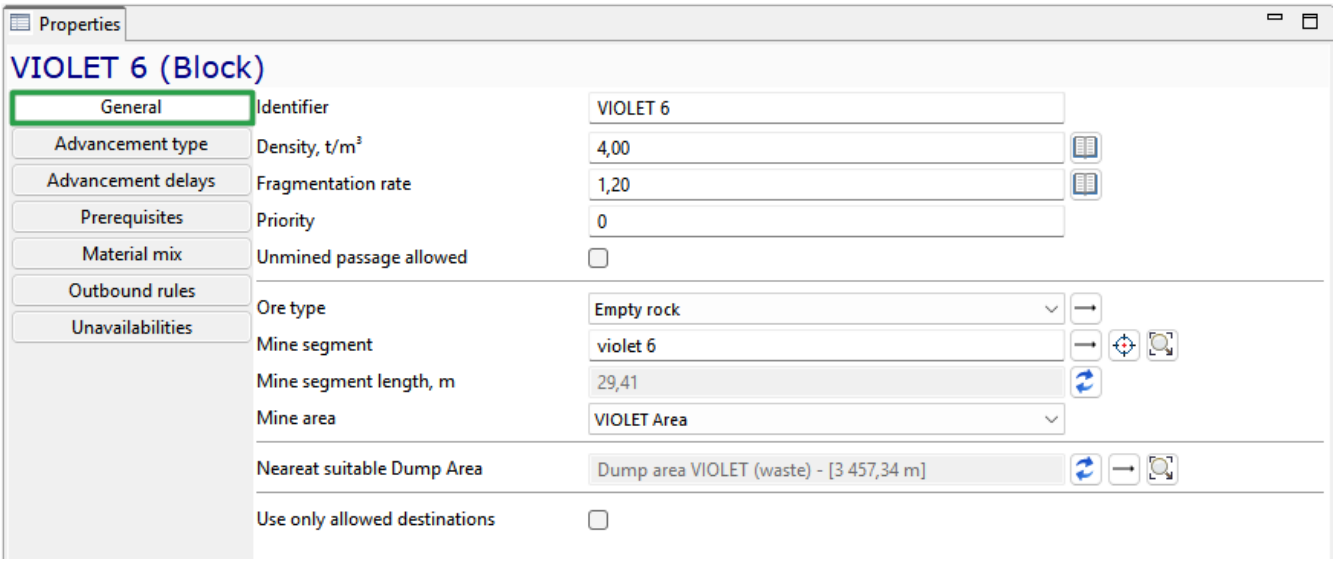
- Unique **identifier** and **name**
- One of two logic **Material types**: substance or empty rock.

Materials are used to calculate ore quality in a block — that is, the grades of the various valuable minerals it contains.

1.7.3. Block

The block is a part of the bench planned for development. The bench is a part of the open mine wall in the form of a step. In MineTwin OpenPit terms, a block is where the equipment performs operations. On the mine plan, the block corresponds to the mine segment. Block properties are set on several tabs:

General tab



Here you set the following main parameters:

- Unique **identifier** and **name**
- **Density, t/m^3** - ore mass per unit volume minus the volume of pores, voids and cracks, in t/m^3
- **Fragmentation rate** - the increase in the volume of ore mass during destruction
- **Priority** - priority of the block
- **Unmined passage allowed** - a parameter indicating whether passage through the block is available before and during its mining
- **Ore type** - one of the possible types of ore in the scenario
- **Mine segment** - link to the mine segment that corresponds to the block
- **Mine segment length, m** - length of the mining segment corresponding to the block
- **Mine area** - sets mine area for the block
- **Nearest suitable Dump Area** - shows the nearest unloading point with a compatible ore type for hauling ore from the block
- **Use only allowed destinations** - when this option is enabled, ore from the block will be hauled only to the dump locations specified on the **Allowed destinations** tab, in the order defined there.

Advancement type

For each block, you must define parameters that describe a and set the block's initial state at the start of planning.

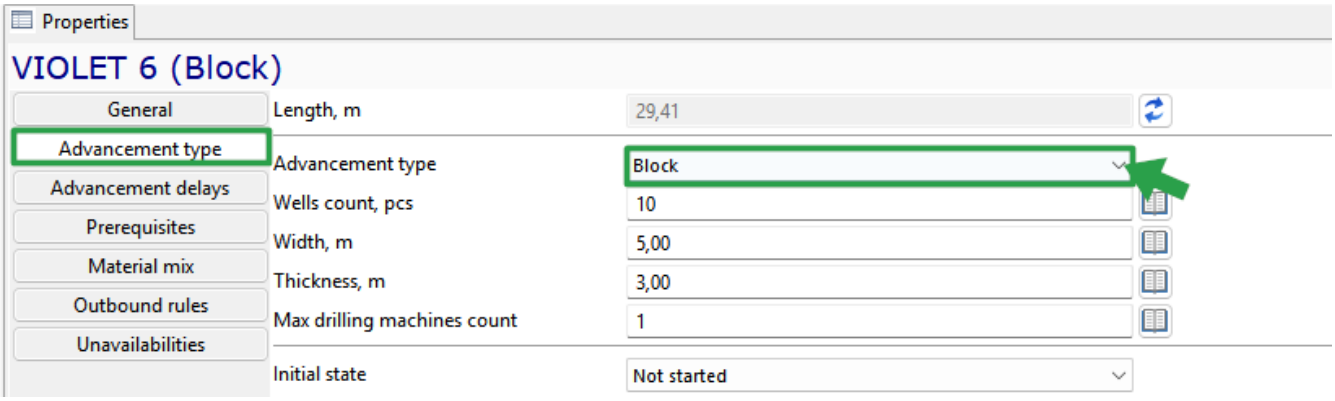
The **Advancement type** tab provides parameter sets for four methods:

- **Block** — a method involving sequential operations of drilling vertical holes, charging, and loading out the entire block's ore in a single cycle.
- **Front** - front advancement of the block with horizontal drilling
- **Top surface** - block advancement with vertical drilling, charging, and loading out the extraction

block in sections of a specified length.

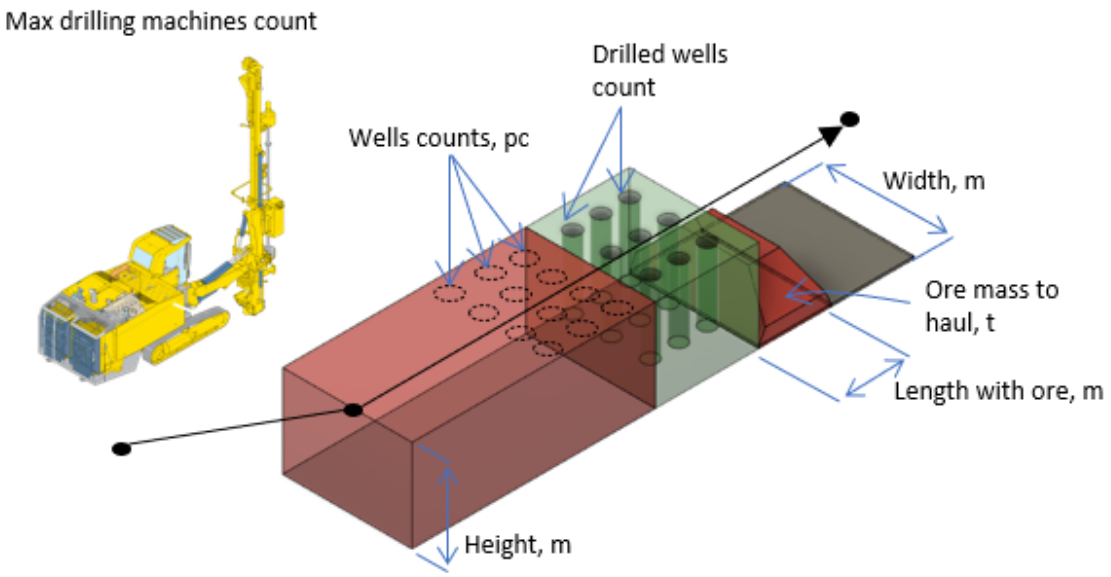
- **Dozing** - moving ore mass with dozers.

Block

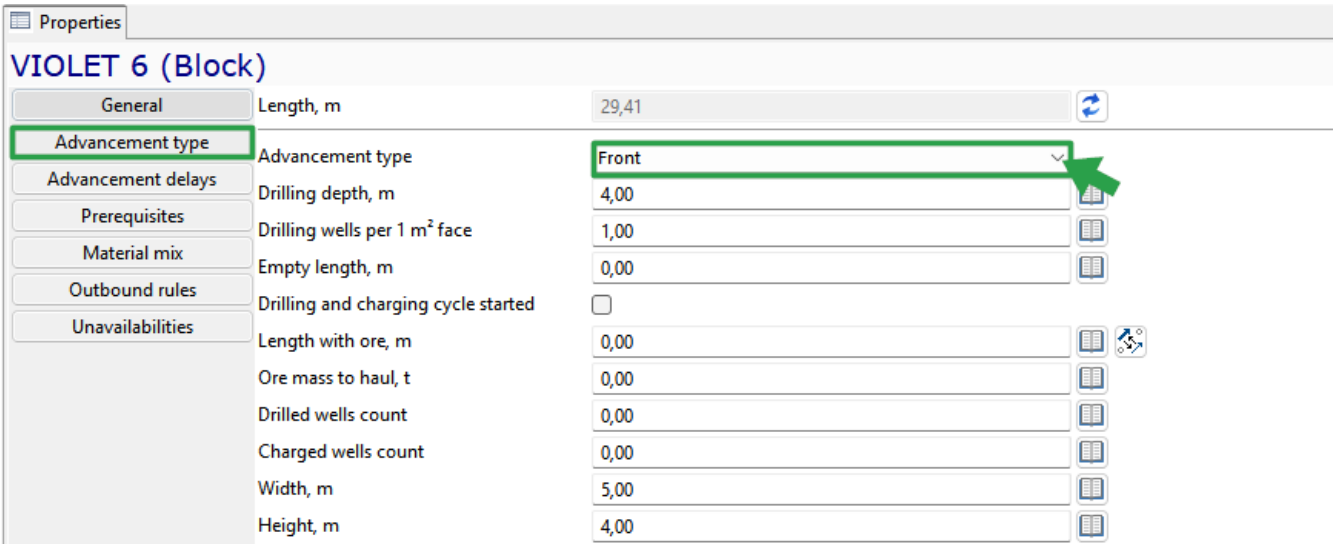


When using the **Block** advancement type, specify the following parameters for the block:

- **Wells count** for the entire block
- **Width, m**
- **Height,m**
- **Thickness, m**
- **Max drilling machines count** - number of drill rigs, that can operate in the block simultaneously
- **Initial state**:
  - **Not started** — the block has not been worked yet
  - **Drilling** — drilling has already begun; additionally specify the number of holes already drilled
  - **Drilling completed** — the block is awaiting charging of the drilled holes
  - **Haulage** — ore haulage is in progress; additionally specify the amount of ore to be hauled and the length of the block over which this ore is located



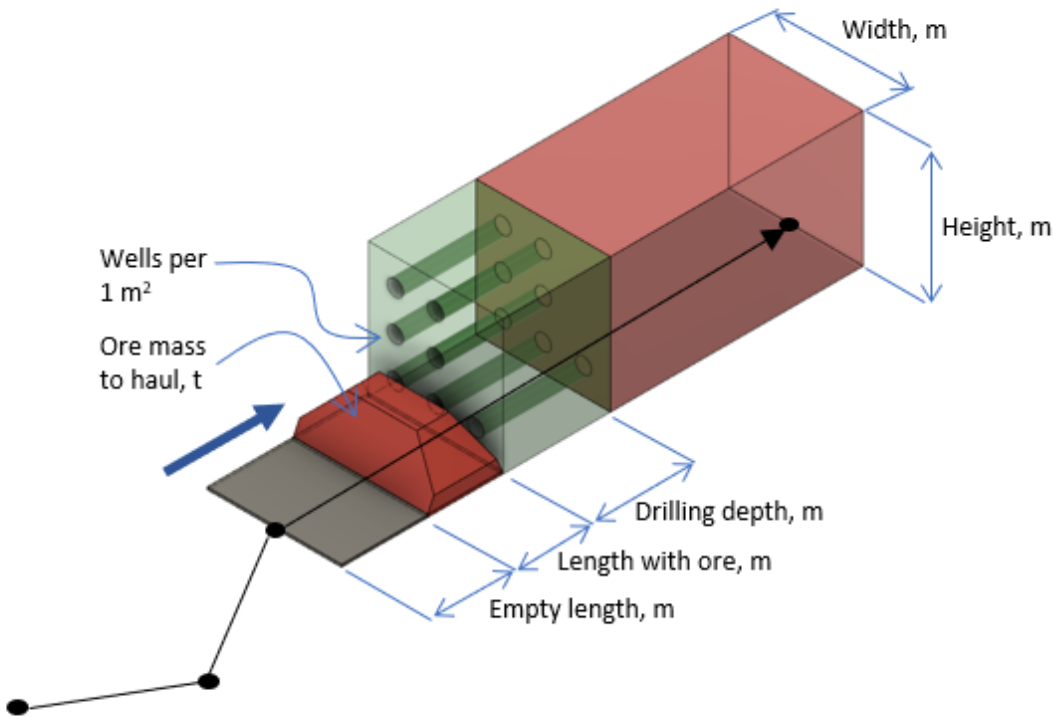
Front



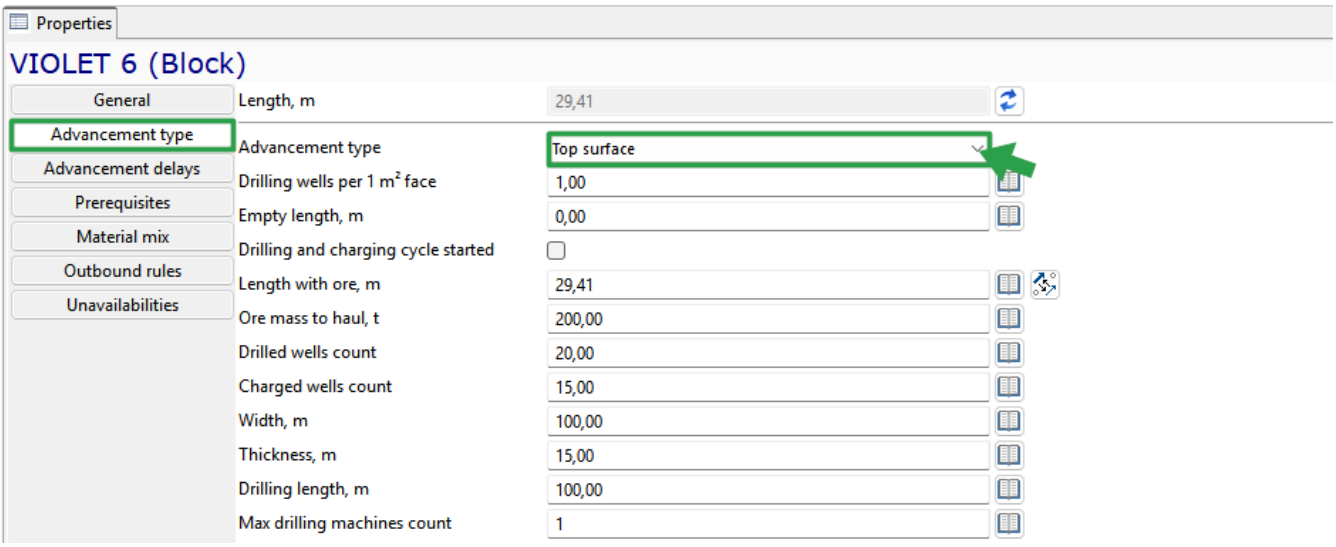
With the **Front** advancement type, the following parameters must be set for the block:

- **Drilling depth, m**
- **Drilling wells per 1 m2 face**
- **Empty length, m** - The length of the block part where drilling, breaking and transportation of ore mass 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 block
- **Length with ore, m** - The length of the block part where drilling, charging and breaking of the ore mass are completed and the haulage of the ore mass is required
- **Ore mass to haul, t**
- **Drilled wells count**
- **Charged wells count**

- **Width, m**
- **Height, m**



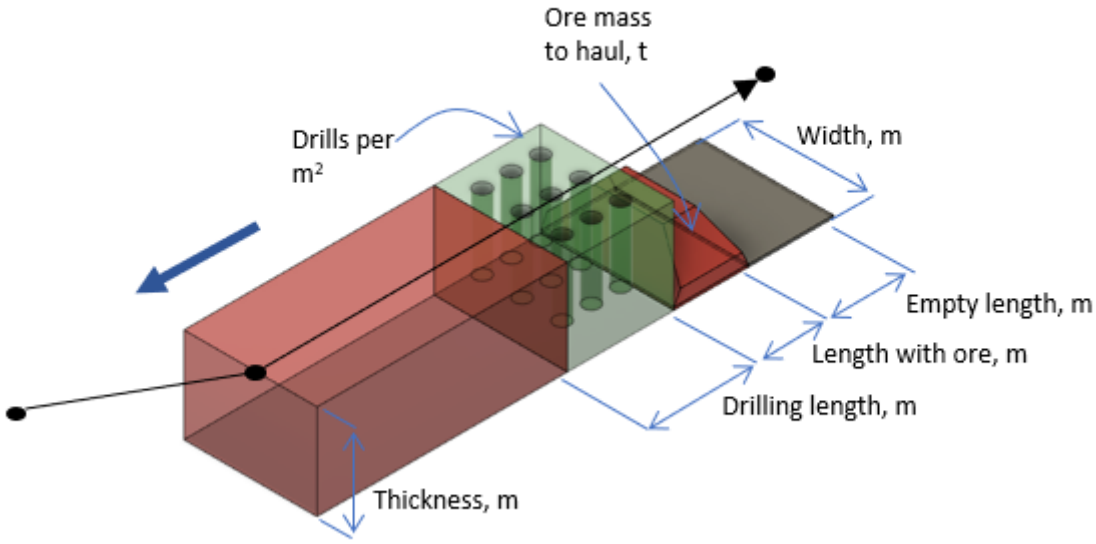
Top surface



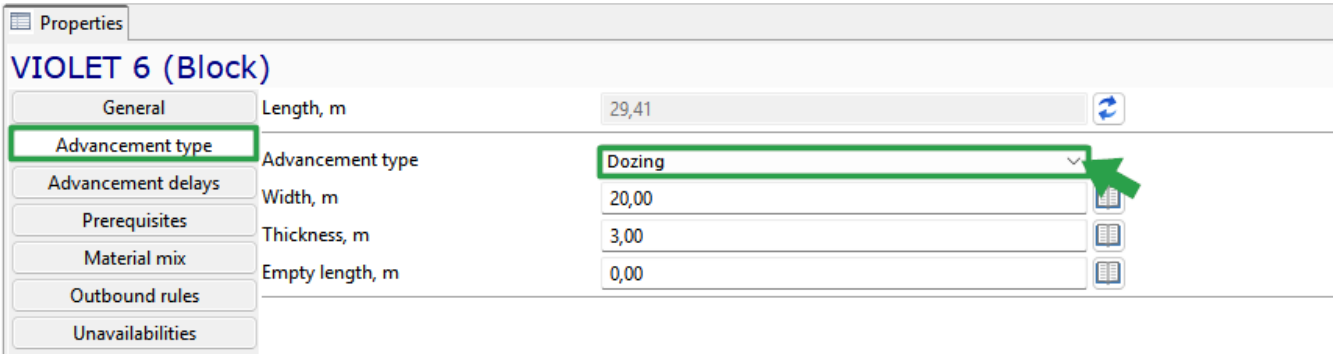
With the **Top surface** advancement type, the following parameters must be set for the block:

- **Drilling wells per m^2 face**
- **Empty length, m** - the length of the block part where drilling, breaking and transportation of ore mass 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 block

- **Length with ore, m** - the length of the block part where drilling, charging and breaking of the ore mass are completed and the haulage of the ore mass is required
- **Ore mass to haul, t.**
- **Drilled wells count**
- **Charged wells count**
- **Width, m**
- **Thickness, m**
- **Drilling length, m.**
- **Max drilling machines count** - number of drill rigs, that can operate in the block simultaneously

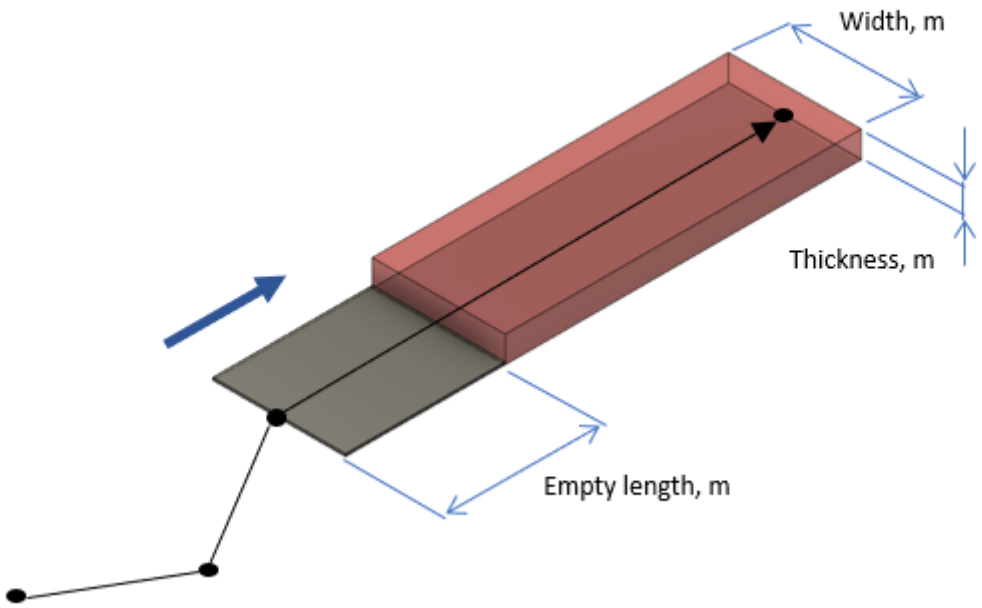


Dozing



With the **Dozing** advancement type, the following parameters must be set for the block:

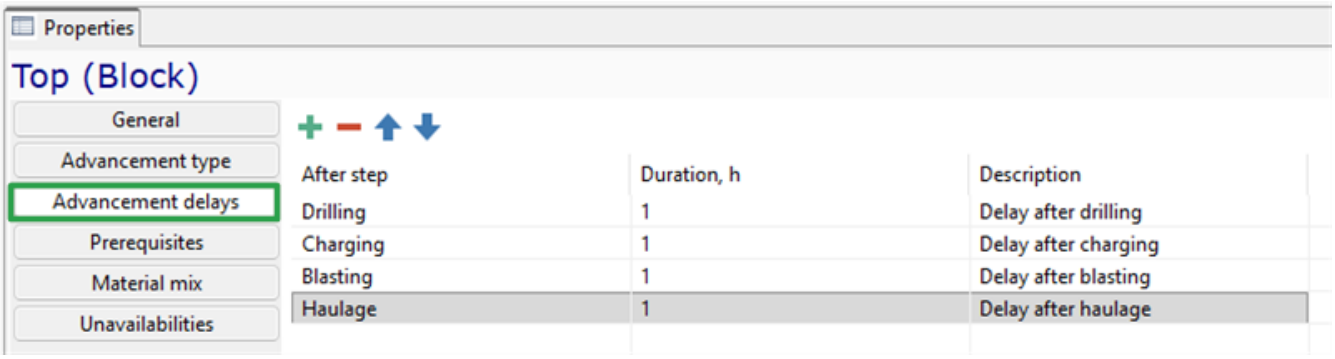
- **Width, m**
- **Thickness, m**
- **Empty length, m** - the length of the block part where dozing is already completed

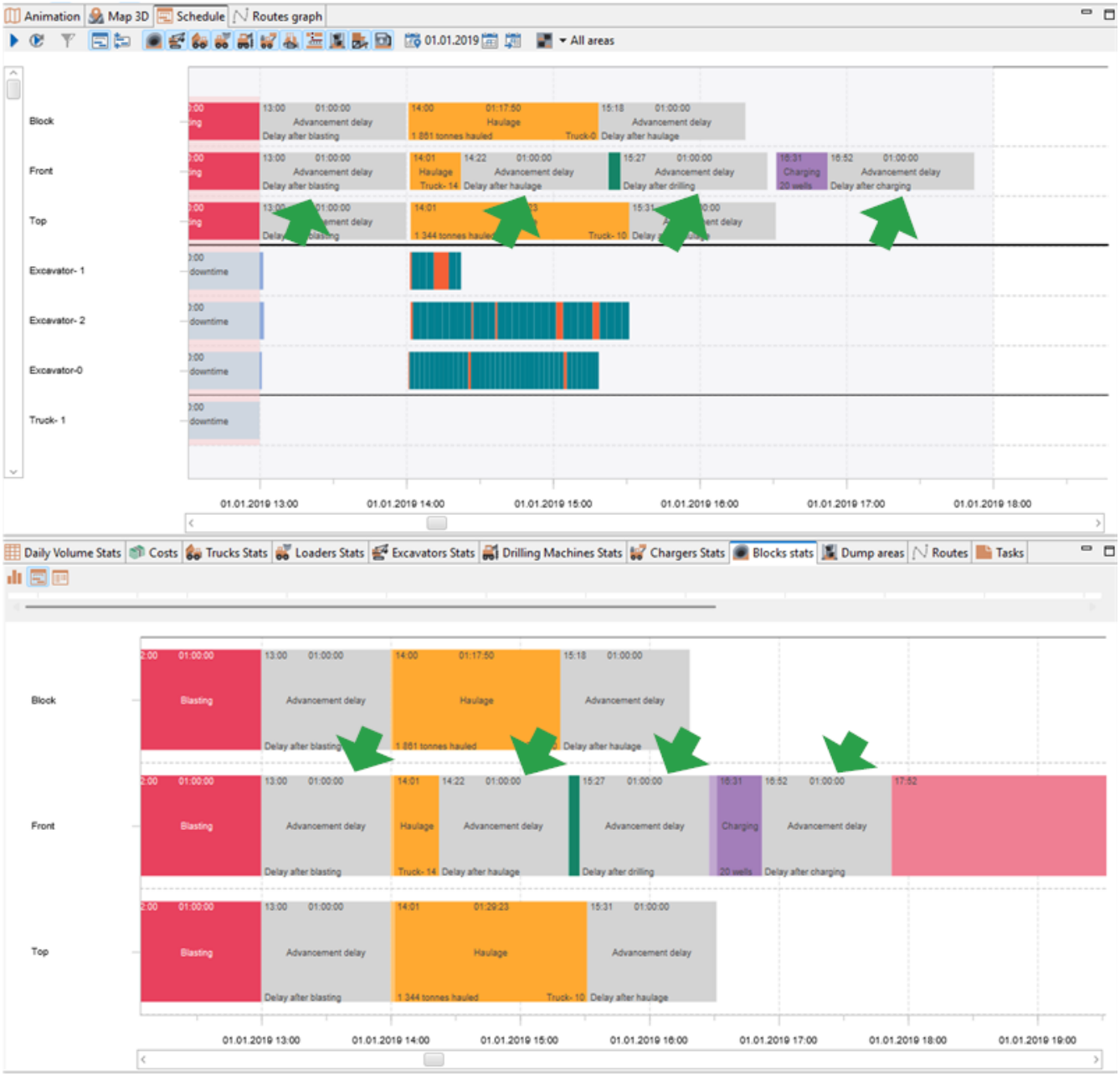


Advancement delays

In the block properties on the **Advancement delays** tab, you can set delays after each stage of block advancement. This feature is designed for modeling technological pauses before the start of the next stage of work.

To create a waiting period, click the + button, then in the row select the advancement step after which the delay will be added, specify its duration in hours, and add a description that will be displayed on the Gantt chart.

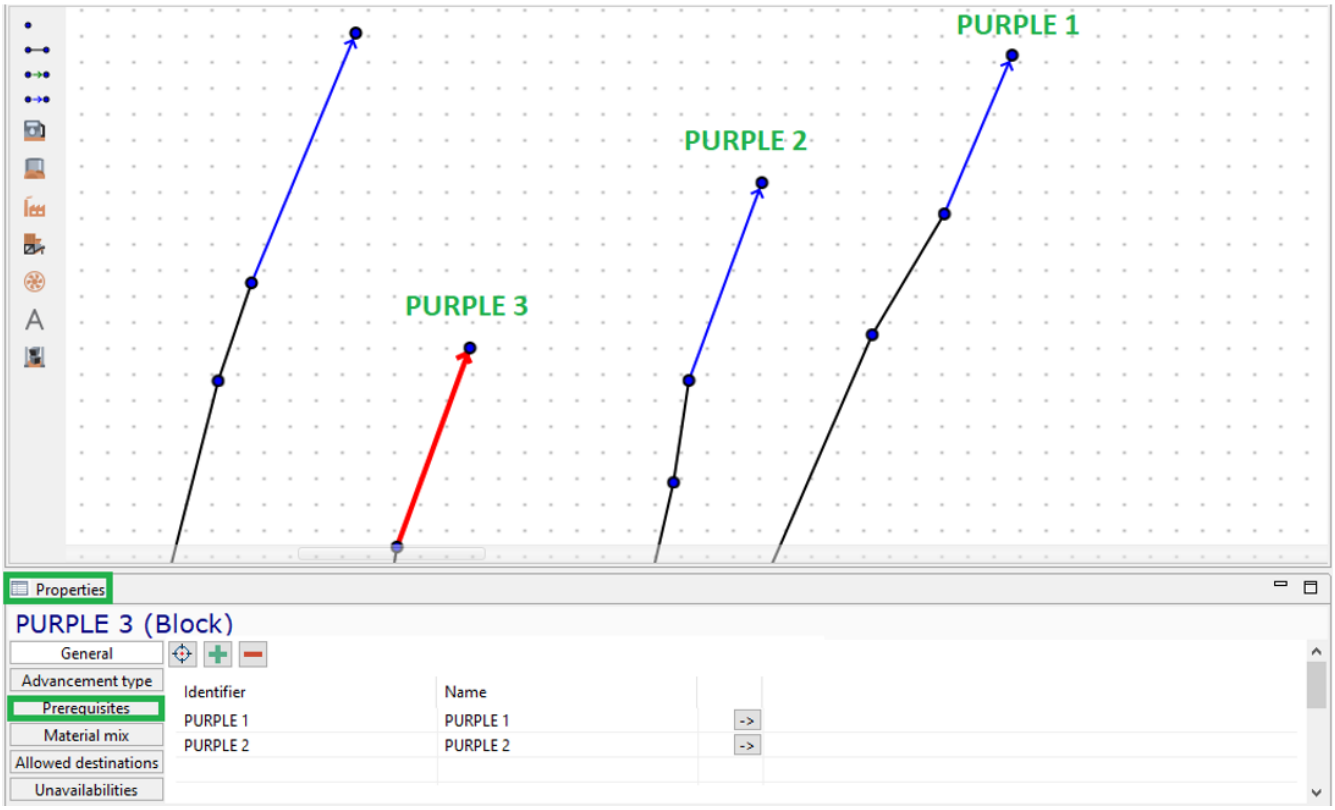




Prerequisites

MineTwin OpenPit allows you to set prerequisites between blocks:

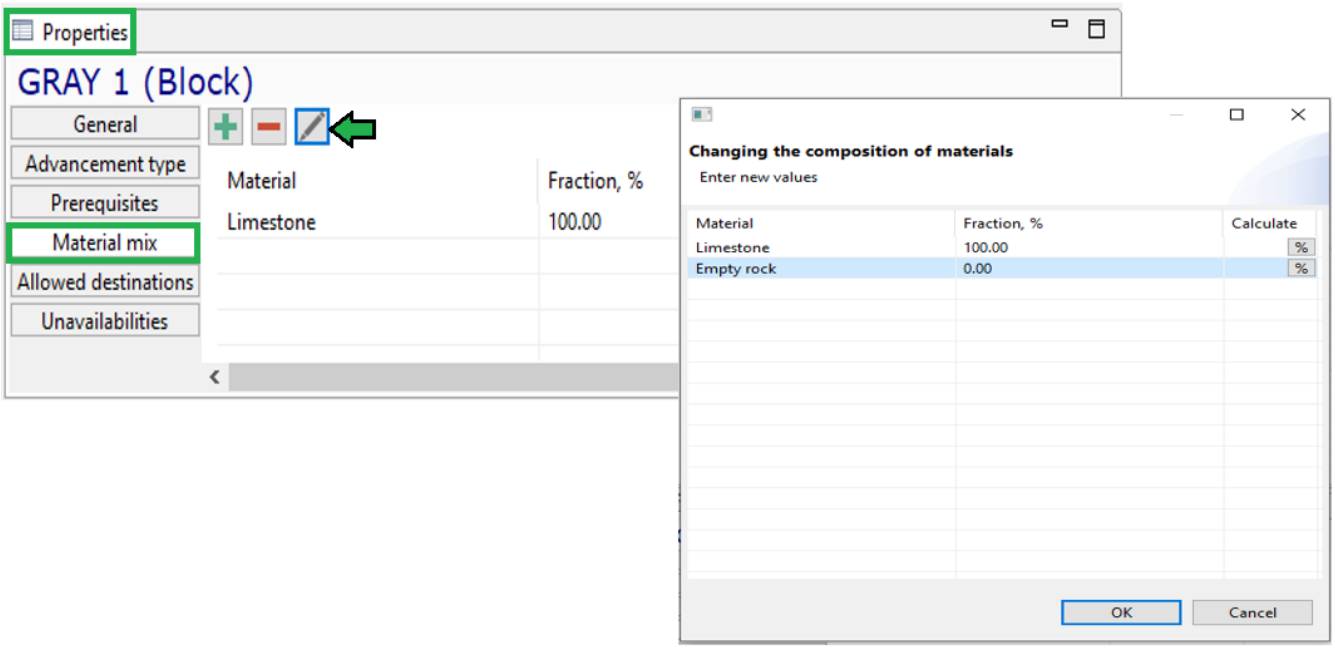
- prohibit drilling the block until the blocks connected to it have been blasted
- prohibit charging and blasting the block until the blocks connected to it have been completely advanced.



In the figure above, drilling in Purple 3 begins only after blasting in Purple 1 and 2 is completed, and charging in Purple 3 begins only after haulage of ore from Purple 1 and 2 is finished. The button allows you to select related blocks on the map, and the button allows you to add related blocks from the list. The button removes related blocks from the list.

Material mix

The **Material mix** tab is mandatory and must be filled in.



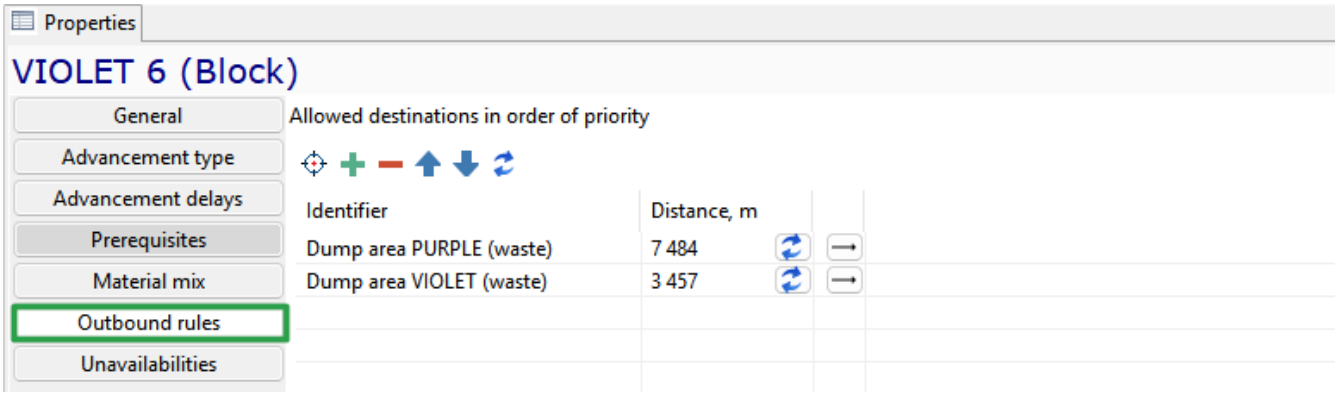
The buttons allow you to add/remove material to block properties.

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

For each material, its proportion in the mix of the ore mass must be specified (from 0 to 100%). The total fraction of the material mix should be equal to 100%. When editing the material composition in a separate window, clicking the **%** button will automatically calculate the value for the selected material that brings the total content of all materials to 100%.

Outbound rules

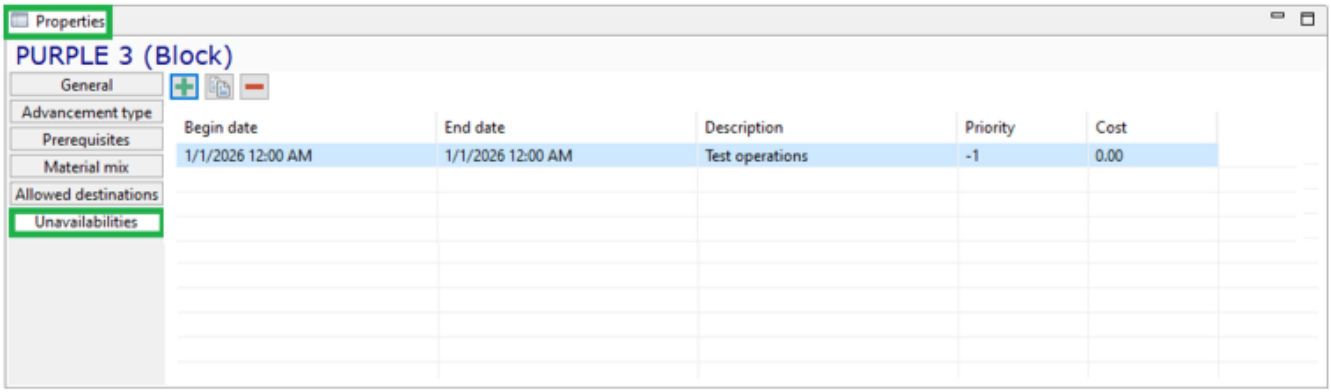
The **Outbound rules** tab contains the list of dump locations for ore from the block. If haulage should be routed by ore type to the nearest suitable dump location, you do not need to fill out this table.



The button  allows you to select dump locations from the map, and the button  allows you to add dump locations from the list. The button  removes dump locations from the table. The arrow buttons allow to change the relative order of locations. The locations will always be used in specified order.

Unavailabilities

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

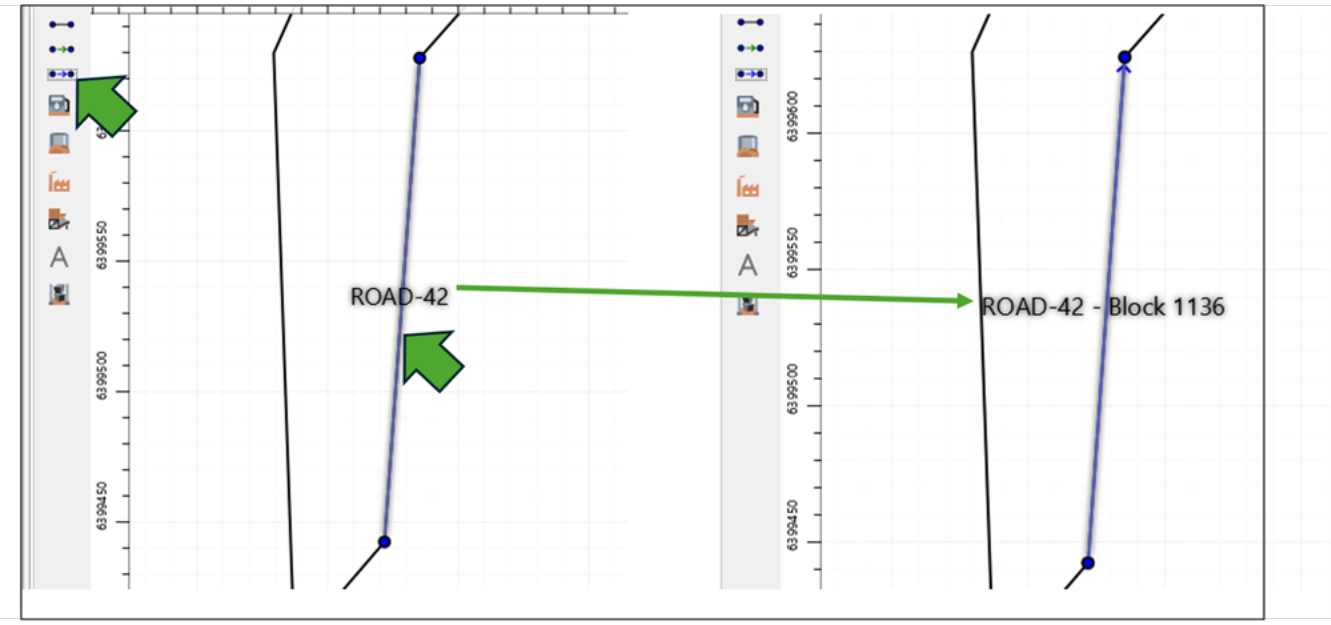


The buttons  allow you to add/remove block periods of unavailability. Note that unavailabilities can be scheduled based on priority, and the cost associated with them can be specified.

Creating a Block

You can add a block to the scenario in two ways:

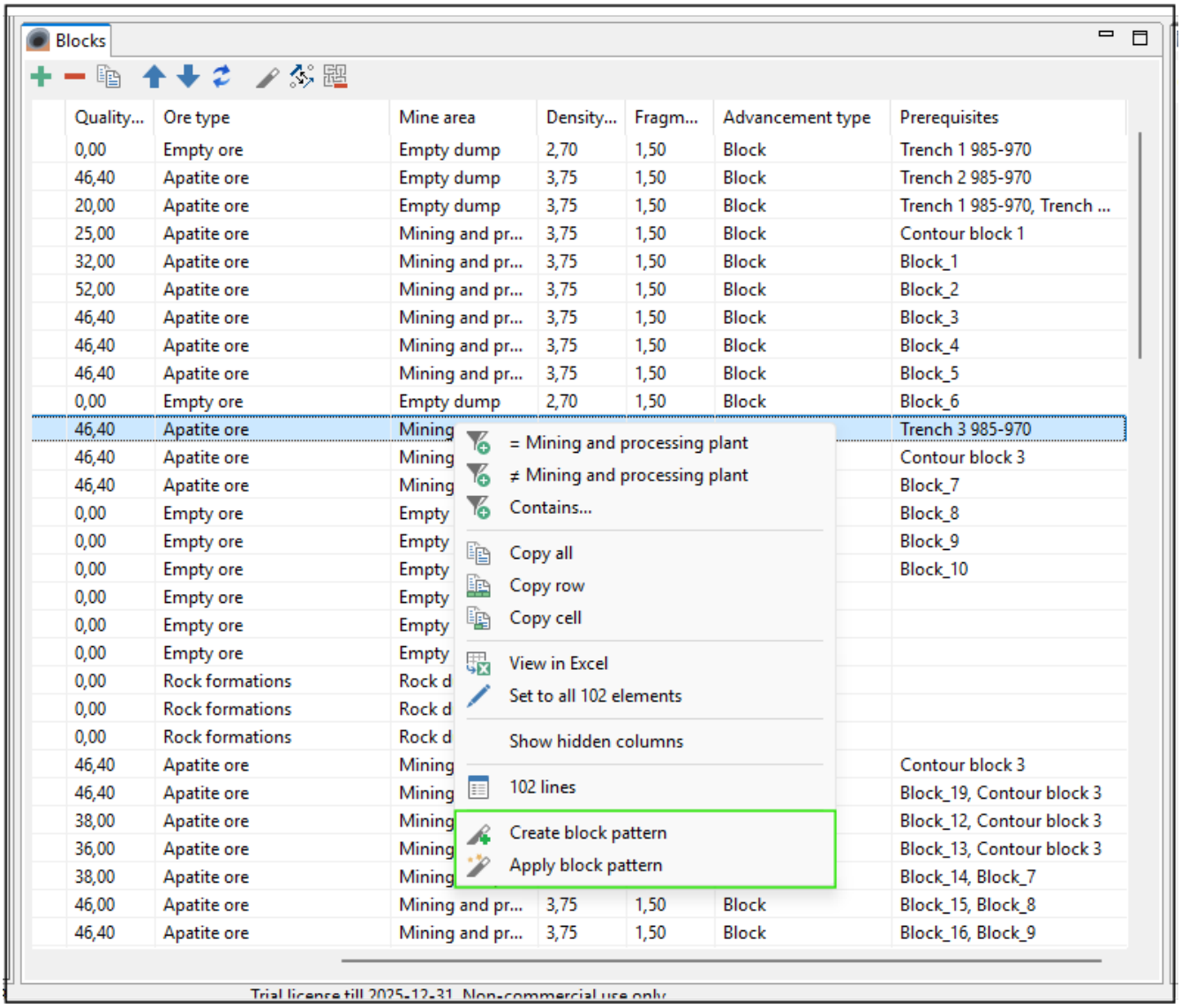
- By clicking the button in the Blocks list.
- By using the **Block** button on the 2D map left toolbar — when add mode is enabled, click a mine arc.



In both cases, a new row with a unique identifier and name will appear in the Blocks list.

If you need to assign the same properties to multiple blocks, you can set the properties for a single block, then copy its pattern and apply it to other blocks.

To create a block pattern (so you can copy its characteristics and transfer them to other blocks), use the button on the **Blocks** list toolbar. You can also choose **Create block pattern** from the context menu, and then apply the pattern's properties to any other block in the list by clicking the target block's row and selecting **Apply block pattern**.

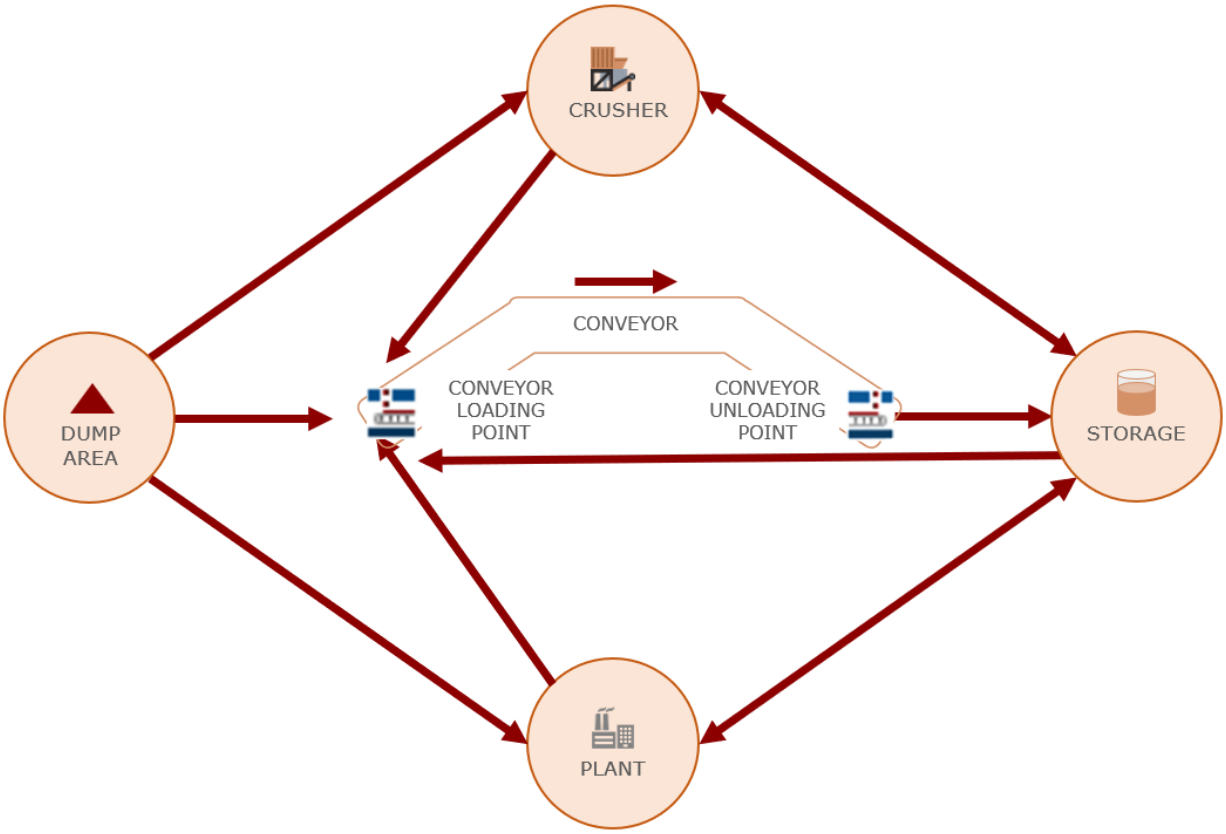


The  button sets, for all blocks in the Haulage state, the length of the block over which the ore is located to be equal to the entire block length.

The  button deletes all dependency records in the block properties.

1.8. Material flow

MineTwin OpenPit allows you to simulate the movement and processing of ore mass after its excavation from blocks. 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 dump areas or the storages to crushers, processing plants and conveyors, and then goes back to the storages for further processing or storage.

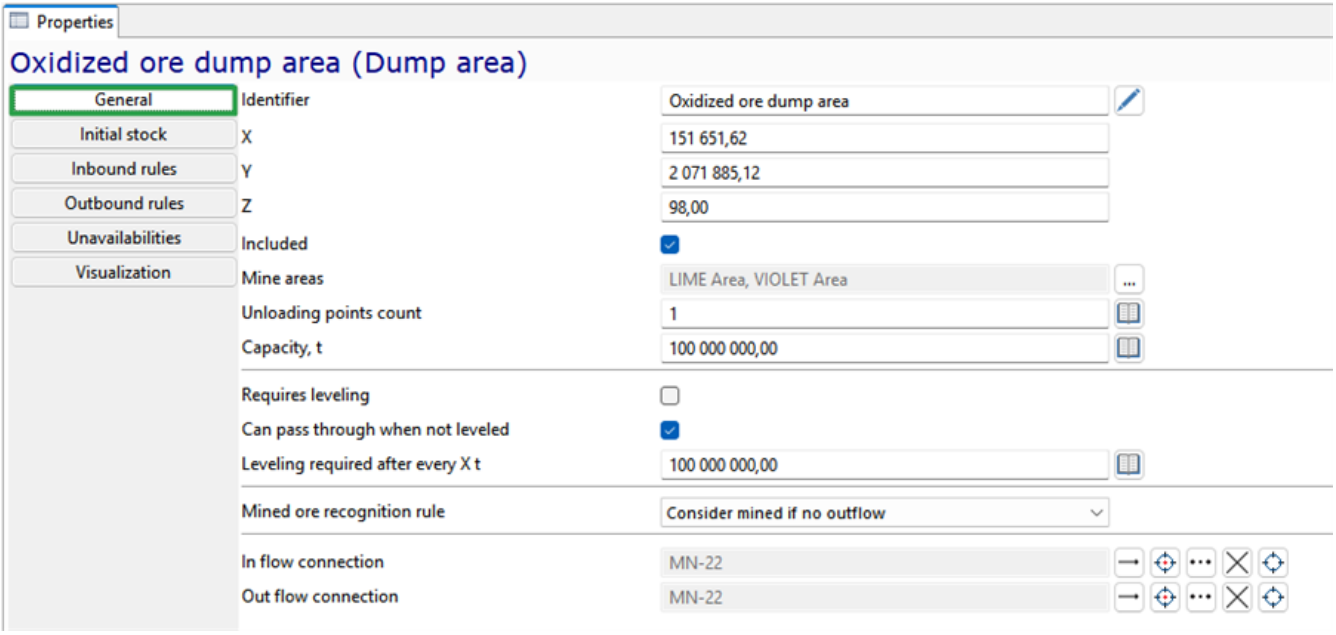
Elements of the system of transportation and processing ore mass are combined into a block of the model tree "Material flow":

- Dump areas
- Storages
- Crushers
- Conveyors
- Processing plants.

1.8.1. Dump area

Dump area - a location of the ore mass (empty (overburden) rocks and useful minerals) on the surface.

General tab



The dump area is characterized by the following main parameters:

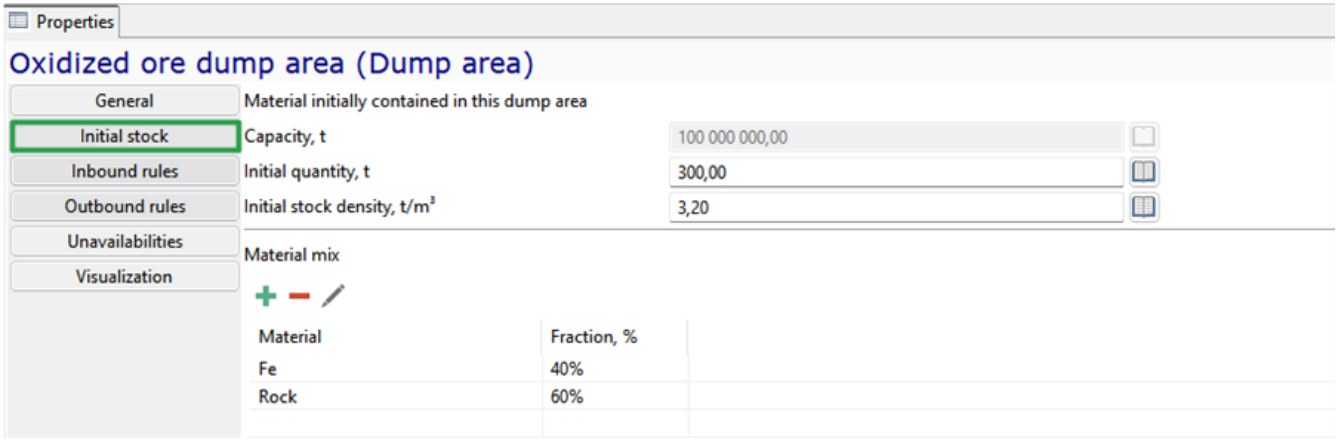
- Unique **identifier**
- **X-**, **Y-** and **Z-coordinates**
- **Included** - when checked, indicates that this dump area will be used in simulation
- **Mine areas** - optional parameter. If specified, then:
  - Only ore mass from blocks with the same area will be hauled to this dump location
  - During bulldozer leveling/formation of the dump at this location, only dozers assigned to this area will be used
- **Unloading points count** is a parameter that indicates the number of simultaneously unloaded vehicles
- **Capacity, t** of the dump area
- **Requires leveling** - if checked, then leveling is scheduled when leveling threshold is met
- **Can pass through when not leveled** - when checked, then movement through the dump area is not restricted while leveling
- **Leveling required after every X t** - the amount of ore mass in tons, at which stockpile/dump formation by dozers is required.
- **Mined ore recognition rule** — a rule that defines when material should be counted as mined for statistics:
  - **Consider mined if no outflow** — ore mass delivered to this dump area is counted as mined only if the dump area is a terminal storage point, i.e., it has no connection to a conveyor, crusher, etc and is not an intermediate stockpile.
  - **Always consider mined** — any ore mass delivered to this dump area is always counted as mined.
  - **Never consider mined** — ore mass delivered to this dump area is never counted as mined (it should be accounted for at a later stage of the material flow).

- **In flow connector** - link to the mine node of the transportation network from which the ore mass enters the dump area via trucks
- **Out flow connector** - link to the object that has compatible in flow (crusher, processing plant or mine node for conveyor loading point) to receive ore mass from this dump area.

Initial stock

On the **Initial stock** tab the volumes and characteristics of the mining mass stored in the dampf area at the start of simulation are set:

- **Capacity, t**
- **Initial quantity, t** of ore mass at the dump area at the start of scheduling
- **Initial stock density, t/m^3** of ore mass at the dump area at the start of scheduling
- **Material mix** - filling of the storage location with materials in their percentage ratio at the start of planning

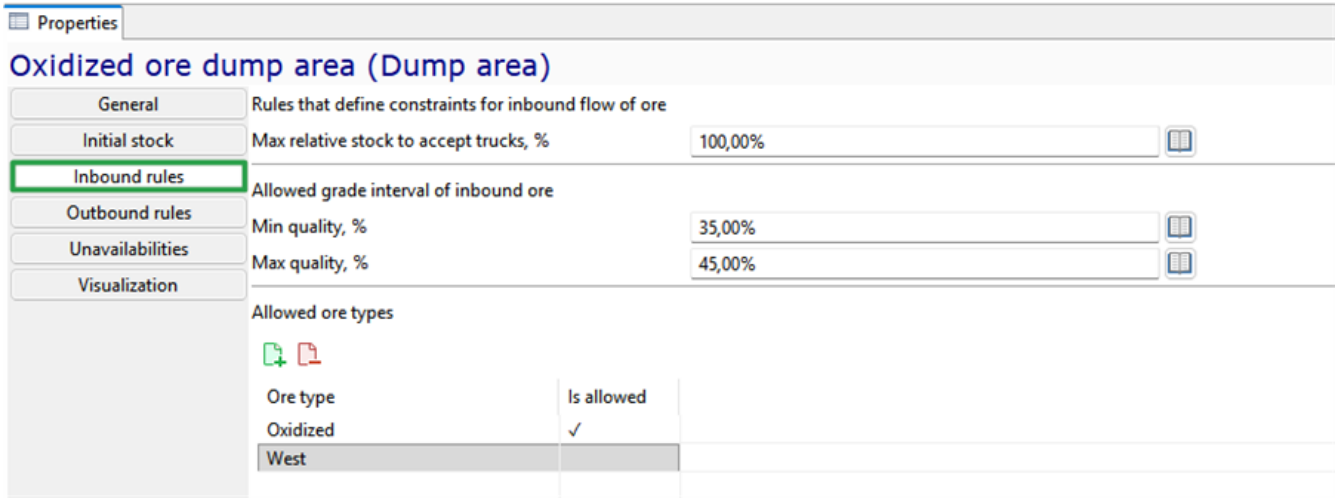


If the dampf area is empty at the start of simulation, the material composition does not need to be filled.

Inbound rules

On the **Inbound rules** tab, restrictions on the incoming flow of mining mass are set:

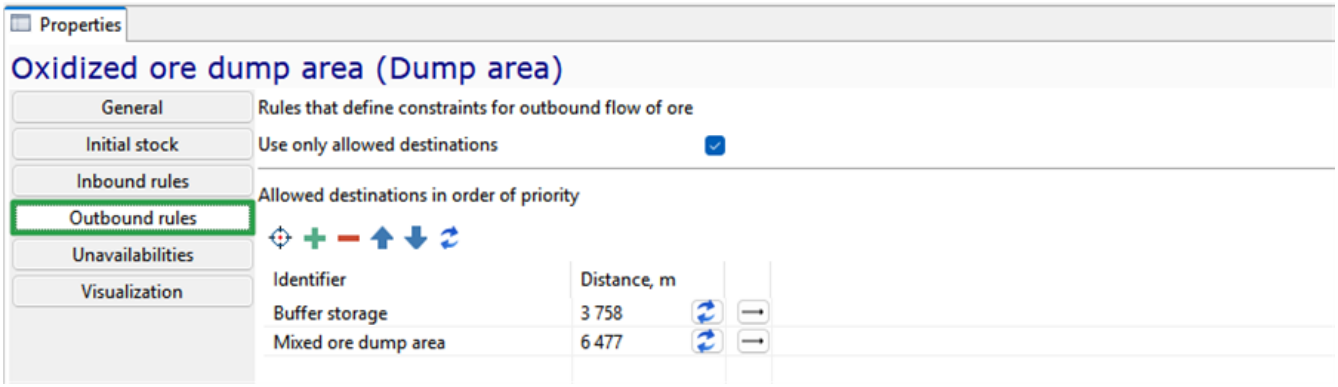
- **Maximum relative stock to accept trucks, %** — the dump area fill level at which trucks stop hauling material to this location and, if alternatives exist, start hauling to alternative dump locations.
- Allowed grade interval of inbound ore:
  - **Minimum quality, %** of ore mass that can be transported to the dump area
  - **Maximum quality, %** of ore mass that can be transported to the dump area
- **Allowed ore types** - in the "In allowed" column, a mark must be placed next to the type of mining mass that the dumpf area can inbound



The buttons are intended for setting/clearing marks opposite the entire list of ore types.

Outbound rules

If the dumpf area is an intermediate storage location, the **Outbound rules** tab specifies subsequent transport destinations for the mining mass from this dumpf area.



The order of the other dump areas on this tab defines the priority of destinations (top is highest priority, bottom is lowest priority).

Using the button you can select objects from the 2D map, button – select from the list, button deletes the row. Buttons allow swapping rows. Button allows navigating to the properties of the selected removal place. Button updates data, including the distance value from the current dampf area to the selected one.

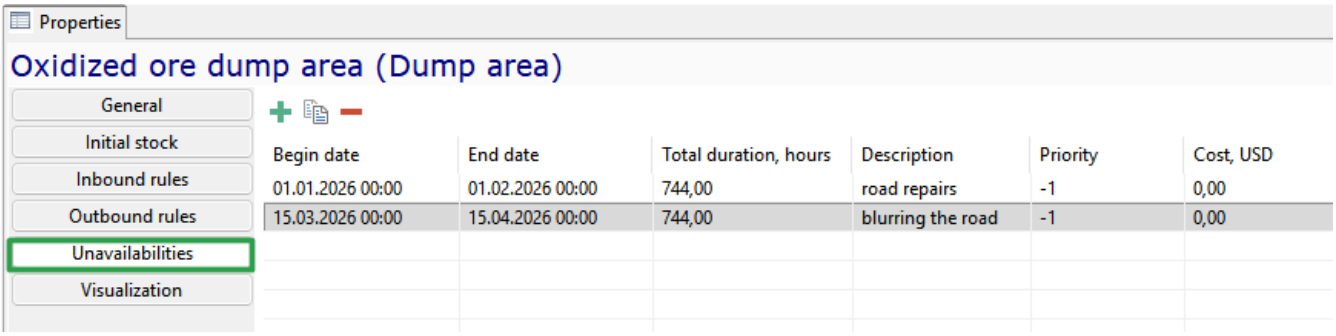
Unavailabilities

Unavailability of the dampf area may be due to any reasons, for example, seasonal access. If there are no such periods in the modeled interval, the tab is not filled; if present, the following data is filled:

- **Begin date** and **End date** of the unavailability period
- **Total duration, hours** - calculated automatically
- **Description** - information is not mandatory to fill
- **Priority** - an integer specifying the order in the hierarchy of unavailabilities for this unloading

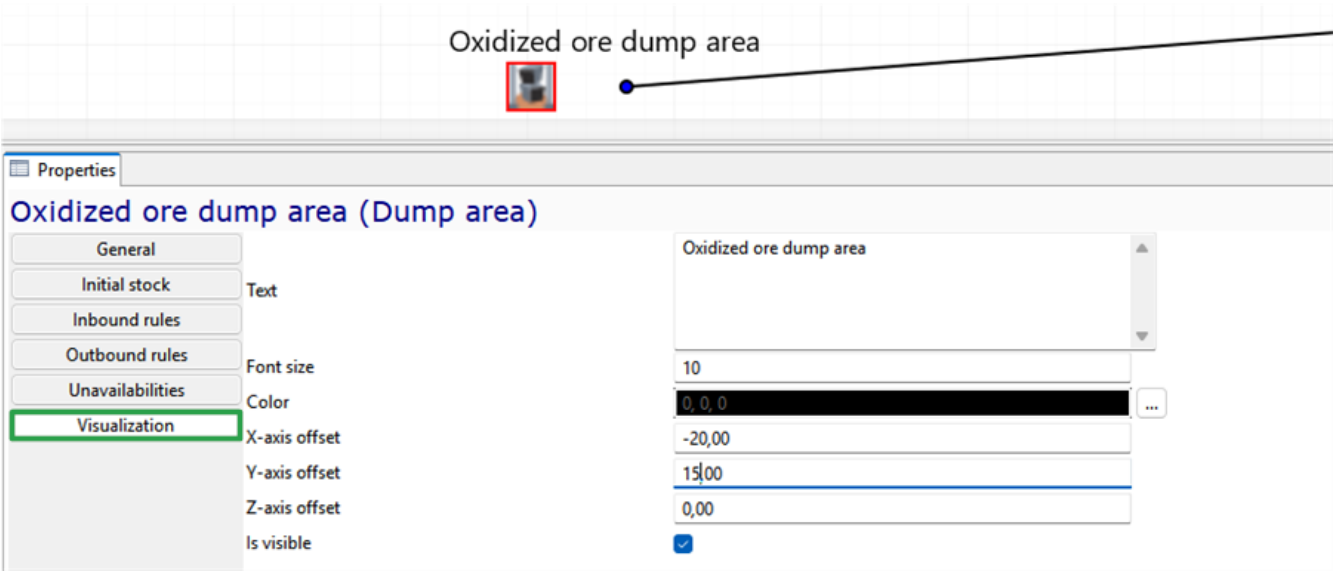
place. The lower the value, the higher the priority

- **Costs, USD** - an optional parameter, filled if costs calculation is present and required



Visualization

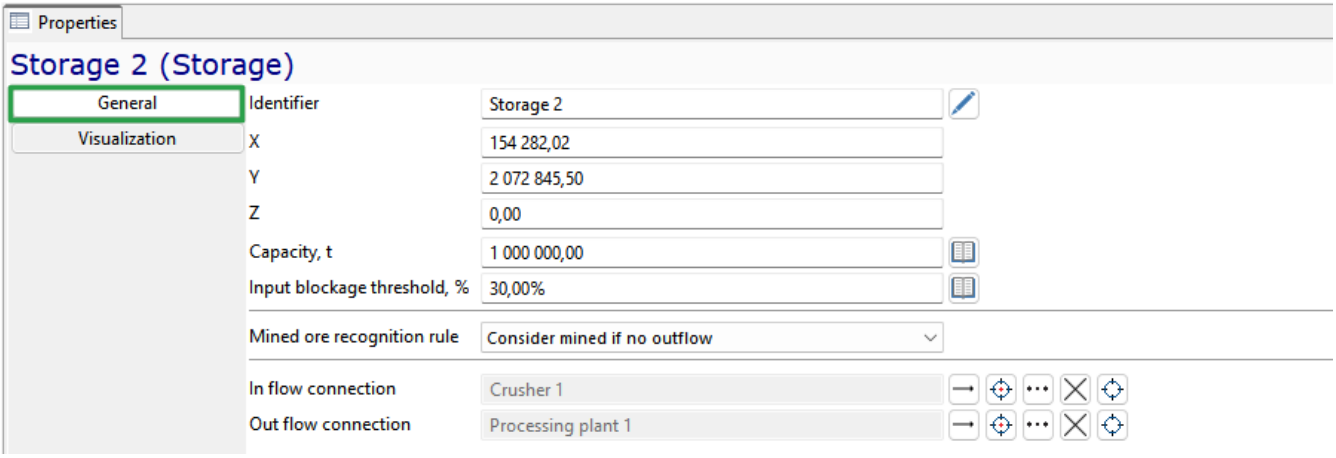
The Visualization tab is intended for creating text labels for the object.



The tab allows setting the font size and color, defining the label position via offsets along the X, Y, and Z axes relative to the object icon on maps, and enabling/disabling visibility on 2D and 3D maps.

1.8.2. Storage

Storage - a place for intermediate storage of ore mass.



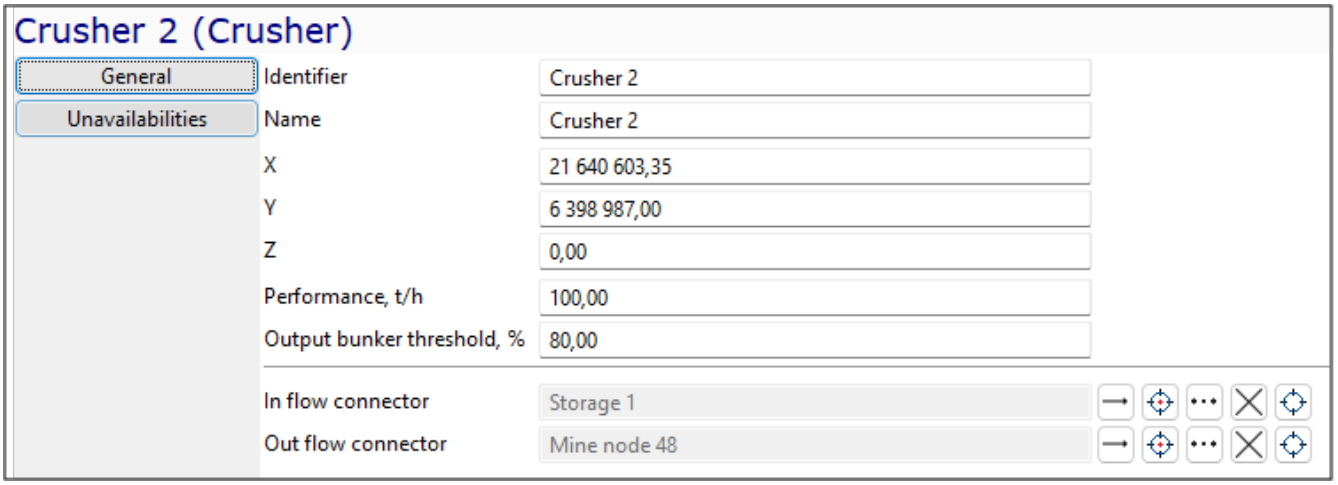
The storage is characterized by the following general properties:

- Unique **identifier**
- **X-**, **Y-** and **Z-coordinates**
- **Capacity, t**
- **Input conveyor blockage threshold, %** - is used to determine when to resume the operation of in-flow conveyor. For example, if a storage is filled to its maximum capacity of 10,000 t, the conveyor feeding ore mass into it stops (is blocked). Ore mass from the storage is then delivered to the crusher. The conveyor will resume operation only when the amount of ore mass in the storage drops to the specified level, e.g., 30% (i.e., when only 3,000 t remain in the storage).
- **Mined ore recognition rule** — a rule that defines when material should be counted as mined for statistics:
  - **Consider mined if no outflow** — ore mass delivered to this dump area is counted as mined only if the dump area is a terminal storage point, i.e., it has no connection to a conveyor, crusher, etc and is not an intermediate stockpile.
  - **Always consider mined** — any ore mass delivered to this dump area is always counted as mined.
  - **Never consider mined** — ore mass delivered to this dump area is never counted as mined (it should be accounted for at a later stage of the material flow).
- **In flow connector** - link to to the object from which the ore mass enters the storage: crusher, processing plant or conveyor unloading point
- **Out flow connector** - link to the object that has compatible in flow (crusher, processing plant or mine node for conveyor loading point) to receive ore mass from this storage.

The Visualization tab is intended for creating text labels for the object.

1.8.3. Crusher

Crusher - Equipment for crushing, mechanical impact on the rock to destroy it.

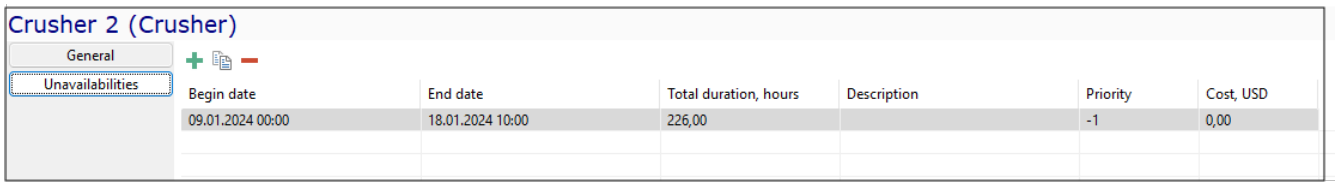


The crusher is characterized by the following main parameters:

- Unique **identifier**

- **X-**, **Y-** and **Z-coordinates**
- **Performance, t/h** - the maximum possible outflow (as well as inflow) from the crusher if always supplied with ore mass
- **Output bunker threshold, %** - is used to determine when to resume the operation of the crusher. For example, if an output storage is filled to its maximum capacity of 10,000 t, the crusher will stop (is blocked). The crusher will resume operation only when the amount of ore mass in the output storage drops to the specified level, e.g., 30% (i.e., when only 3,000 t remain in the storage).
- **In flow connector** - link to to the object from which the ore mass enters the crusher: storage or dump area
- **Out flow connector** - link to the object that has compatible in flow (storage or conveyor loading point) to receive ore mass from this crusher.

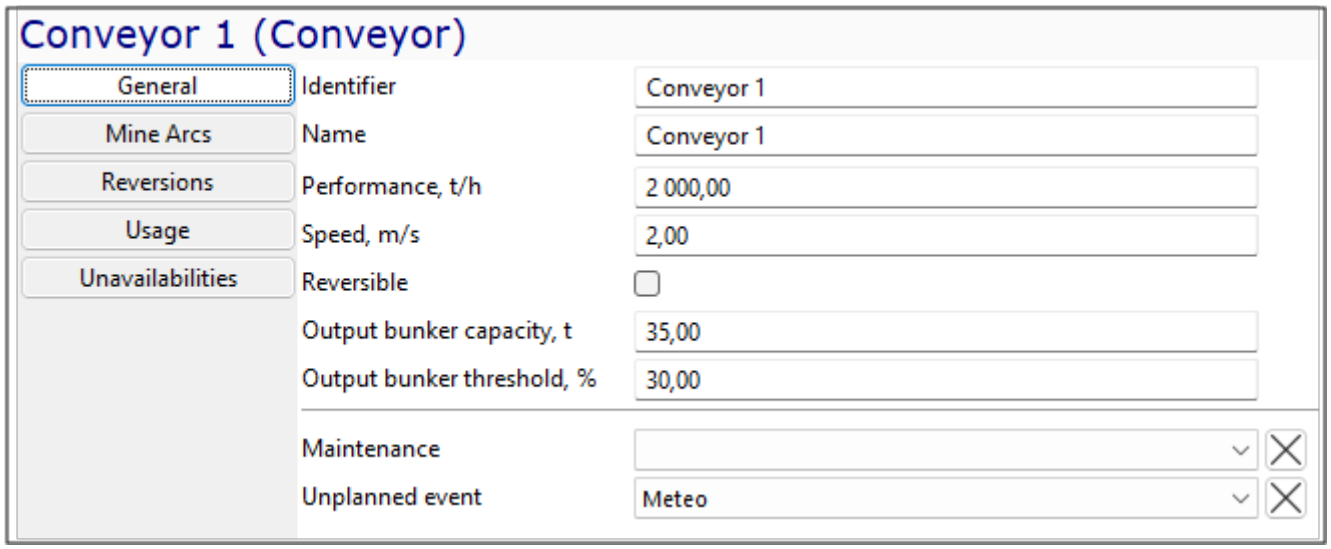
You can set periods of unavailability for the crusher.



The buttons  allow you to add, copy or remove crusher unavailabilities.

1.8.4. Conveyor

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

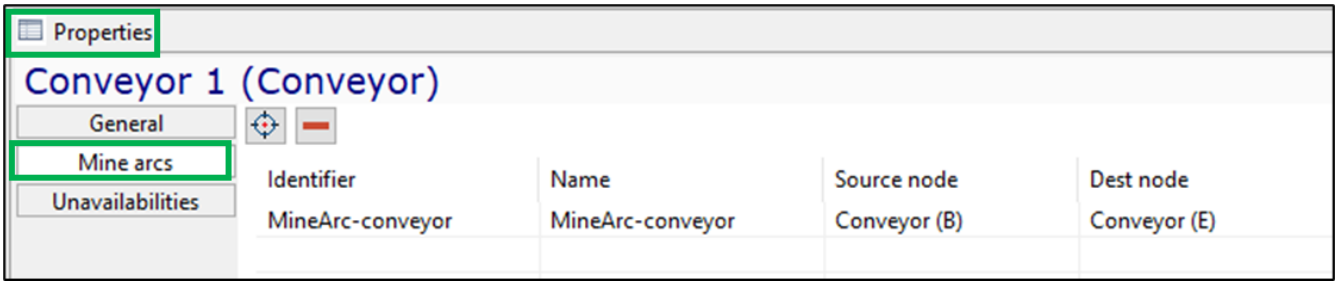


The conveyor is characterized by the following main parameters:

- Unique **identifier**
- **Performance, t/h** of ore mass transportation
- **Speed, m/s** - conveyor belt speed, m/sec

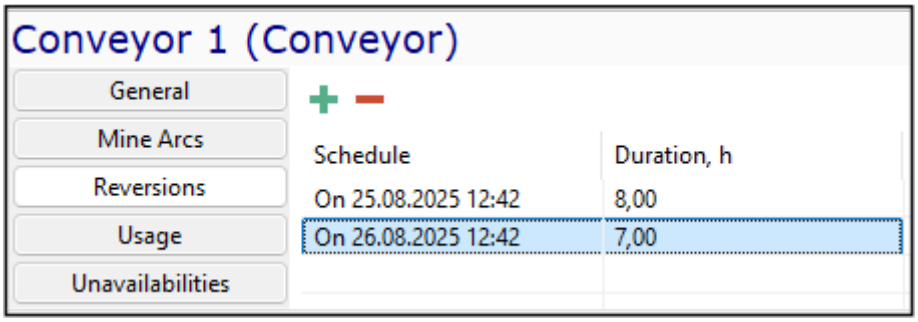
- **Reversible** - if checked, allows conveyor to work in the reverse direction during time periods, specified on the **Reversions** tab
- **Output bunker capacity, t** and **Output bunker threshold, %** - A technical parameters used to prevent the simulation from stopping with an error. In reality, conveyor overflow is an emergency situation. In the simulation, excess material is sent to an internal virtual buffer, and once it fills up to the specified value, the conveyor stops (is blocked). This may occur if material is fed onto one conveyor from multiple conveyors, or if a downstream conveyor stops due to a break or failure. When the capacity of this internal virtual buffer will go below specified threshold, if the conveyor was blocked, it will resume its operation.

In the **Mine arcs** tab, you can set the list of mine arcs of the conveyor type that make up the given conveyor. One conveyor can consist of several arcs.



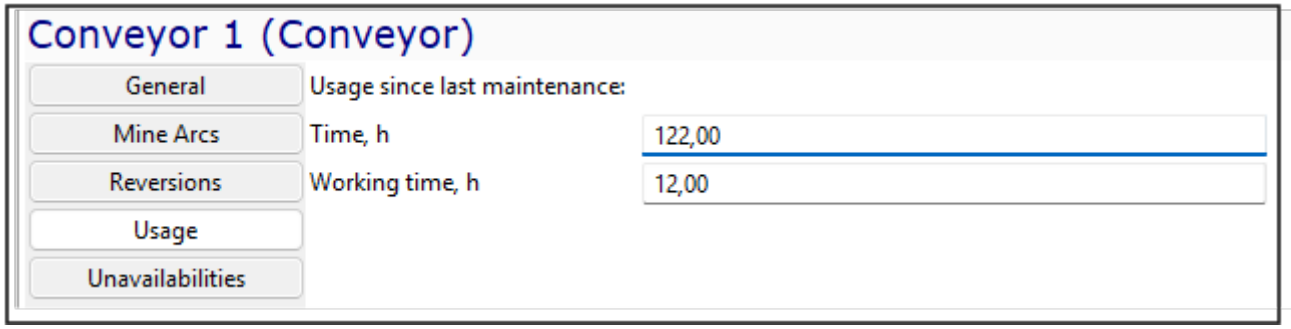
Mine arcs are added by selecting them on the map using the button  and removed from the conveyor using the button  .

On the **Reversions** tab, you can set the time periods during which the conveyor operates in reverse mode (opposite direction).

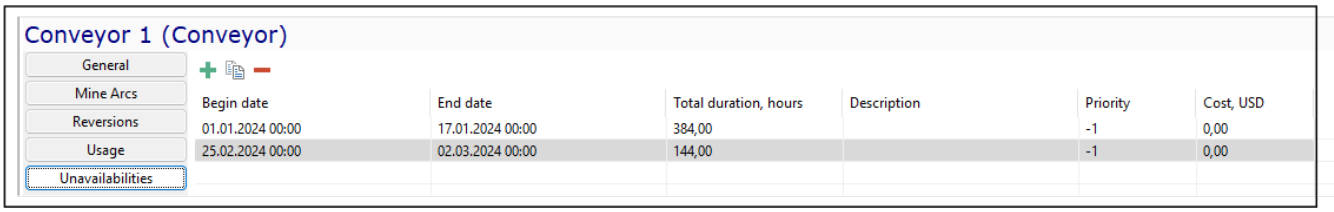


On the **Usage** tab, you can set the initial state of parameters related to conveyor maintenance based on operating hours since last maintenance:

- **Time,h** — the total elapsed time since last maintenance.
- **Working time, h** - total operating time of the conveyor since last maintenance.



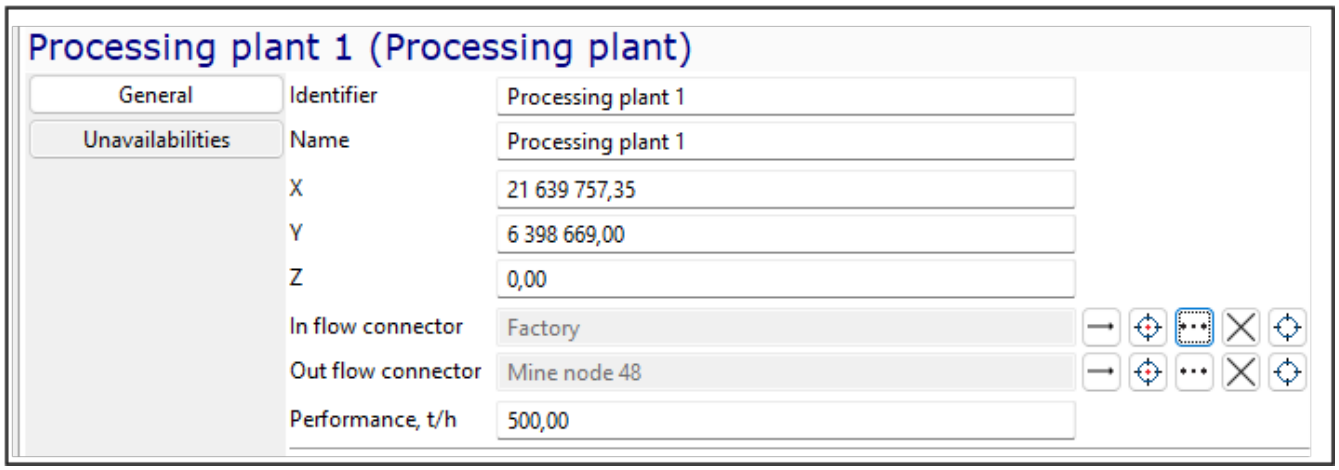
You can set periods of unavailability for the conveyor on the tab **Unavailabilities**.



The buttons  allow you to add, copy or remove conveyor unavailabilities.

1.8.5. Processing plant

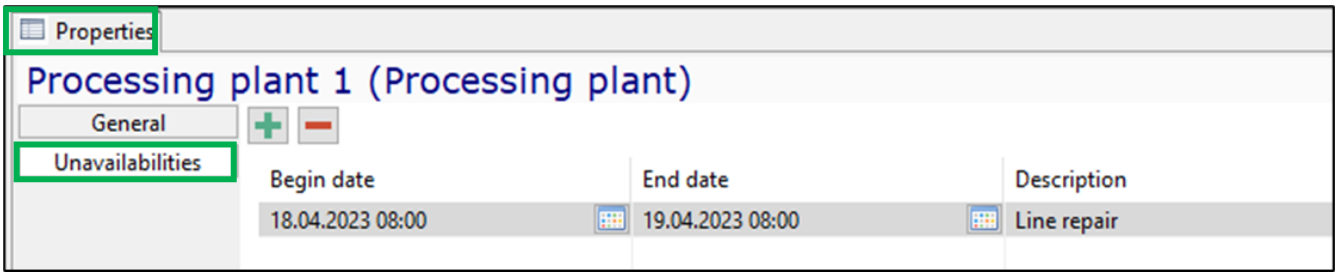
Processing plant - A mining enterprise for the primary processing of ore mass to obtain technically valuable products suitable for industrial use.



The processing plant is characterized by the following main parameters:

- Unique **identifier**
- **X-**, **Y-** and **Z-coordinates**
- **In flow connector** - link to the object from which the ore mass enters the processing plant: storage or dump area
- **Out flow connector** - link to the object to which the ore mass enters from the processing plant: storage or conveyor loading p[oint
- **Performance** in tons per hour

You can set periods of unavailability for the processing plant.



The buttons  allow you to add, copy or remove processing plant unavailabilities.

1.9. Parameters of mobile equipment

Mobile equipment in MineTwin OpenPit 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
- Excavator types
- Drilling machine types
- Loader types
- Charger types
- Dozer types.

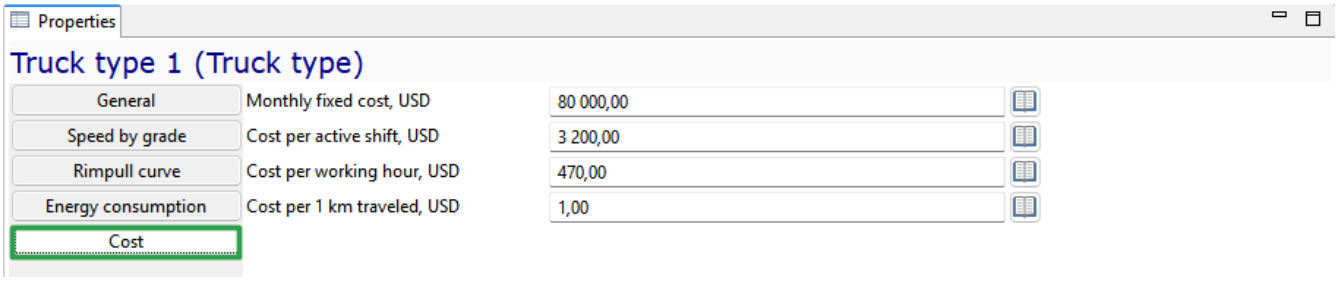
Scheduled repairs (maintenance sets), scheduled downtime period sets and unscheduled (emergency) repairs sets (unplanned events) are specified in the context of equipment types.

For equipment types, the parameter **Bypassing enable** in passing manoeuvres is specified, which determines whether equipment of this type takes part in passing manoeuvres when travelling along roads for which such manoeuvres are required (mine arcs of the *Road* type with the **Opposite moving allowed**, and **Moving overtaking allowed** and **Stopped overtaking allowed** functions enabled. When traveling on the same arc, equipment passes according to the following rules:

- If two units are moving in opposite directions, the second one waits at a mine node until the first completes its travel along the arc
- If two units are moving in the same direction, they cannot overtake each other on the arc; overtaking is only possible at a node
- If a piece of equipment has stopped on a road section, the second piece will require additional time to go around it. If a piece of equipment has stopped on an edge with the Overtaking stopped equipment function disabled, then the equipment participating in passing manoeuvres will stop before this edge and wait until the road is clear.

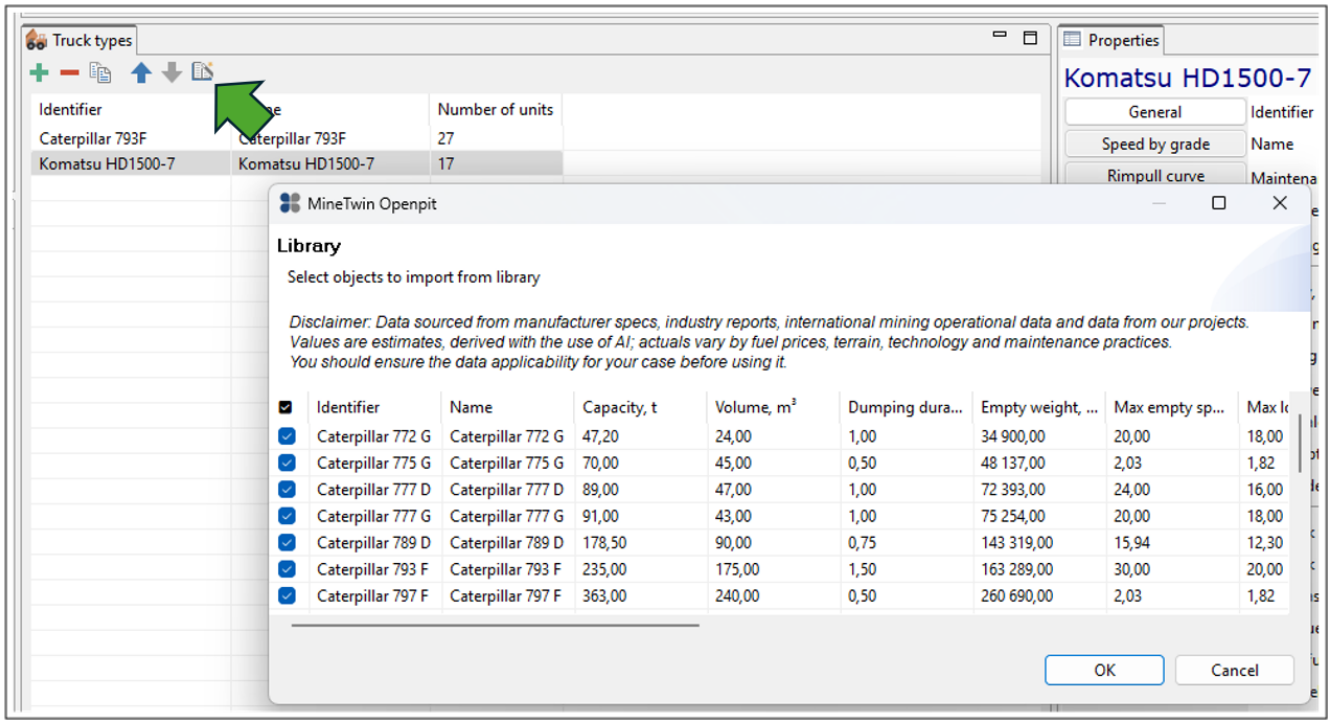
Additionally, maintenance costs for equipment types are specified at the equipment type level. On the **Cost** tab, the following cost parameters can be filled in for all equipment types:

- **Monthly fixed cost, USD**
- **Cost per active shift, USD**
- **Cost per working hour, USD**
- **Cost per 1 kilometer traveled, USD**.



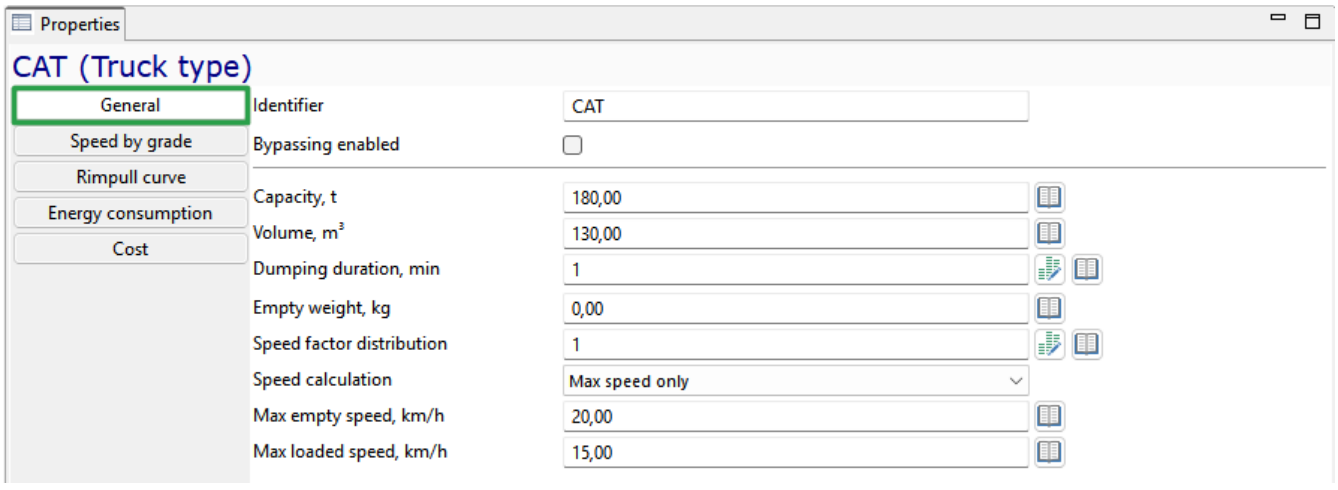
Filling in these parameters is optional and is used when estimating operational expenditures during the simulation.

MineTwin OpenPit 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.



1.9.1. Truck types

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

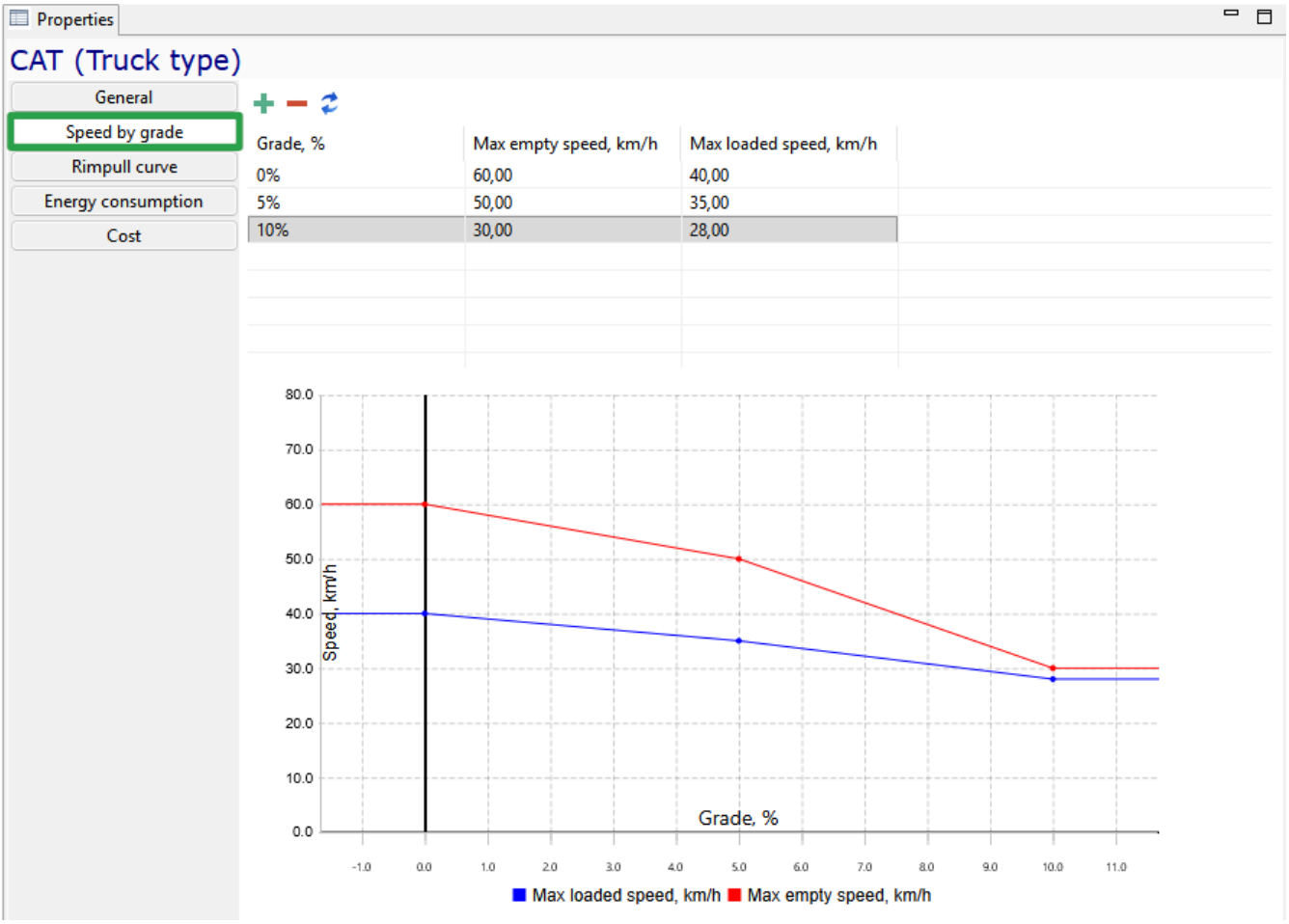


The following properties must be set for each truck type:

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Capacity,t** of trucks of this type
- **Volume, m^3** - the maximum quantity of ore that can accommodate the truck of this type
- **Dumping duration, min**
- **Empty wight,kg** - empty haul truck mass in kilograms. This parameter is used in speed calculations based on tractive **Rimpull curves**
- **Speed factor distribution** - this parameter allows specifying speed variability within a defined range. The parameter can be a constant or a random variable with one of the built-in distribution functions
- **Speed calculation** - one of three options for calculating the speed of rock mass haulage equipment:
  - Using only the maximum speed of this equipment type. In this case, travel speed will depend solely on road quality
  - Speed calculation accounting for road gradient. In this case, simulation uses linear interpolation of a tabular speed function defined on the **Speed by grade** tab. If the defined maximum speeds are lower than those in the table, the maximum speeds will be used. The speed calculated based on gradient is also adjusted by the road quality coefficient
  - Speed calculation accounting for rolling resistance, which occurs when wheeled equipment tires roll on the road surface. In this case, a function of vehicle speed versus the force it exerts on the road is used. This function is defined on the **Rimpull curve** tab. The speed obtained by any of these rules is adjusted for road quality. On all arcs with a road quality of 1, the speed will equal the calculated value. On arcs where road quality is not 1, the speed will be adjusted by the specified coefficient. The speed factor distribution is also applied to the calculated speed.
- **Max empty speed, km/h** - absolute maximum speed of moving empty. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving empty can never be greater than this value
- **Max loaded speed, km/h** - absolute maximum speed of moving loaded. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving loaded can never be greater than this value

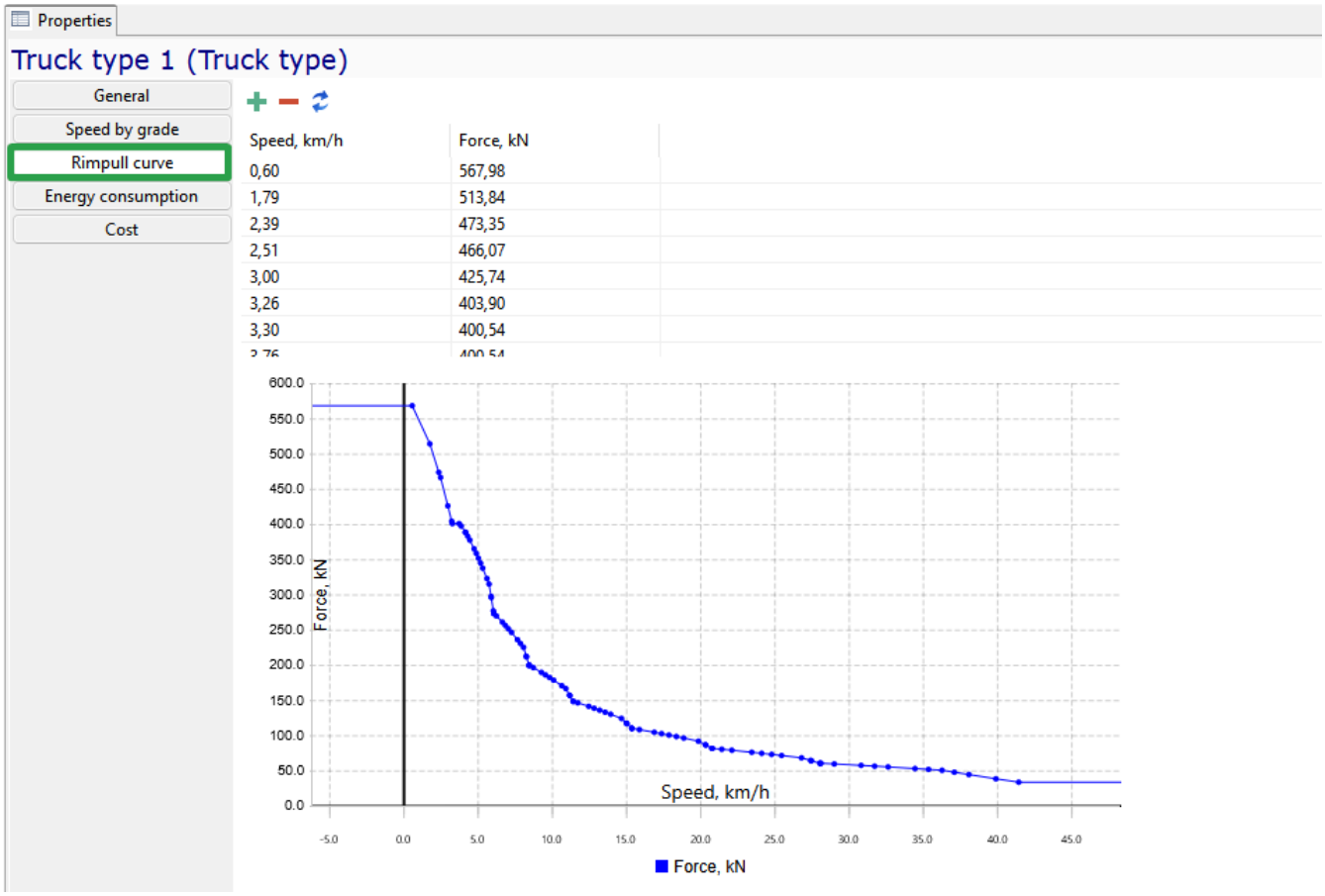
Speed by grade

On the **Speed by grade** tab, the speed characteristics of haul truck types are defined as a function of road gradient angle. For each range of angles, the corresponding travel speeds with and without load are indicated. Intermediate values are determined by linear interpolation and are displayed on the graph.



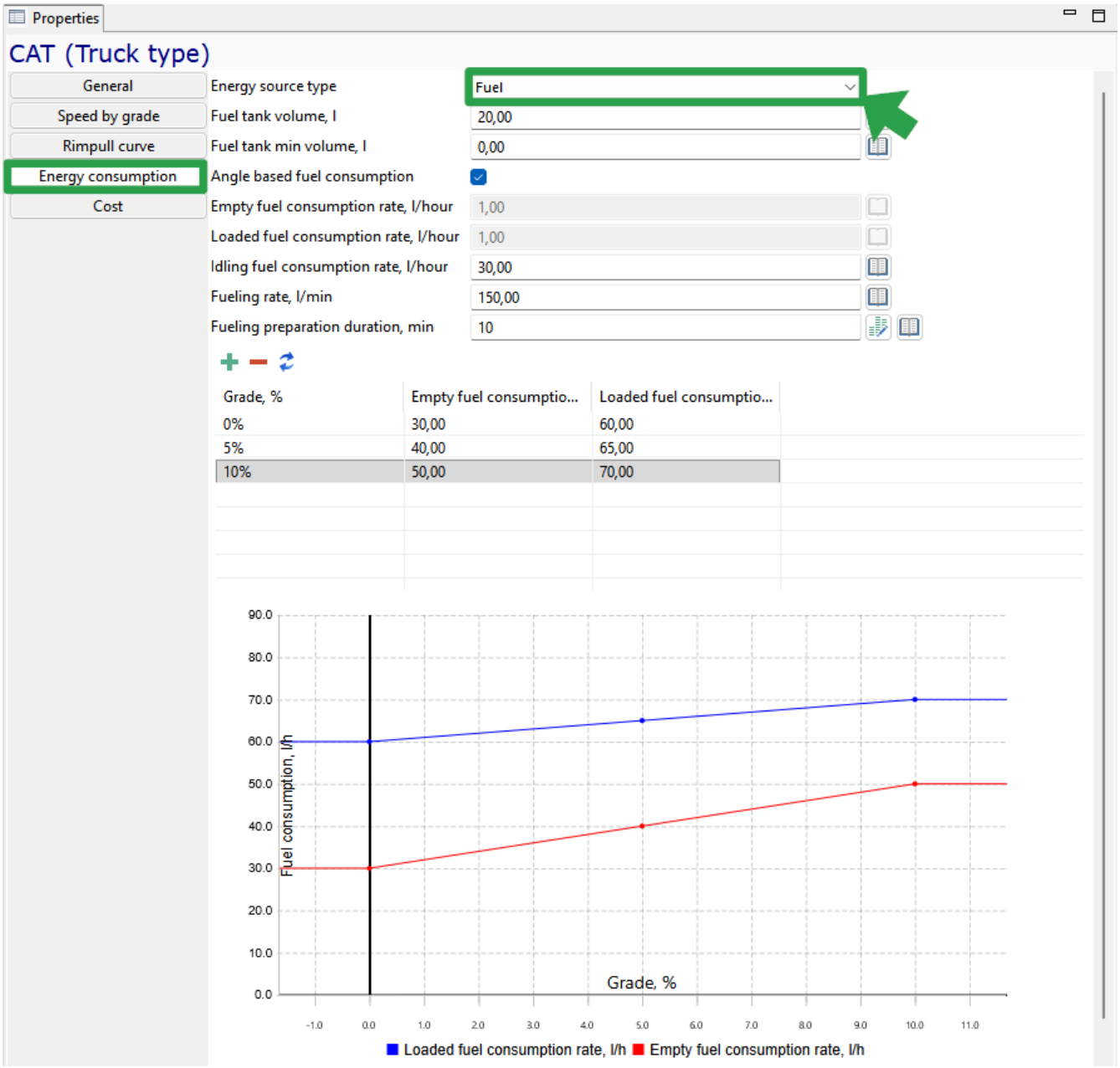
Rimpull curve

On the **Rimpull curve** tab, values describing the relationship between tractive effort (the tractive force available at the wheels) and the travel speed of a haul truck of this type can be specified. Intermediate values are determined by linear interpolation and are displayed on the graph.



Energy consumption

On the **Energy Consumption** tab, one of three available energy source options must be selected: *Fuel*, *Fixed battery*, or *Swappable battery*. After selecting the energy source, the corresponding energy consumption parameters must be filled in.



When *Fuel* is selected as the energy source, the following values are specified:

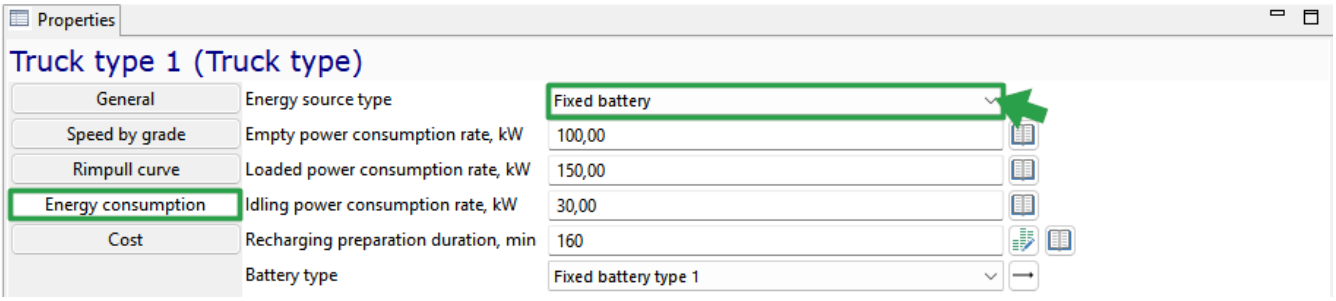
- **Fuel tank capacity, liters**
- **Fuel tank volum, liters**
- **Fuel tank min volum, liters** — the minimum volume of fuel in the tank that cannot be utilised
- **Angle based fuel consumption** — if this checkbox is selected, fuel consumption for haul trucks of this type is calculated based on fuel consumption curves vs. road gradient; otherwise, a constant consumption rate is used for various states (loaded, empty, idling). The dependencies are entered in tabular form for travel with load and without load. Road gradient is specified as a percentage, and the curves on the chart are generated automatically
- **Empty fuel consumption rate, l/hour** — constant consumption rate when travelling without load, used if the effect of road gradient does not need to be taken into account
- **Loaded fuel consumption rate, l/hour** — constant consumption rate when travelling with load, used if the effect of road gradient does not need to be taken into account
- **Idling fuel consumption rate, l/hour** — constant consumption rate when the haul truck is not

in motion

- **Fueling rate, l/min** — the refuelling rate for haul trucks of this type
- **Fueling preparation time, min** — the delay required to prepare haul trucks of this type before refuelling begins. This may be specified as either a constant or a random variable.

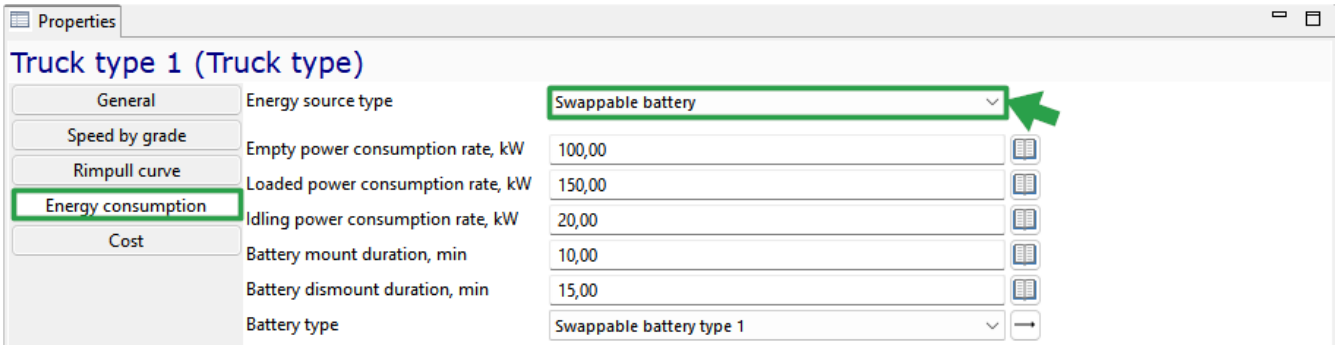
When Fixed battery is selected as the energy source, the following values are specified:

- **Empty power consumption rate, kW**
- **Loaded power consumption rate, kW**
- **Idling power consumption rate, kW**
- **Recharding preparation duration, min** — the delay before charging begins. This may be specified as either a constant or a random variable
- **Battery type** — selection of a battery type from the list available in the scenario.



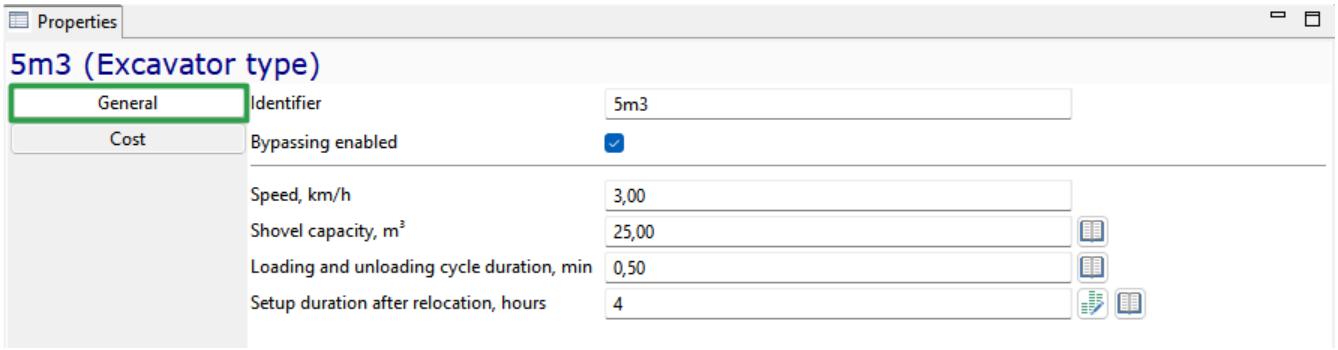
When Swappaable battery is selected as the energy source, the following values are specified:

- **Empty power consumption rate, kW**
- **Loaded power consumption rate, kW**
- **Idling power consumption rate, kW**
- **Battery mount duration, min** — the delay before charging begins. This may be specified as either a constant or a random variable
- **Battery dismount duration** — selection of a battery type from the list available in the scenario.



1.9.2. Excavator types

Excavator is the equipment designed for excavation (mining) of ore mass in an open-pit mine from the pile and loading into trucks or dumping.



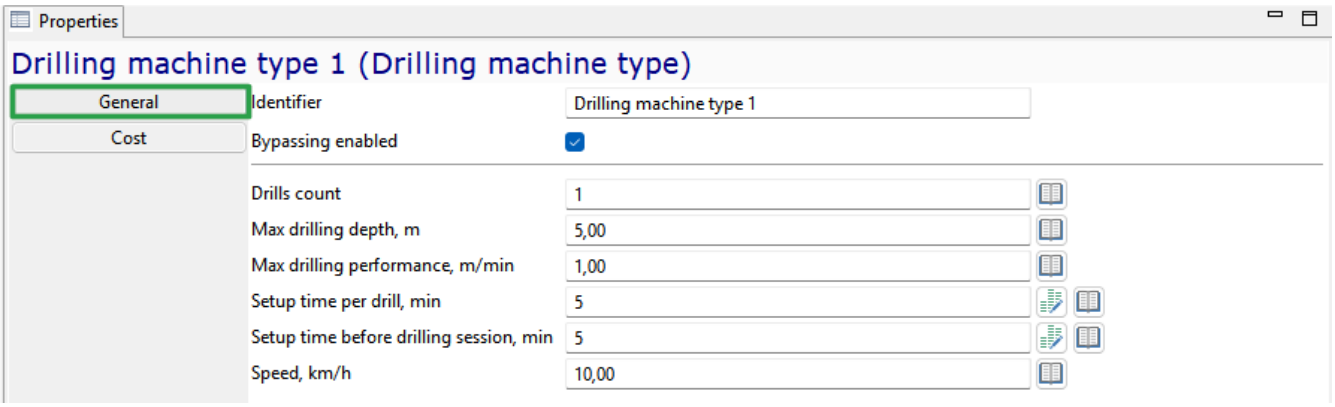
The following basic properties must be set for each excavator type:

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Speed, km/h**
- **Shovel capacity, m^3**
- **Loading/ unloading cycle duration, min**
- **Setup duration after relocations, in hours**. The preparation duration can be set by a constant value or by one of the distributions .

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.3. 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:

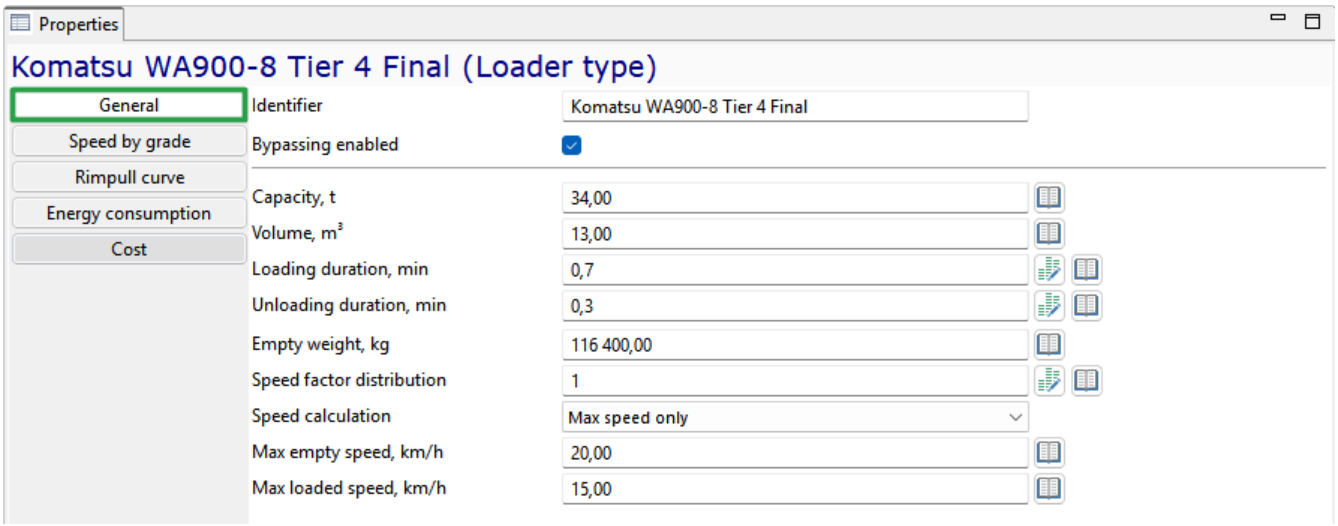
- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Drills count** - the number of drilling tools. As a rule, a horizontal drilling machine has 2 booms, a vertical drilling machine has 1 boom
- **Max drilling depth, m** possible for this type of drilling machine

- **Max drilling performance, m/min**
- **Setup time per drill, min** - duration of preparatory work, such as installing the drilling machine, connecting electricity and water, etc.
- **Setup time before drilling session, min** - duration of manipulations before drilling each well/hole
- Constant **speed** of this type of drilling machines in km/h.

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.4. 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**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Capacity,t** 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
- **Loading duration, min**
- **Unloading duration, min**
- **Empty weight, kg**
- **Speed factor distribution** - this parameter allows to set speed variability within a range using statistical distributions. For example, a truck's loaded speed is 10 km/h, and its empty speed is 20 km/h. With a triangular distribution (0.8; 1; 1.2), the speed range will be: from 0.8 * 10 = 8 to 1.2 * 10 = 12 km/h for a loaded truck from 16 to 24 km/h for an empty truck
- **Speed calculation** - one of three options for calculating the speed of rock mass haulage equipment:
  - Using only the maximum speed of this equipment type. In this case, travel speed will depend

solely on road quality

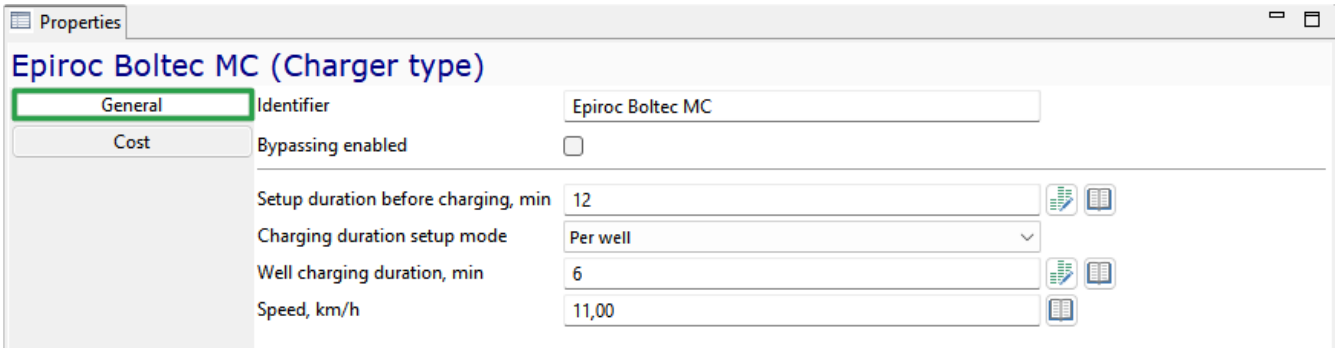
- Speed calculation accounting for road gradient. In this case, simulation uses linear interpolation of a tabular speed function defined on the **Speed by grade** tab. If the defined maximum speeds are lower than those in the table, the maximum speeds will be used. The speed calculated based on gradient is also adjusted by the road quality coefficient
- Speed calculation accounting for rolling resistance, which occurs when wheeled equipment tires roll on the road surface. In this case, a function of vehicle speed versus the force it exerts on the road is used. This function is defined on the **Rimpull curve** tab. The speed obtained by any of these rules is adjusted for road quality. On all arcs with a road quality of 1, the speed will equal the calculated value. On arcs where road quality is not 1, the speed will be adjusted by the specified coefficient. The speed factor distribution is also applied to the calculated speed.

- **Max empty speed, km/h** - absolute maximum speed of moving empty. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving empty can never be greater than this value
- **Max loaded speed, km/h** - absolute maximum speed of moving loaded. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving loaded can never be greater than this value

Similarly to truck types, on the Speed by grade tab, the speed characteristics of LHD equipment types are defined as a function of road gradient angle. On the Rimpull curve tab, values describing the relationship between tractive effort and the travel speed of an LHD of this type can be specified. On the Energy consumption tab, the energy source type and its consumption parameters are specified. As with haul trucks, one of the following options is available: *Fuel*, *Fixed battery or _Swappable battery*. On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.5. 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**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing

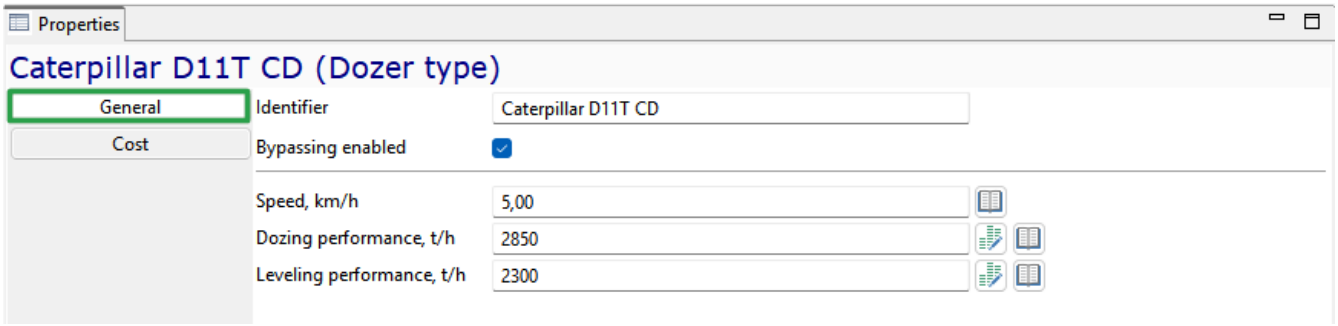
- **Setup duration before charging, min**
- **Charging duration setup mode** - one of two possible methods for accounting for the time to charge blast holes/wells with explosive material: *Time per blast hole/well* or *Time per meter of hole/well depth*
- **Well chargigng duration, min**
- **Speed, km/h** - constant travel speed of this type of chargers

The setup and charging duration can be set by a constant value or by one of the distributions.

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.6. Dozer types

Dozer is the equipment designed to move ore mass by blading.



The following **General** properties must be set for each dozer type:

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Speed, km/h**
- **Dozing performance, t/h** - bulldozer productivity for in-pit operations:
  - *Clearing and preparing block surfaces before drilling*
  - *Mining blocks using the **Dozing** method*
- **Leveling performance, t/h** - bulldozer productivity for dump/stockpile operations:
  - *During waste dump formation (leveling/trimming work)*
  - *During ore leveling/stockpiling at the processing plant's stockyard*

The dozer type performance and leveling can be set by a constant value or by one of the distributions.

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.7. Mobile equipment

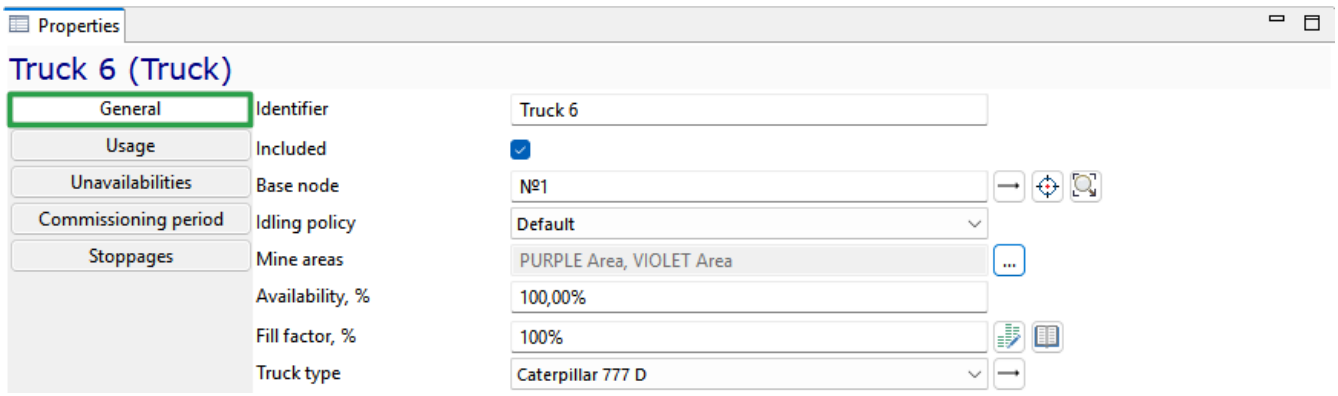
The **Mobile equipment** object tree element contains lists of all mobile equipment units used in the scenario, in terms of equipment types, as well as the list of trains which unlike other moving

equipment, are not grouped into types.

General parameters

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

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Base node** - base location (garage)
- **Idling policy**:
  - *Default* — haul trucks and LHDs return to the base node, drilling machines, excavators and bulldozers remain in the blocks/dumps
  - *Return to base location* — all equipment returns to the garage after work completion
  - *Stay at current position* — all equipment remains at the place where work was performed after completion
- **Mine area** to which the equipment unit is assigned
- **Equipment type** - selection of an equipment type from those available in the scenario. The properties of the equipment type are displayed in the properties of the equipment unit as reference information and are not available for editing.



The properties of Trucks, Excavators, and LHDs include **Fill factor**, %, which allows accounting for the average loading of the body or bucket with rock mass as a percentage. By default, the factor is set to 100%.

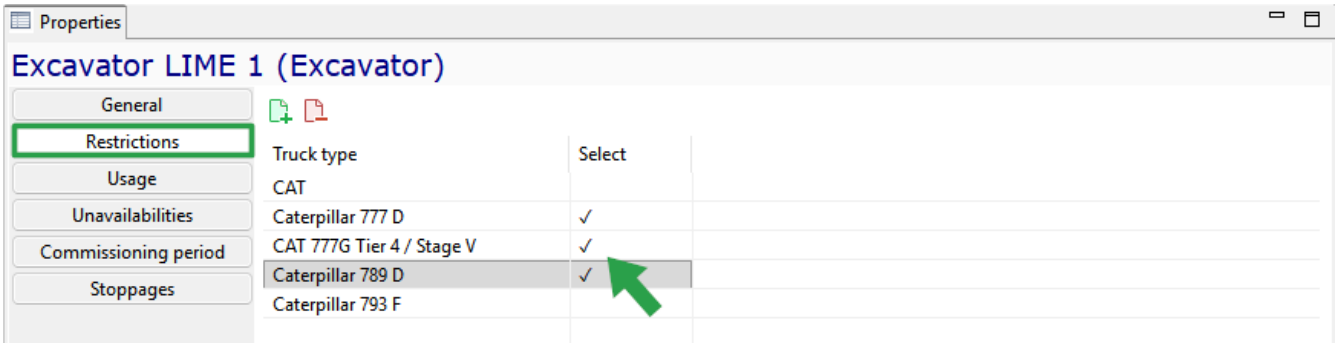
The properties of Excavators include a function for selecting the **Excavators task type**:

- *Block excavation* — excavation of blasted rock mass at the production area
- *Dump area load-out* — excavation of rock mass from intermediate stockpile locations

Restrictions

Excavator units include a **Restrictions** tab in their properties, which allows selecting the types of

trucks that can operate with this excavator.

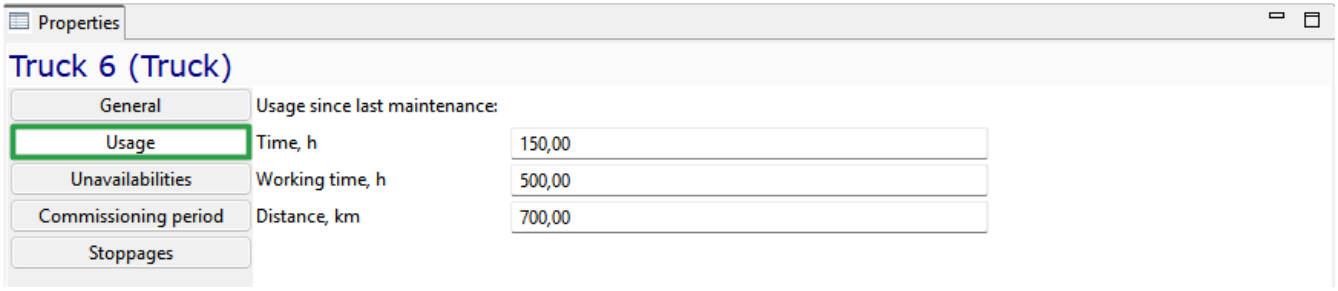


The properties of an equipment unit include tabs for entering the technical condition at the start of planning, periods of unavailability (e.g., scheduled maintenance), technical condition data, as well as commissioning and decommissioning dates. These tabs are optional.

Usage

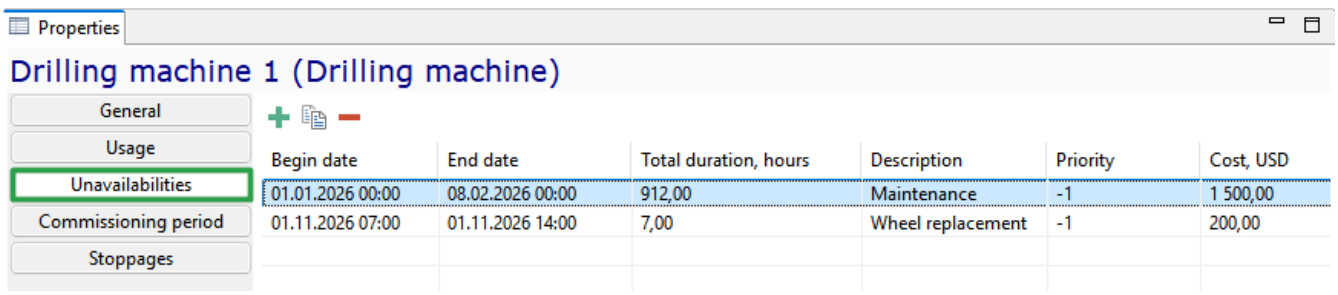
On the **Usage** tab, the initial state of parameters related to maintenance based on operating hours is specified for each mobile equipment unit:

- **Time, h** — total time accumulated by the equipment unit since its last maintenance at the start of planning/simulation
- **Working time, h** — number of engine hours (hours of engine operation during travel, loading, unloading) accumulated by the equipment unit since its last maintenance at the start of planning/simulation
- **Distance, km**— number of kilometres travelled by the equipment unit since its last maintenance at the start of planning/simulation



Unavailabilities

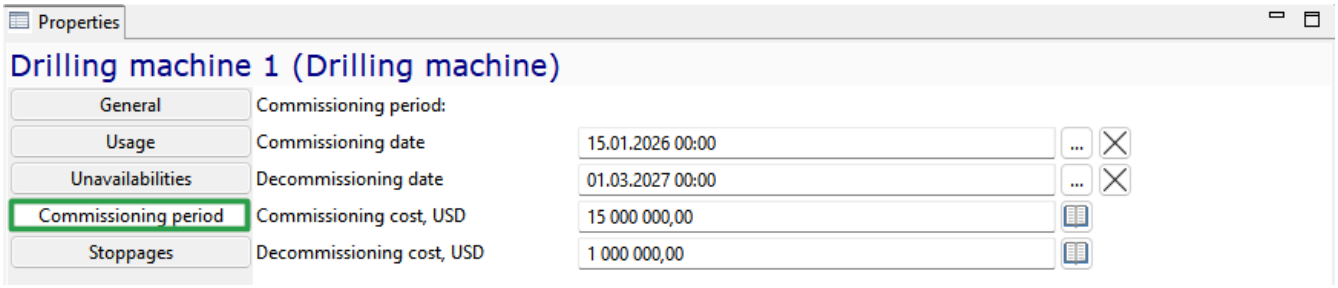
On the **Unavailabilities** tab, scheduled periods of unavailability can be specified for each equipment unit.



The buttons allow you to add, copy, and delete unavailability periods.

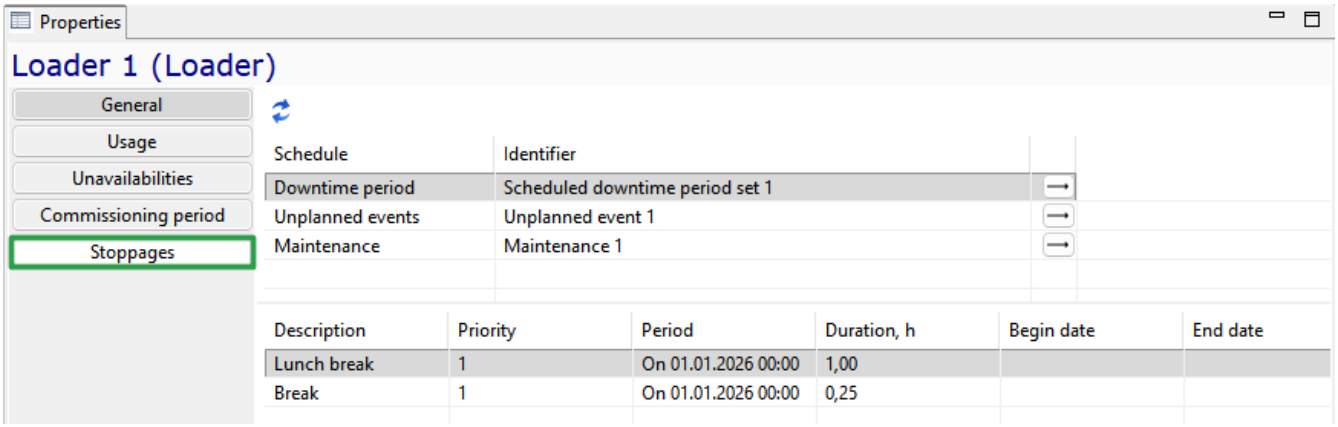
Commissioning period

On the **Commissioning period** tab, the commissioning and decommissioning dates of an equipment unit may be specified, as well as the costs associated with commissioning (purchase) and decommissioning (disposal). Prior to the commissioning date / after the decommissioning date, the equipment unit does not participate in planning/simulation.



Stoppages

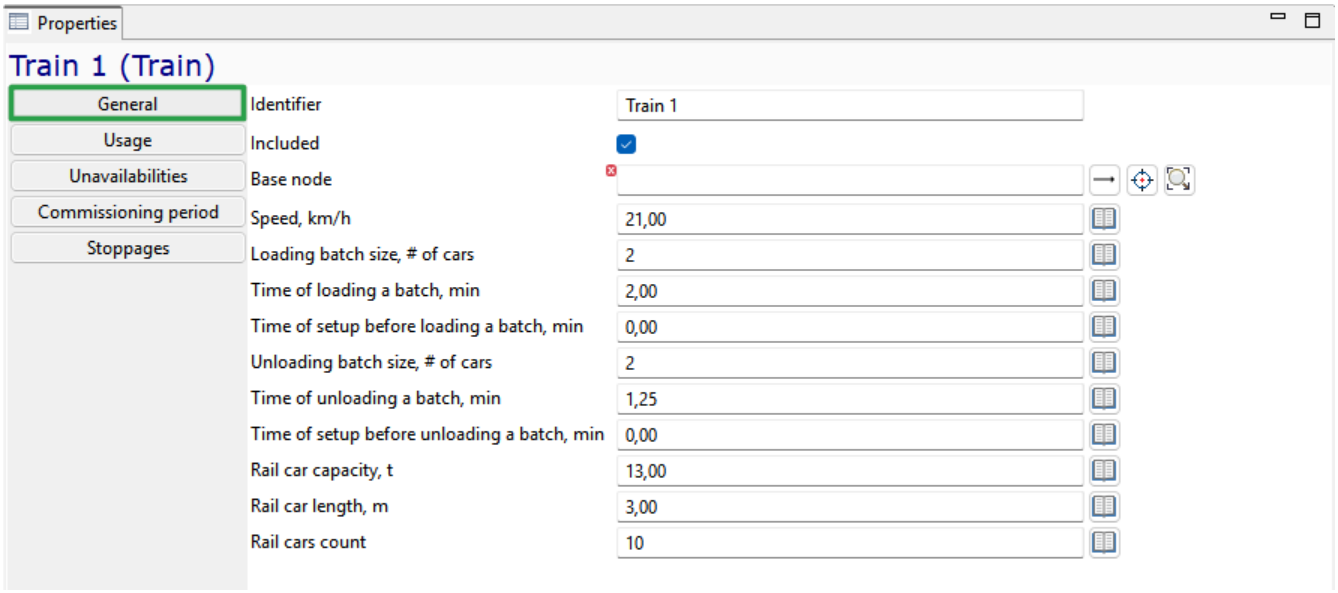
On the **Stoppages** tab, all downtime events (maintenance, scheduled downtime periods, unplanned events) assigned to the equipment unit in the **Schedules** object tree group are displayed.



The button allows you to refresh the list of schedules, and the button allows you to navigate to the selected schedule for editing.

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**
- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Base node** - base location (garage)
- **Speed, km/h**
- **Loading batch size, number of cars** — the batch of wagons being loaded
- **Time of loading a bach, minutes**
- **Time of setup before loading a batch, in minutes**
- **Unloading batch size, number of cars** — the batch of wagons being unloaded
- **Time of unloading a batch, min**
- **Time of setup before unloading a batch, min**
- **Rail car capacity, in metric tonnes**
- **Rail car length, in metres**
- **Rail car count**

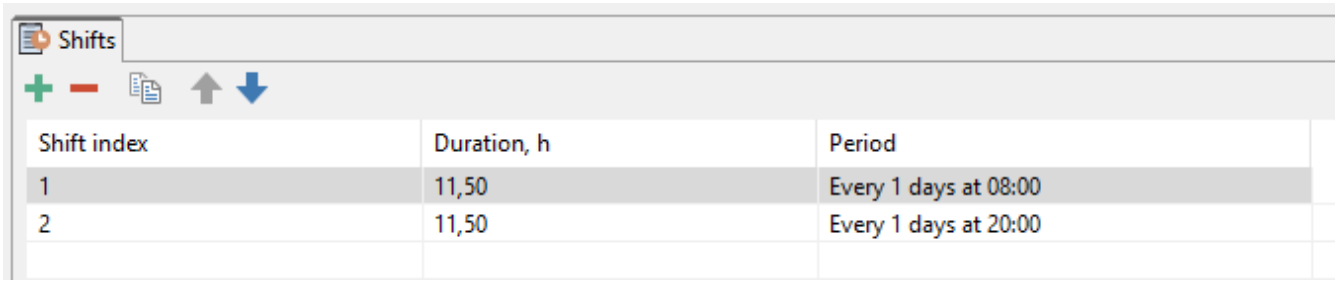
1.10. Schedules

The **Schedules** model tree element contains the following entities that define the work of the mine:

- Shifts
- Blast periods
- Scheduled downtime period sets
- Maintenance sets
- Unplanned events.

1.10.1. Shifts

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



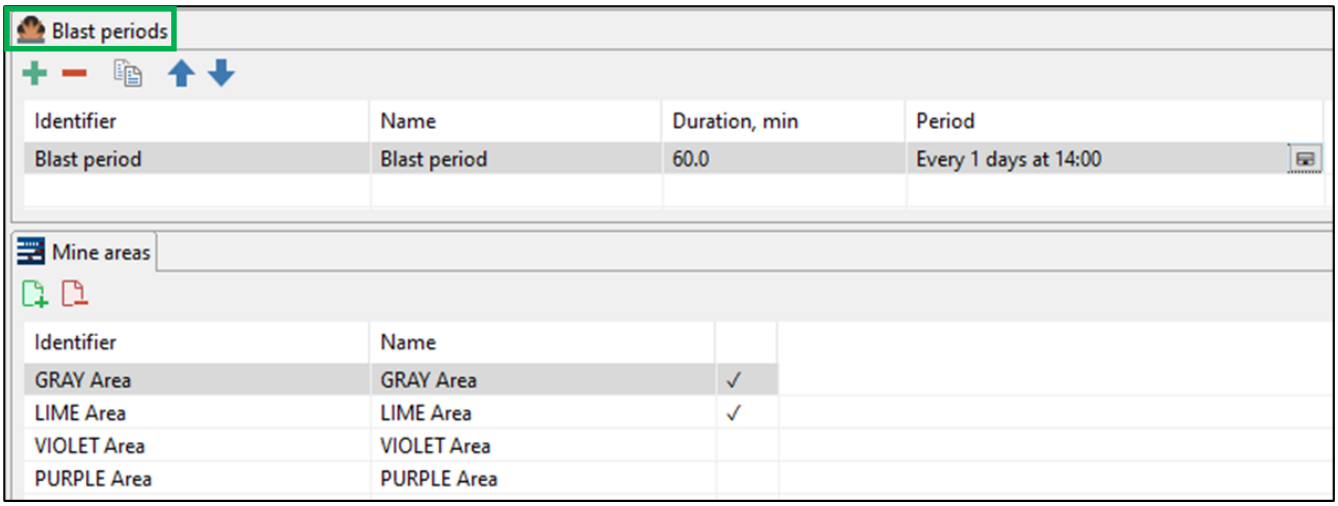
The following parameters are set for each shift:

- **Shift index** - an optional field to indicate a shift
- **Duration** of shift, in hours
- **Period** - the period of the shift can be specified as an exact time or as a recurrence pattern (every n-th day of the month, every last day of the month, every week, every n days).

Shifts in the **Shifts** model tree group are common to all mobile equipment units and applied during scheduling and simulation only to them.

1.10.2. Blast periods

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



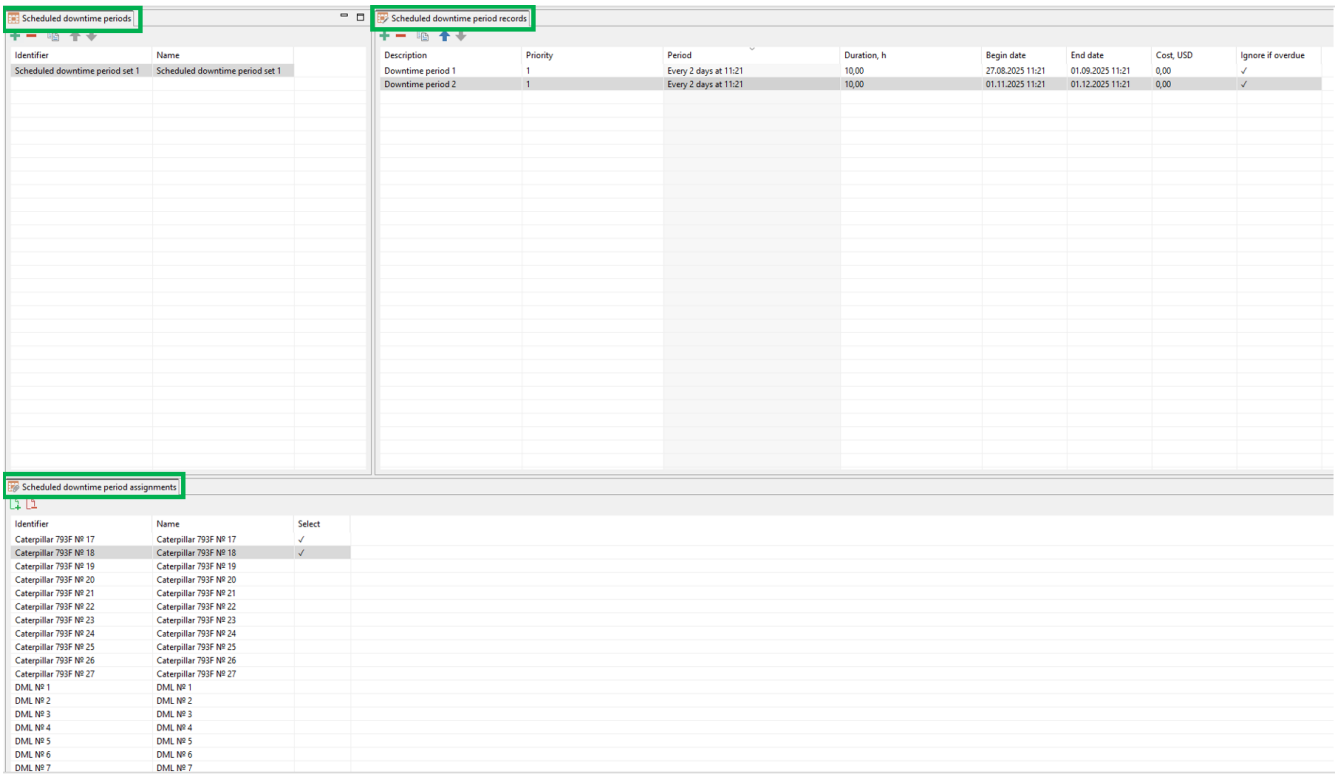
The **Blast period** has following parameters:

- Unique **identifier** and **name** of the blast period
- **Duration** of the blast period in minutes
- **Period** of the blast period, which can be specified as an exact time or as a recurrence pattern (every n-th day of the month, every last day of the month, every week, every n days)
- **Mine areas** where the above blasting operations are carried out.

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

1.10.3. Scheduled downtime period sets

Scheduled downtime period sets are used to model planned periods of equipment unavailability within a fixed time interval, regardless of the equipment's operating time, engine hours, or mileage. In this way, this period sets can represent lunch breaks, routine shift maintenance (RSM), major repairs, or equipment upgrades.



Three types of entities are created in MineTwin OpenPit to set up **Scheduled downtime period sets**:

- **Scheduled downtime periods** in the upper-left window, each possibly containing several individual **Scheduled downtime period records**
- **Scheduled downtime period record** — a row of data describing a single downtime in the upper-right **Scheduled downtime period records** window. A downtime record is defined by the following parameters:
  - **Description** — an optional description of the scheduled downtime period
  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.
  - **Duration, h** — the length of the planned downtime period, in hours
  - **Begin and end dates** — specified if the downtime occurs only during a limited time frame, e.g., winter months. If left blank, the downtime applies throughout the entire scenario.
  - **Cost, USD** — the expenses associated with carrying out this downtime type, e.g., routine

shift maintenance (RSM) cost

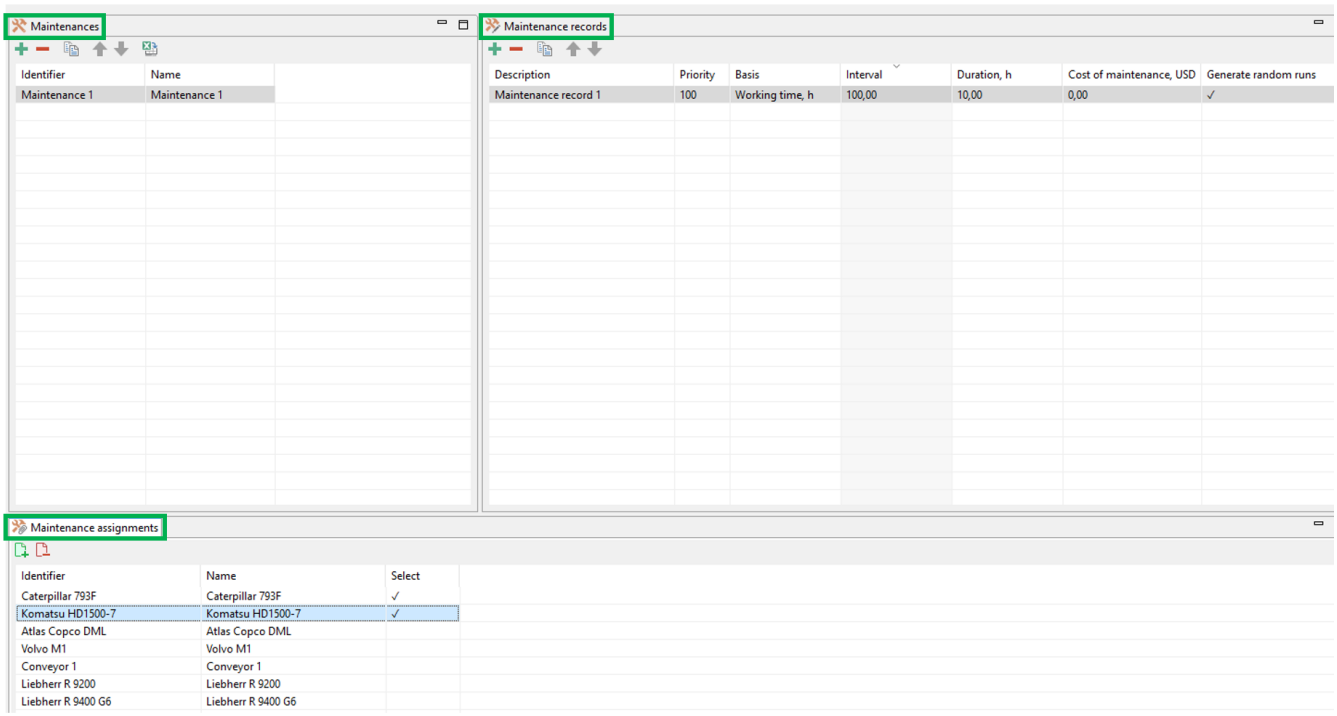
- **Ignore if overdue** — if checked, this parameter allows to ignore the downtime if its time interval has already passed. For example, a truck has a scheduled lunch break from 13:00 to 14:00, but it is still waiting to be loaded by an excavator that is on break. In this case, the truck effectively experiences a break during that wait, so there is no need to simulate an additional one-hour break once the truck completes its trip after the excavator returns.

- **Scheduled downtime period assignments** window at the bottom allows you to assign **Scheduled downtime periods** to selected equipment units.

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

1.10.4. Maintenance sets

Maintenance sets are used to simulate scheduled equipment repairs — those carried out after a specified calendar time of operation, upon reaching a defined number of engine/impact mechanism hours, or upon reaching a specified mileage. In this way, different types of maintenance can be defined, such as routine maintenance, intermediate repairs, major overhauls, etc.



Three types of entities are created in MineTwin OpenPit to set up **Maintenance sets**:

- **Maintenances** in the upper-left **Maintenances** window, each possibly containing several individual **Maintenance records**

- **Maintenance record** — a row of data describing a single maintenance/repair in the upper-right **Maintenance records** window. A maintenance is defined by the following parameters:

  - **Description** — an optional description of the maintenance/repair

  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.

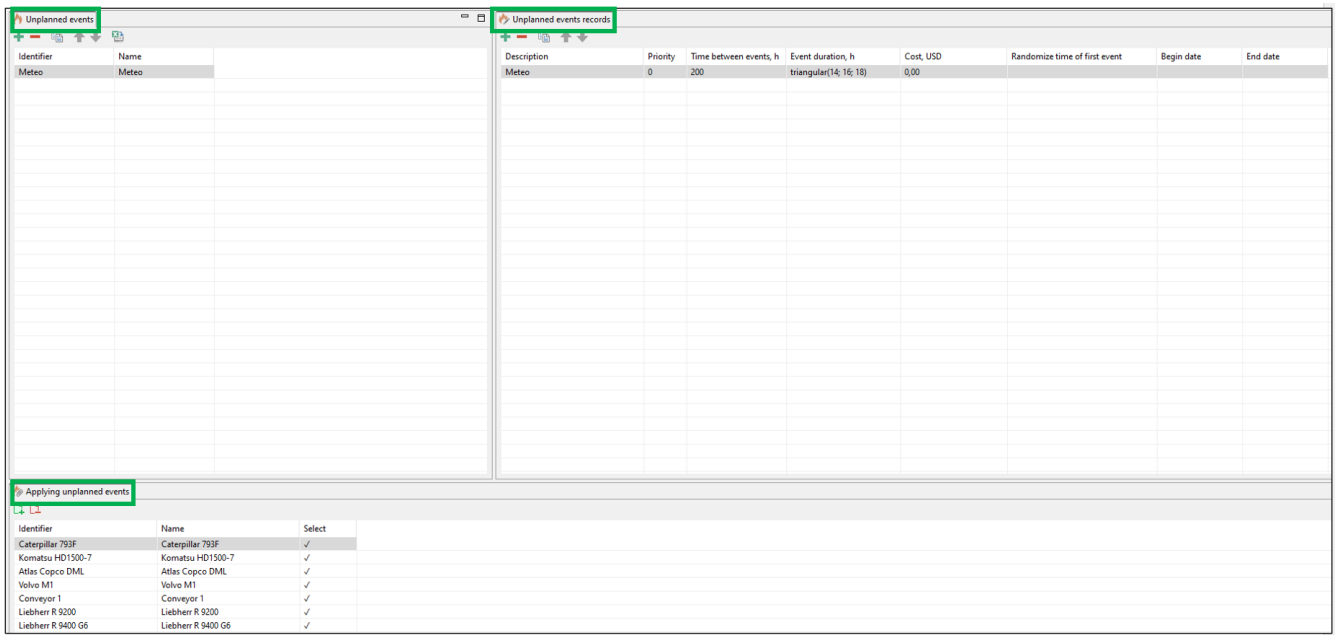
- **Basis** — the type of maintenance trigger: calendar time, engine operating hours, or equipment mileage.
- **Interval** — the interval between two maintenance triggers, expressed either in hours or kilometers, depending on the chosen basis.
- **Duration, h** — the duration of the maintenance
- **Cost, USD** — the expenses associated with the maintenance (optional)
- **Generate random runs** — if checked, maintenance for all equipment units without a defined initial operating time will not be simulated simultaneously. Instead, maintenance triggers will occur at different randomly assigned times for each unit.

- **Maintenance assignments** window at the bottom allows you to assign **Maintenances** to selected equipment types.

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

1.10.5. Unplanned events

Unplanned events are used to simulate emergency equipment failures, breakdowns, or downtime caused by weather conditions.

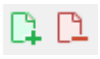


To define **Unplanned events** in MineTwin OpenPit, three types of entities are created:

- **Unplanned events** in the upper-left **Unplanned events** window, each possibly containing several individual **Unplanned events records**
- **Unplanned events record** — a row of data describing a single **Unplanned event** in the upper-right **Unplanned events records** window. Such event is defined by the following parameters:
  - **Description** — an optional description of the event
  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.

- **Time between events, h** — may be specified as a constant or as a random variable using one of the built-in distributions.
- **Event duration, h** — may be specified as a constant or as a random variable using one of the built-in distributions.
- **Cost, USD** — the expenses associated with the event (optional)
- **Randomize time of first event** — used so that equipment failures are not simulated simultaneously for all units; instead, the countdown starts at different randomly assigned times for each unit
- **Begin and end dates** — specified if the events occur only during a limited time frame, e.g., winter months. If left blank, the events will happen throughout the entire scenario.

- **Unplanned events assignments** window at the bottom allows you to assign **Unplanned events** to selected equipment types.

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

Note: **Scheduled downtime periods** are assigned to *Equipment units* and most *Material flow elements*, while **Maintenances** and **Unplanned events** are assigned to *Equipment types* and *Conveyers*.

1.10.6. Hierarchy of Unavailability Periods

For each equipment unit, different types of unavailability periods can be defined:

- Blasting periods, scheduled downtime periods, maintenance, and unplanned events (via schedules)
- Commissioning/decommissioning and unavailability (in equipment properties)

During planning/simulation, these periods may overlap in time. Priorities are used to regulate overlapping periods.

Breaks with a lower priority index are higher priority and override (absorb) breaks with a higher index (lower priority). By default:

- Unavailability periods and out-of-service periods have the highest priority = -1
- Scheduled downtime periods = 1
- Maintenance = 100
- Unplanned events = 1000

This means that if a major repair (priority -1) coincides with a daily lunch break (priority 1), the lunch break will not be scheduled. If a failure (priority 1000) occurs during current maintenance (priority 100), that failure will not be considered in the simulation.

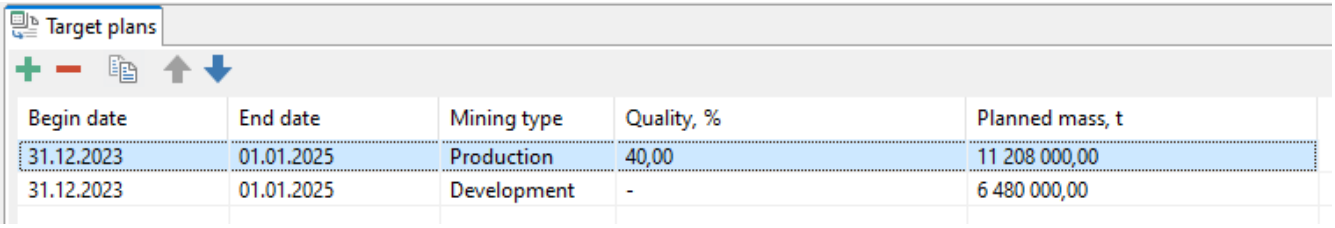
If necessary, the user can adjust the priorities of unavailability periods.

1.11. Production plans

MineTwin OpenPit can automatically form an equipment operation plan based on target plans for mining ore mass.

1.11.1. Target plan

The target plan specifies how much ore mass and what quality must be mined in each target period across entire pit/mine.



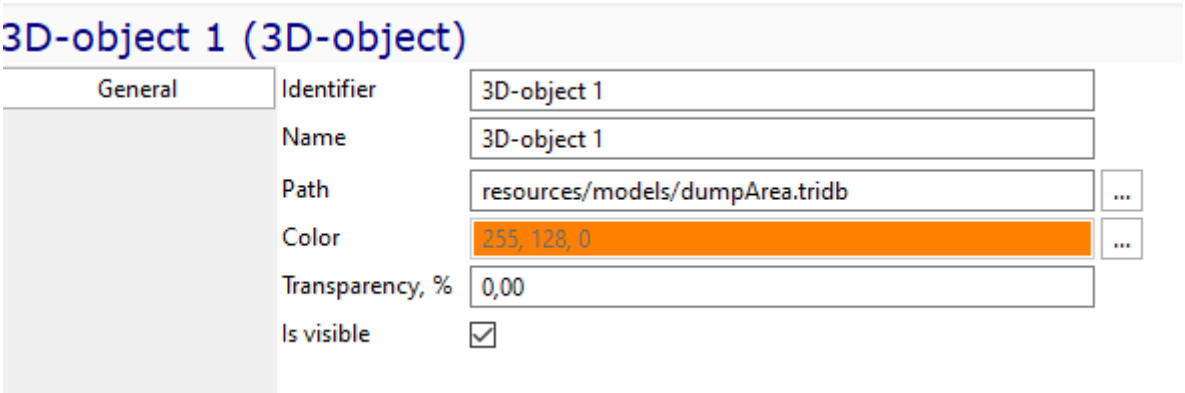
Begin date	End date	Mining type	Quality, %	Planned mass, t
31.12.2023	01.01.2025	Production	40,00	11 208 000,00
31.12.2023	01.01.2025	Development	-	6 480 000,00

Each target plan record is characterized by the following parameters:

- **Begin and end dates** of the planning period
- **Mining type** - production or development
- **Quality,%** - target quality of the mined ore mass
- **Planned mass, t** - target quantity of the mined ore mass in metric tons.

1.12. 3D-objects

Model tree group **3D Objects** allows you to load a three-dimensional **Surfaces** (formats: .tridb, .dxf, .obj, .dtm) to display pit/mine surfaces in 3D mode.



A loaded **Surface** is defined by the following parameters:

- Unique **identifier** and **name**
- **Path** to the 3D object file on the user's PC
- **Color** of the surface on the 3D map
- **Transparency, %**
- **Is visible** — if checked, surface will be displayed on the 3D map in editing and simulation

modes

2. Scheduling and simulation

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

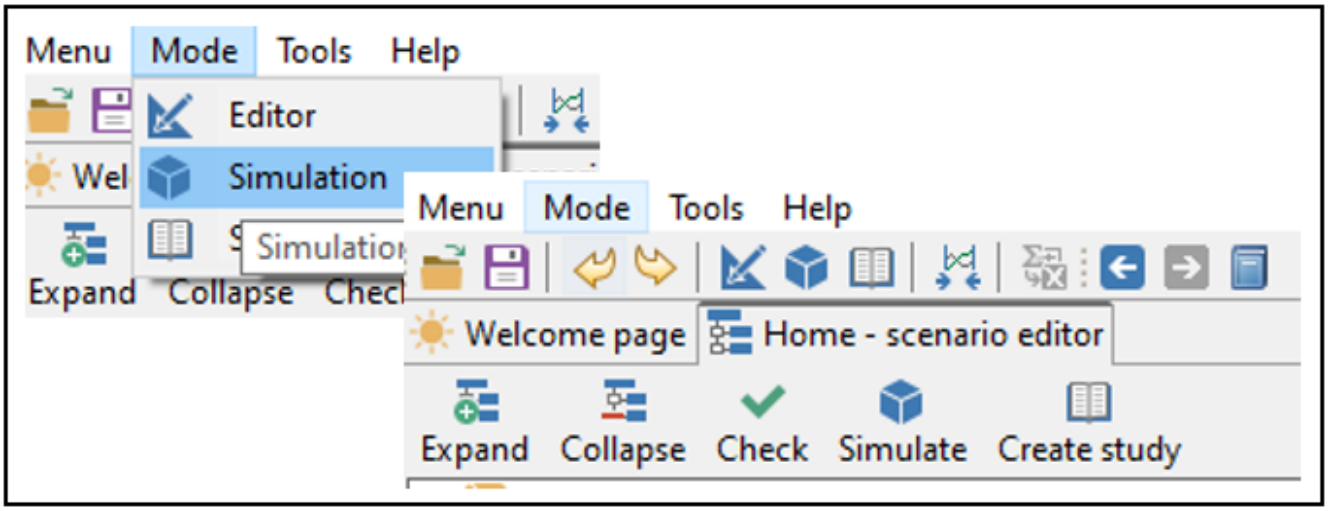
- Target values for ore production volumes and quality
- Sequence of the open-pit/ mine technological cycle
- Duration of operations performed by the selected equipment
- Hauling distances and geometric distance between the blocks
- Equipment operating schedules
- Scheduled equipment maintenance and other regulatory works
- Blasting schedules.

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

- **Unscheduled events** (breakdowns)
- **Delays due to passing maneuvers** on congested pit/mine sections
- **Loading queues**
- **Unloading queues** in front of dumps due to uneven load distribution.

In MineTwin scheduling mode, scheduling for a single shift is carried out first, followed by its simulation. At the end of the shift, the scheduler generates the plan for the next shift based on the results of the previous shift's plan execution by the simulation model.

2.1. Simulation control

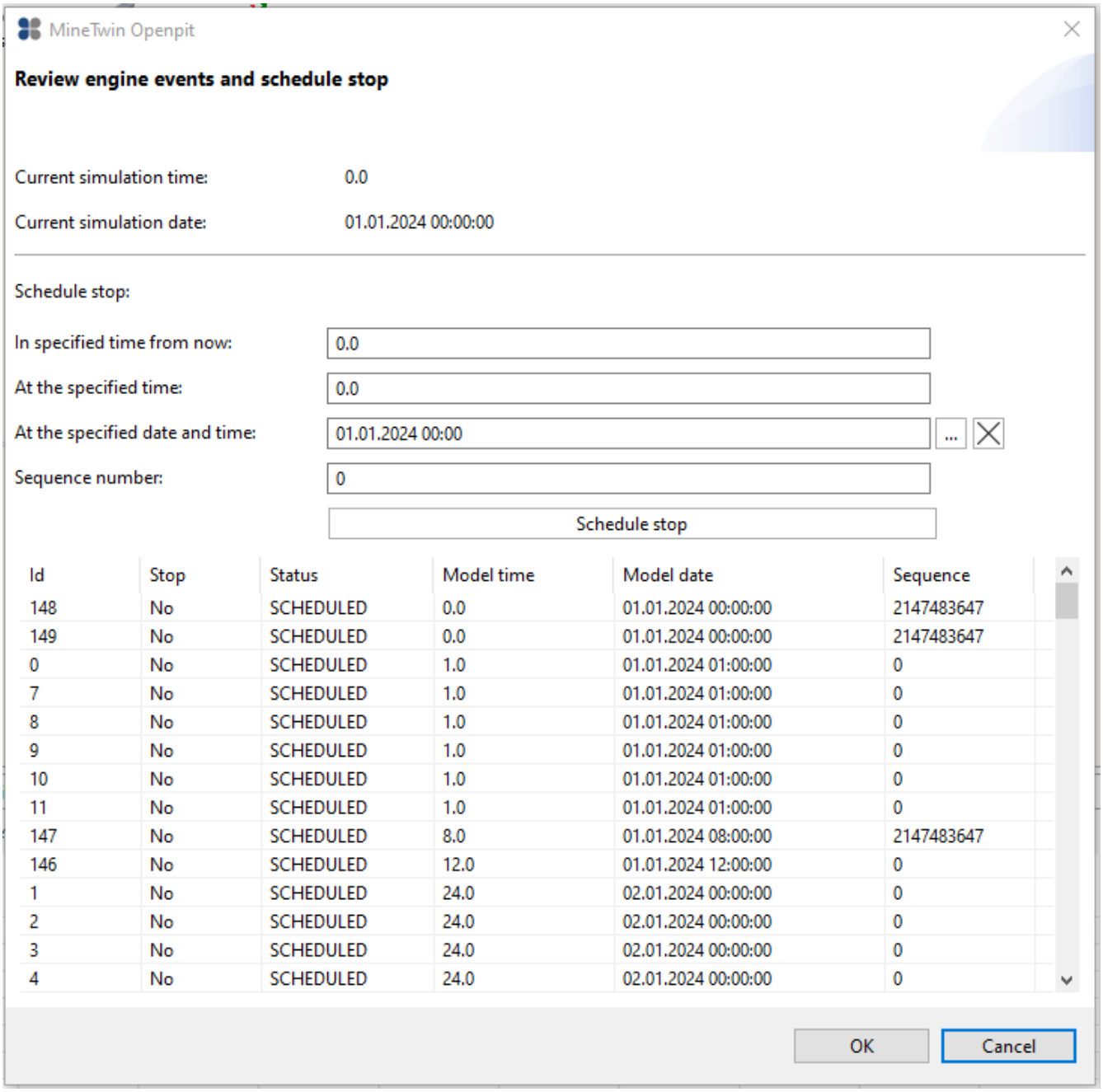


To switch to scheduling/simulation mode, click **Simulation** in the Mode group on the menu bar, or use the **Simulate** button on the editing toolbar.

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

To pause the model, use the button .

To pause at a specified simulation time, use the button .



Clicking this opens a dialog to enter the desired stop time in one of the following ways:

- **In specified time from now** - in simulation hours (for example, enter *24* to stop the model one day after the current time)
- **At specified time** - in simulation hours (for example, enter *48* to stop the model exactly at the start of the third simulation day)
- **At the specified date and time** - in model time (use the dialog window to select exact date and time for the model to stop)

When entering a value into one field, the others are calculated automatically.

Sequence number determines the order of stop points scheduled at the same time.

Press the button **Schedule stop** to add the stop to the table. You can schedule several stop points before closing this window.

Several events are already scheduled by the system in the initial table. Most of them will not cause the simulation to stop (the value in the **Stop** column is *No*), except for the last one, which corresponds to the end of the simulation.

To accelerate / slow down the simulation, use the buttons 

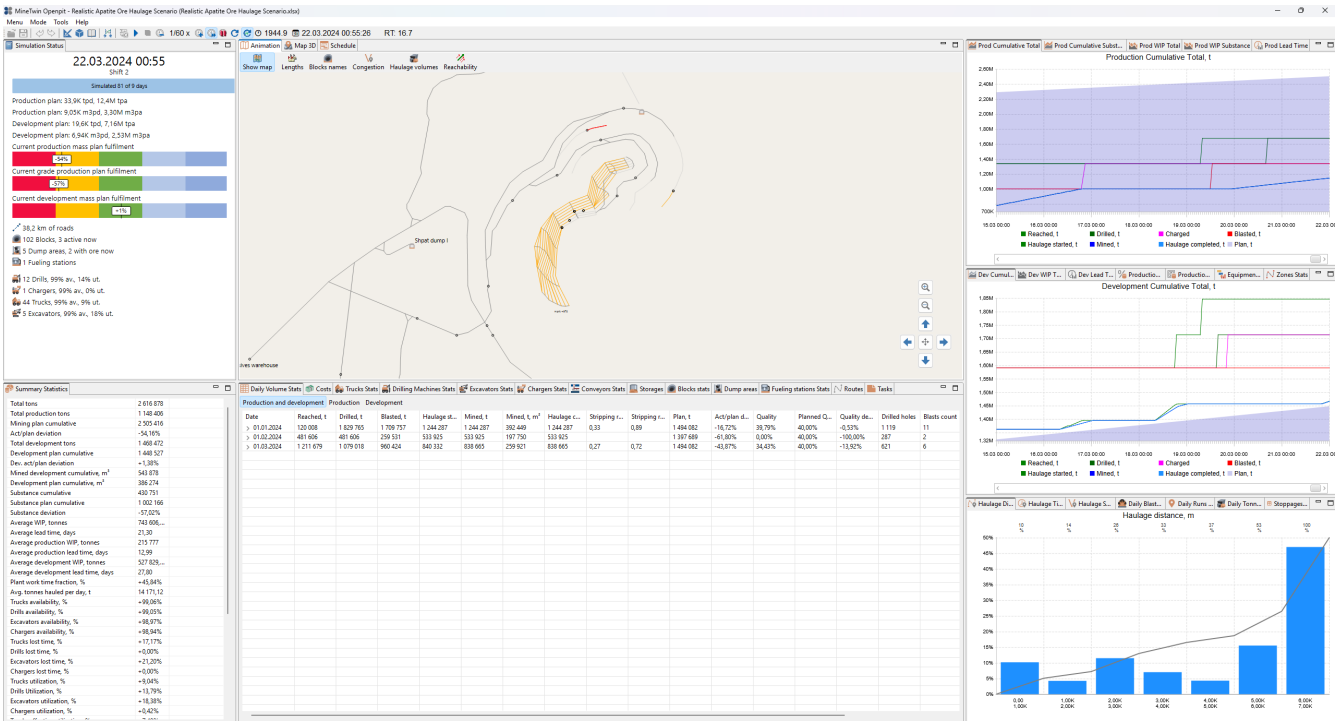
.

For maximum acceleration, use the button 

The  button refreshes the simulation visualization manually, while the  button enables automatic visualization updates. For faster simulation of large scenarios, it is recommended to disable automatic updates.

2.2. Visualization of simulation results

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



2.2.1. Animation window

In the 2D animation, the simulation process is dynamically displayed in two-dimensional space: modeling the movement and operation of equipment and vehicles on the pit/mine map.

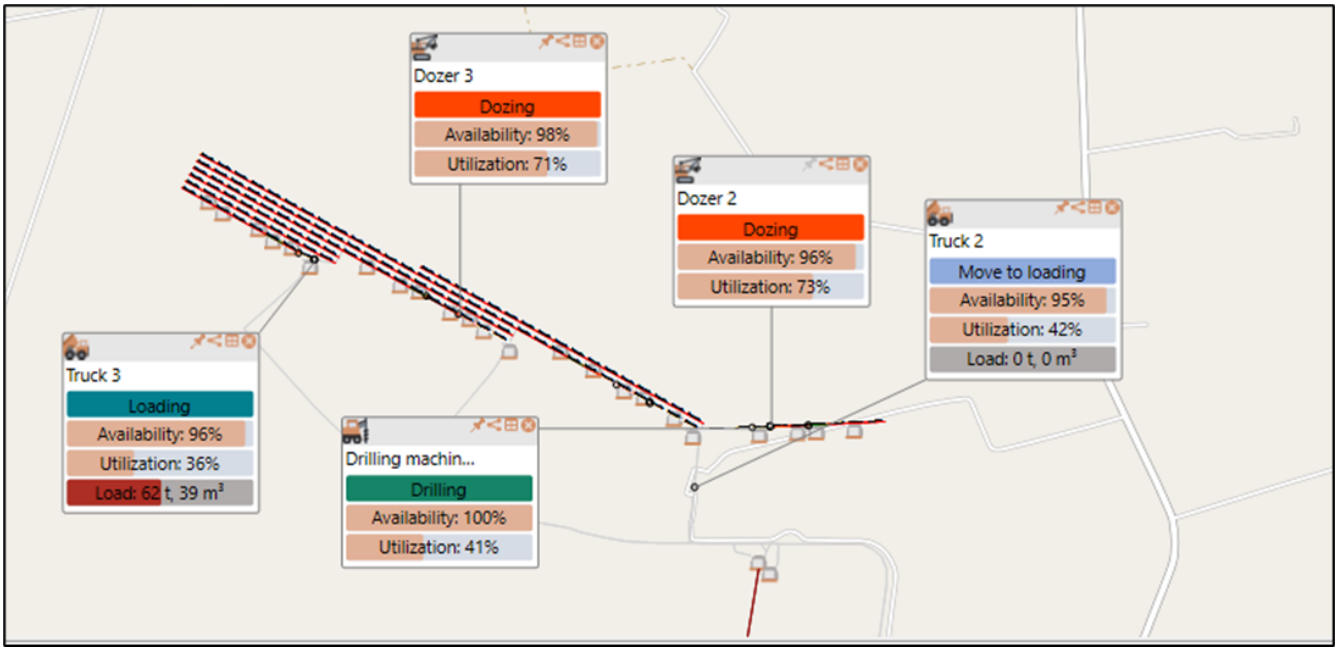
At the bottom right of the animation window, there are buttons that facilitate working with the map. The buttons allow you to zoom in and out of the map, the buttons allow you to pan the map. The button centers the map so that the entire mine is visible at once.

Buttons at the top panel allow you to display additional information on the map. The Show map button toggles the display of the geographical map, the Lengths button toggles the display of mine segment lengths, the Blocks names button toggles the block names.

The Congestion button shows road sections where vehicles move slower than their potential maximum speed due to congestion, road grade, or surface conditions. The Haulage volumes button highlights route load based on the volume of ore mass hauled by LHDs/trucks. The Reachability button highlights isolated segments if any.

Clicking on the equipment unit opens a window showing information about the status of the equipment unit, its availability and equipment use factor.

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

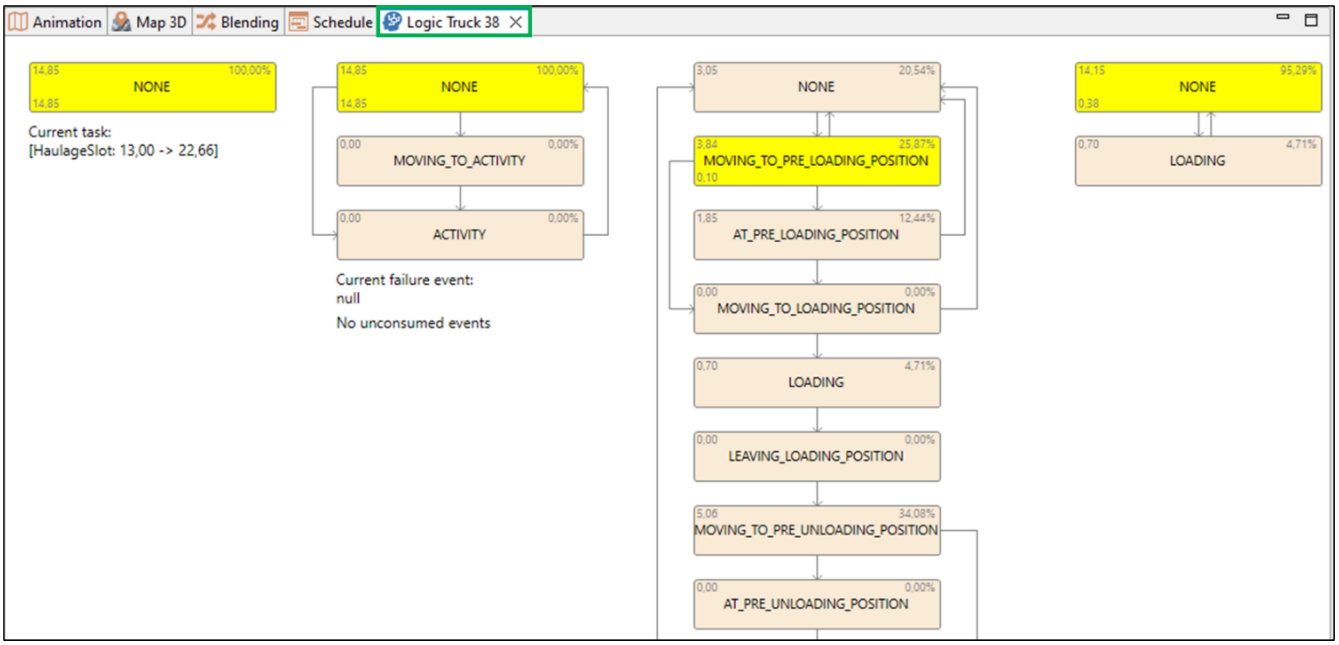


Clicking on the dump area, its loading, quality and density of the ore mass at the dump area are displayed.

The button in the information window closes the window.

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

The button switches to the state chart diagram, useful for debugging system operations.

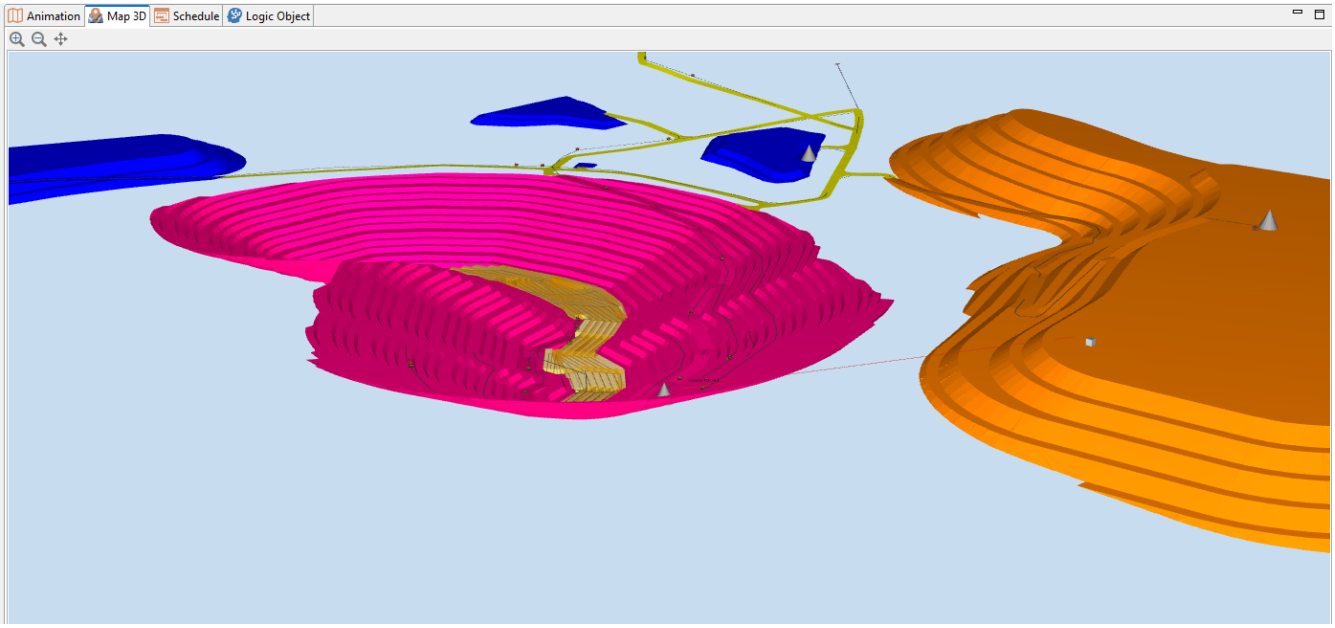


The button pins the information window, keeping it fixed in place when panning the map.

2.2.2. Map 3D window

In the 3D animation, the simulation process is dynamically displayed in three-dimensional space:

modeling the movement and operation of equipment and vehicles on the volumetric pit/mine map.

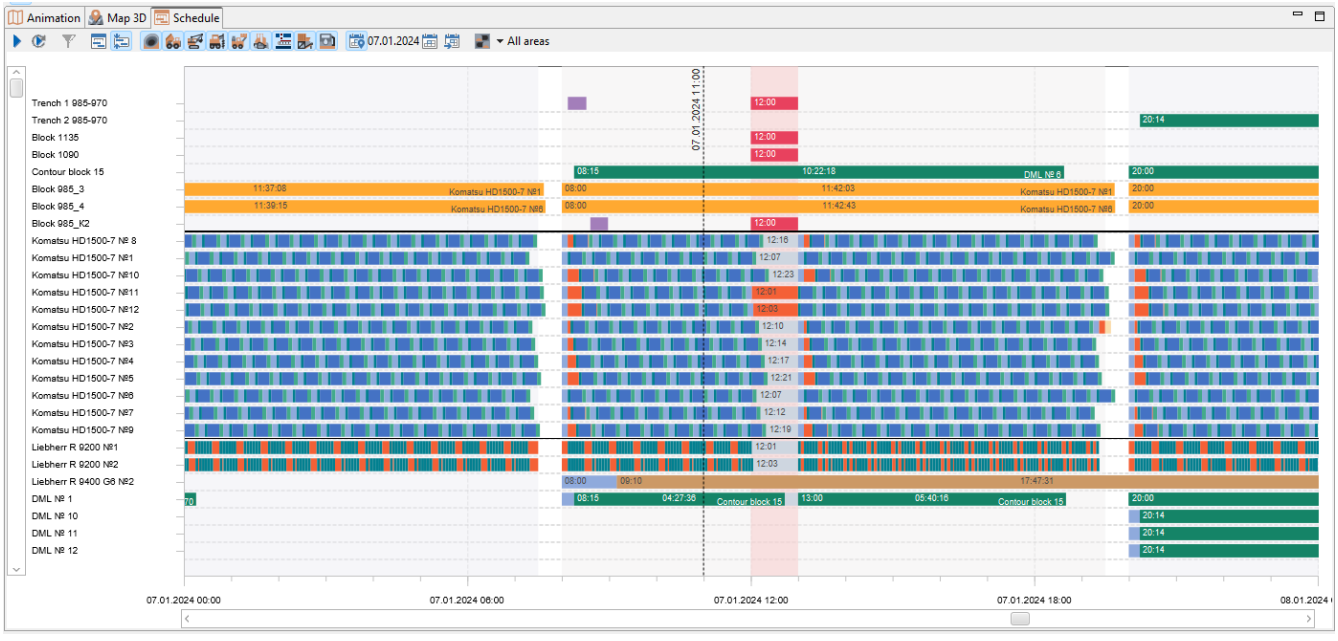


Clicking on a 3D model of an equipment unit displays its name above it.

The buttons  allow to zoom in and out of the map, the buttons  centers the map so that the entire mine is visible at once.

2.2.3. Schedule window

In the **Schedule** window of the planning mode, the Gantt chart displays planned states for blocks (drilling, charging, blasting, haulage of ore mass, etc.) and planned tasks for equipment. During the simulation experiment, the execution of the plan is dynamically displayed, showing adherence to the schedule and any deviations from it.



To start the simulation, use the  button on the top toolbar of the **Schedule** window.

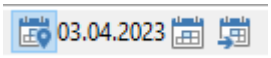
The simulation can be restarted up to the desired simulation time. To do this, place the vertical line

(time marker) at the desired date and click the button.

Use the button (**Normal** mode) for more detailed view or the button (**Compact** mode) for more compact.

When you click the buttons with equipment type icons, only equipment of the selected type(s) are shown in the Gantt chart.

The button allows you to select that only specific mine area will be displayed on the Gantt chart.

A group of buttons 

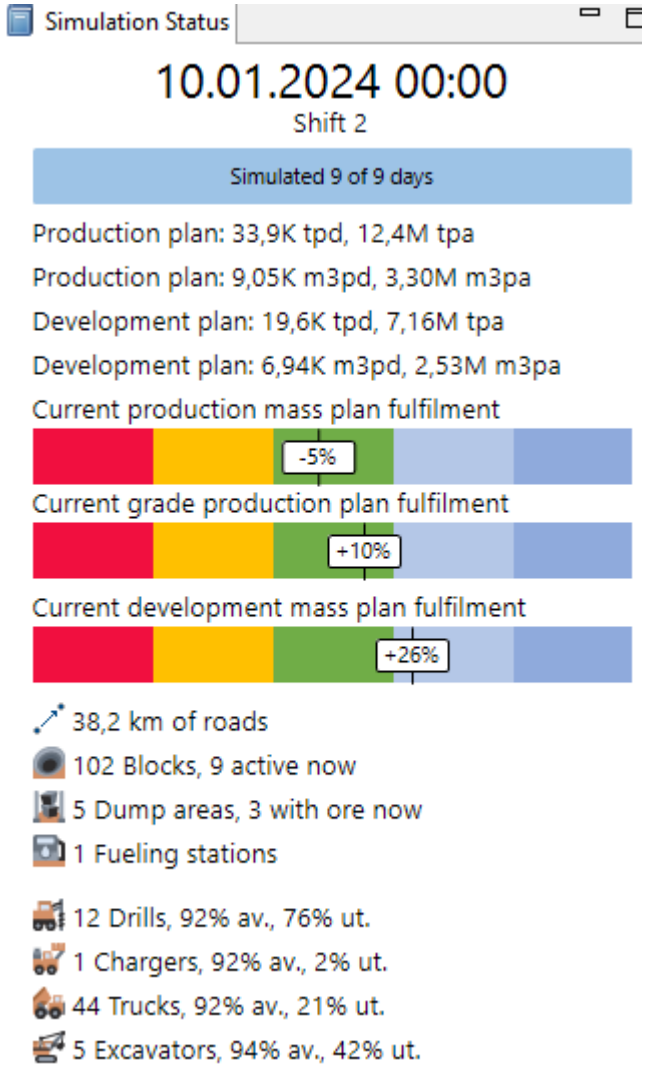
allows you to display the schedule for a specific date. The button hows only the equipment and blocks that have tasks on the selected date. The button allows you to set the date, and the button centers the Gantt chart on the selected date if button is active.

2.3. Statistical information

2.3.1. Simulation status

On the left side of the simulation screen, the **Simulation Status** panel displays general information about the progress of the simulation experiment:

- Current simulation date and time
- Current shift number
- Number of simulated days
- Daily and yearly ore production plan by mass and volume (volume is calculated from mass using weighted average density)
- Daily and yearly development plan by mass and volume (volume is calculated from mass using weighted average density)
- Percentage of ore production plan fulfillment by mass
- Percentage of ore production plan fulfillment by grade
- Percentage of development plan fulfillment by mass
- Total road length (km)
- Total number of blocks in the scenario and the number of blocks currently active
- Number of dump locations and number of dump locations containing ore mass
- Number of fueling stations
- Number of equipment units, their availability factor (av.) and utilization factor (ut.)



2.3.2. Summary statistics

The **Summary Statistics** table displays the key indicators of the simulation experiment results:

- Actual quantity of total mined rock mass delivered to dumping points, and separately for ore and waste
- Planned production (total, ore, waste)
- Deviation from production plan, %
- Cumulative production of substance, t
- Planned cumulative production of substance, t
- Deviation from substance production plan, %
- Average work in progress (WIP), total and separately for production and development, t: the average amount of rock mass (ore, waste, etc.) in tonnes that lies between two mining stages. Example: drilling WIP — rock mass for which drilling has started but charging has not yet begun
- Average lead time to mine one tonne of rock mass, total and separately for production and development, days: the time required to mine one tonne of rock mass from drilling to final dumping point

- Fraction of plant operating time, %
- Equipment availability by equipment type, %
- Downtime fraction by equipment type, %
- Equipment utilization and effective utilization rate by equipment type, %
- Average daily distance traveled by all trucks, km
- Average daily haulage volume, t·km
- Average haulage distance, m
- Average haulage ascent, m
- Average truck cycles per truck per day
- Total costs, and separately fixed, variable, and capital costs, USD

Summary Statistics

Total tons	513 639
Total production tons	290 420
Mining plan cumulative	305 395
Act/plan deviation	-4,90%
Total development tons	223 219
Development plan cumulative	176 567
Dev. act/plan deviation	+26,42%
Mined development cumulative, m^3	82 674
Development plan cumulative, m^3	47 084
Substance cumulative	134 755
Substance plan cumulative	122 158
Substance deviation	+10,31%
Average WIP, tonnes	1 568 89...
Average lead time, days	5,96
Average production WIP, tonnes	568 958
Average production lead time, days	6,19
Average development WIP, tonnes	999 938,...
Average development lead time, days	5,65
Plant work time fraction, %	+95,10%
Avg. tonnes hauled per day, t	32 268,89
Trucks availability, %	+92,22%
Drills availability, %	+91,82%
Excavators availability, %	+93,79%
Chargers availability, %	+91,64%
Trucks lost time, %	+8,80%
Drills lost time, %	+0,00%
Excavators lost time, %	+19,24%
Chargers lost time, %	+0,00%
Trucks utilization, %	+20,67%
Drills Utilization, %	+76,08%
Excavators utilization, %	+42,42%
Chargers utilization, %	+2,30%
Trucks effective utilization, %	+18,85%
Drills effective utilization, %	+76,08%
Excavators effective utilization, %	+34,26%
Chargers effective utilization, %	+2,30%
Avg. all trucks kilometers per day, km	1 945
Avg. haulage mass per day, t*km	288 963
Avg. tonnes per truck per day, t	733
Avg. haulage mass per truck per day, t*km	6 567
Avg. haulage distance, m	5 214
Avg. haulage ascent, m	228
Avg. truck cycles per truck per day	513 639
Total costs, USD	0,00
Fixed costs, USD	0,00
Variable costs, USD	0,00
Capital costs, USD	0,00

2.3.3. Daily volume stats

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

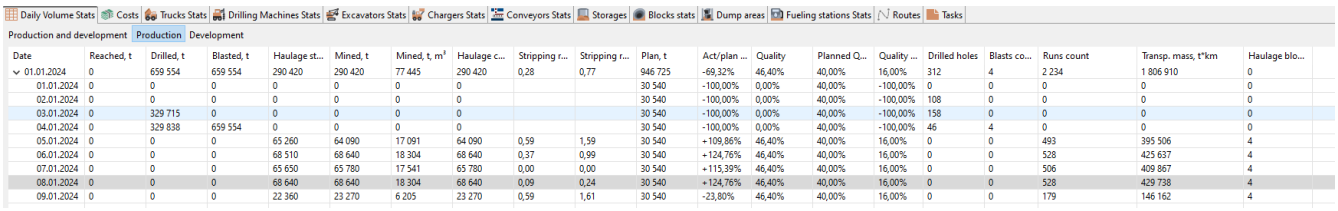
- **Reached** - amount of rock mass available for drilling(ore mass in blocks with open access)
- **Drilled** - amount of rock mass prepared for blasting, t
- **Blasted** - Amount of blasted rock mass ready for haulage, t
- **Haulage started** - amount of rock mass loaded into trucks, t
- **Mined, t and m^3** - amount of rock mass delivered to dumping points where it could be recognized as mined according to **Mined ore recognition rule**, t and m³ — corresponds to the mined rock mass volume resulting from the simulation
- **Haulage completed** - amount of rock mass unloaded from trucks, t

The following production indicators are also displayed:

- **Stripping ratio, m³/t** — ratio of waste volume mined (m³) to ore mass mined (t)
- **Stripping ratio, t/t** — ratio of waste mass mined (t) to ore mass mined (t)
- **Plan** - planned mining volume for the period (daily or monthly), t
- **Act/plan deviation** - deviation of simulated volume from the plan
- **Quality** - simulated ore quality, daily and monthly (percentage of valuable component)
- **Planned quality** - planned ore quality, daily and monthly (percentage of valuable component)
- **Quality deviation** - deviation of simulated ore quality from the plan

Additionally, general daily statistics are provided:

- **Drilled holes** - number of drilled blast holes
- **Blasts count** - number of blasts
- **Runs count** - number of truck trips
- **Transp. mass** - haulage volume, t·km
- **Haulage blocks** - number of blocks with ore to haul at the beginning of the period

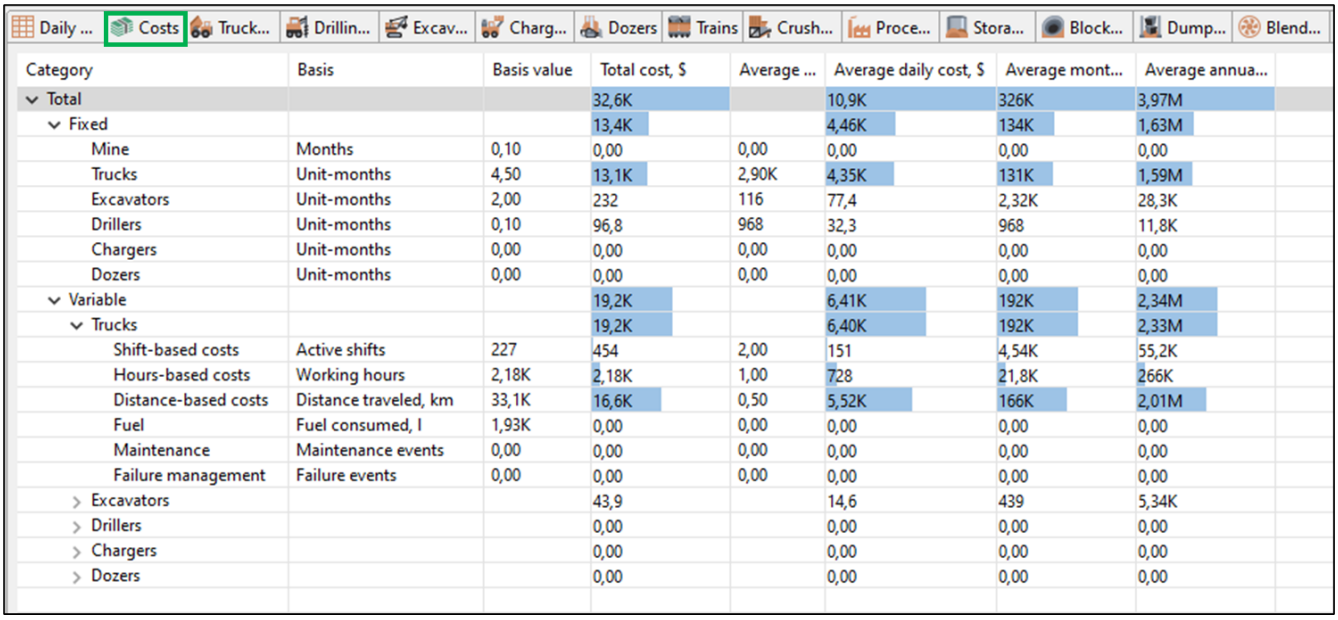

Daily Volume Stats | Costs | Trucks Stats | Drilling Machines Stats | Excavators Stats | Chargers Stats | Conveyors Stats | Storages | Blocks stats | Dump areas | Fueling stations Stats | Routes | Tasks

Production and development | Production | Development

Date	Reached, t	Drilled, t	Blasted, t	Haulage st...	Mined, t	Mined, t, m³	Haulage c...	Stripping r...	Stripping r...	Plan, t	Act/plan ...	Quality	Planned Q...	Quality ...	Drilled holes	Blasts co...	Runs count	Transp. mass, t*km	Haulage blo...
01.01.2024	0	659 554	659 554	290 420	290 420	77 445	290 420	0,28	0,77	946 725	-69,32%	46,40%	40,00%	16,00%	312	4	2 234	1 806 910	0
01.01.2024	0	0	0	0	0	0	0			30 540	-100,00%	0,00%	40,00%	-100,00%	0	0	0	0	0
02.01.2024	0	0	0	0	0	0	0			30 540	-100,00%	0,00%	40,00%	-100,00%	108	0	0	0	0
03.01.2024	0	329 715	0	0	0	0	0			30 540	-100,00%	0,00%	40,00%	-100,00%	158	0	0	0	0
04.01.2024	0	329 838	659 554	0	0	0	0			30 540	-100,00%	0,00%	40,00%	-100,00%	46	4	0	0	0
05.01.2024	0	0	0	65 260	64 090	17 091	64 090	0,59	1,59	30 540	+109,86%	46,40%	40,00%	16,00%	0	0	493	395 506	4
06.01.2024	0	0	0	68 510	68 640	18 304	68 640	0,37	0,99	30 540	+124,76%	46,40%	40,00%	16,00%	0	0	528	425 637	4
07.01.2024	0	0	0	65 650	65 780	17 541	65 780	0,00	0,00	30 540	+115,39%	46,40%	40,00%	16,00%	0	0	506	409 867	4
08.01.2024	0	0	0	68 640	68 640	18 304	68 640	0,09	0,24	30 540	+124,76%	46,40%	40,00%	16,00%	0	0	528	429 738	4
09.01.2024	0	0	0	22 360	23 270	6 205	23 270	0,59	1,61	30 540	-23,80%	46,40%	40,00%	16,00%	0	0	179	146 162	4

2.3.4. Costs

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



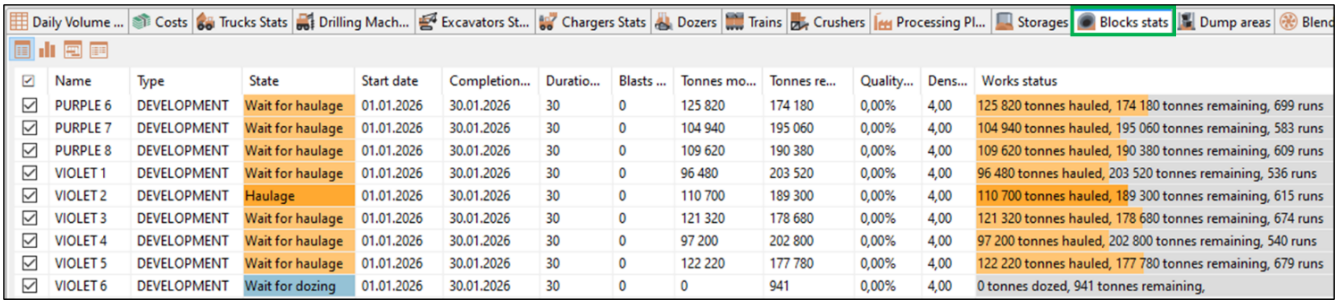
Category	Basis	Basis value	Total cost, $	Average ...	Average daily cost, $	Average mont...	Average annua...
Total			32,6K		10,9K	326K	3,97M
Fixed			13,4K		4,46K	134K	1,63M
Mine	Months	0,10	0,00	0,00	0,00	0,00	0,00
Trucks	Unit-months	4,50	13,1K	2,90K	4,35K	131K	1,59M
Excavators	Unit-months	2,00	232	116	77,4	2,32K	28,3K
Drillers	Unit-months	0,10	96,8	968	32,3	968	11,8K
Chargers	Unit-months	0,00	0,00	0,00	0,00	0,00	0,00
Dozers	Unit-months	0,00	0,00	0,00	0,00	0,00	0,00
Variable			19,2K		6,41K	192K	2,34M
Trucks			19,2K		6,40K	192K	2,33M
Shift-based costs	Active shifts	227	454	2,00	151	4,54K	55,2K
Hours-based costs	Working hours	2,18K	2,18K	1,00	728	21,8K	266K
Distance-based costs	Distance traveled, km	33,1K	16,6K	0,50	5,52K	166K	2,01M
Fuel	Fuel consumed, l	1,93K	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	0,00	0,00	0,00	0,00	0,00	0,00
Excavators			43,9		14,6	439	5,34K
Drillers			0,00		0,00	0,00	0,00
Chargers			0,00		0,00	0,00	0,00
Dozers			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.

2.3.5. Blocks stats

The "Blocks Stats" table shows data on the state of blocks at each moment of time.



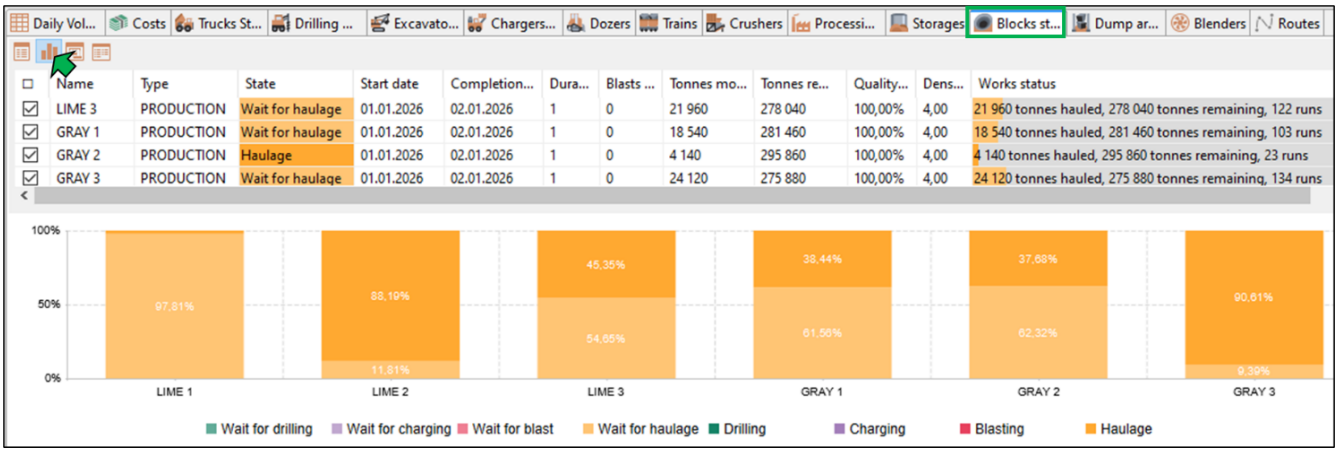
Name	Type	State	Start date	Completion...	Duratio...	Blasts ...	Tonnes mo...	Tonnes re...	Quality...	Dens...	Works status
PURPLE 6	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	125 820	174 180	0,00%	4,00	125 820 tonnes hauled, 174 180 tonnes remaining, 699 runs
PURPLE 7	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	104 940	195 060	0,00%	4,00	104 940 tonnes hauled, 195 060 tonnes remaining, 583 runs
PURPLE 8	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	109 620	190 380	0,00%	4,00	109 620 tonnes hauled, 190 380 tonnes remaining, 609 runs
VIOLET 1	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	96 480	203 520	0,00%	4,00	96 480 tonnes hauled, 203 520 tonnes remaining, 536 runs
VIOLET 2	DEVELOPMENT	Haulage	01.01.2026	30.01.2026	30	0	110 700	189 300	0,00%	4,00	110 700 tonnes hauled, 189 300 tonnes remaining, 615 runs
VIOLET 3	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	121 320	178 680	0,00%	4,00	121 320 tonnes hauled, 178 680 tonnes remaining, 674 runs
VIOLET 4	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	97 200	202 800	0,00%	4,00	97 200 tonnes hauled, 202 800 tonnes remaining, 540 runs
VIOLET 5	DEVELOPMENT	Wait for haulage	01.01.2026	30.01.2026	30	0	122 220	177 780	0,00%	4,00	122 220 tonnes hauled, 177 780 tonnes remaining, 679 runs
VIOLET 6	DEVELOPMENT	Wait for dozing	01.01.2026	30.01.2026	30	0	0	941	0,00%	4,00	0 tonnes dozed, 941 tonnes remaining,

The following is shown for each block:

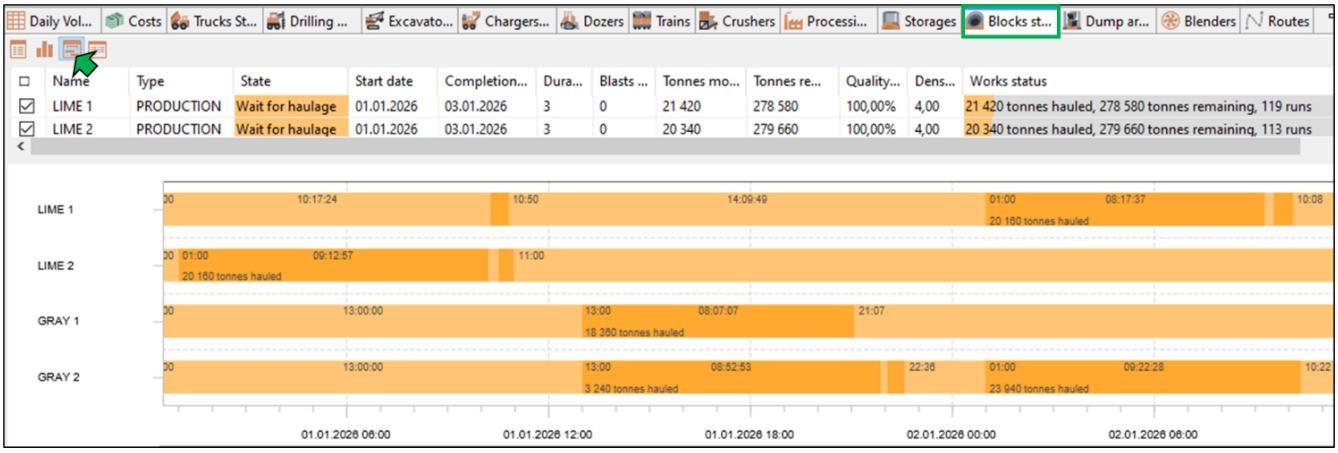
- Mine area to which the block belongs
- Type (production or development)

- State of the block (wait for haulage, haulage, etc.)
- Start and completion date
- Duration of state
- Blasts count
- Tonnes hauled
- Tonnes remaining
- Quality (substance content)
- Density
- Works status: volume of completed and remaining work in the block (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 blocks stats.



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



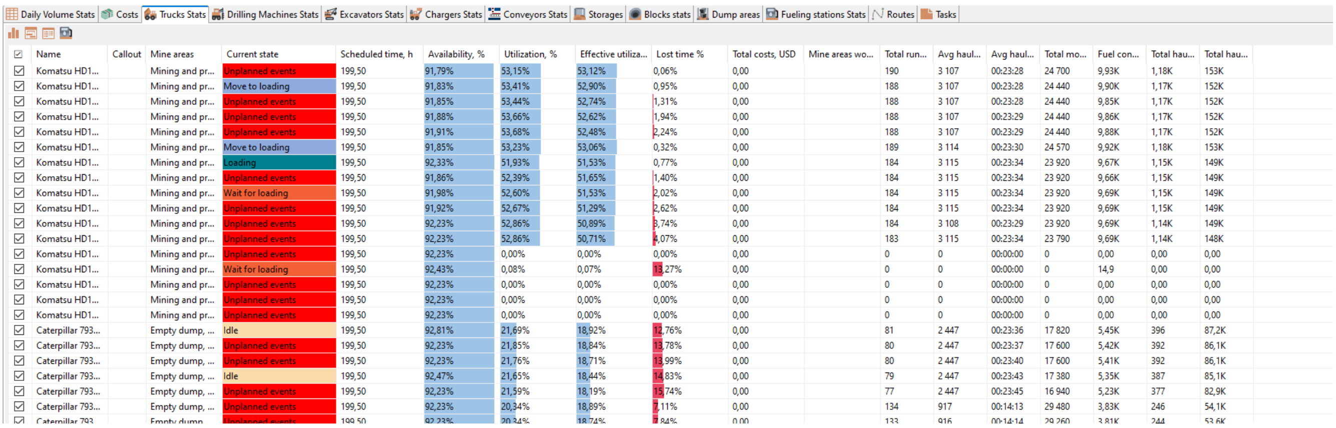
2.3.6. Equipment stats

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

- **Callout** - allows you to display callout window for selected equipment unit

- **Mine area** to which the equipment unit is assigned
- **Current state** — movement, operating, no tasks, etc.
- **Scheduled time** — scheduled operating in-shift time of the equipment unit
- **Availability, %** — the ratio of the time when the equipment was available for work (according to the schedule and planned unavailability periods) to the total scheduled time. For example, a truck operates two shifts of 10 hours each. Its total in-shift time is therefore 20 hours. Within each shift, it has a 0.5-hour lunch break, and at the start of the first shift it has scheduled maintenance lasting 2 hours. Thus, the truck's available working time for that day is: *20 − 0.5 × 2 − 2 = 17 hours*; *Availability = 17 ÷ 20 = 85 %*
- **Utilization, %** — the ratio of the time when the equipment was performing tasks to the total scheduled time. For example, a truck operates two shifts of 10 hours each. Its total in-shift time is therefore 20 hours. During this time, the truck spent 5 hours in motion, 3 hours loading, 2 hours unloading, and 1 hour waiting in the loading queue at an excavator. Thus, the total time spent on work during the day is: *5 + 3 + 2 + 1 = 11 hours*; *Utilization = 11 ÷ 20 = 55 %*
- **Effective utilization, %** — the utilization factor excluding non-productive time. In the previous example, the total time the truck spent on productive work, excluding time spent waiting in the queue, is: *11 − 1 = 10 hours*; *Effective utilization = 10 ÷ 20 = 50 %*
- **Lost time, %** — the ratio of non-productive time to the total task execution time. In the previous example, the total time the truck spent on work is 11 hours, of which 1 hour was "lost" while waiting in a queue. Thus, the share of lost time is: *1 ÷ 11 = 9 %*
- **Total costs, USD**
- **Mine areas worked** — a list of the mining areas where this equipment unit operated during the simulation.

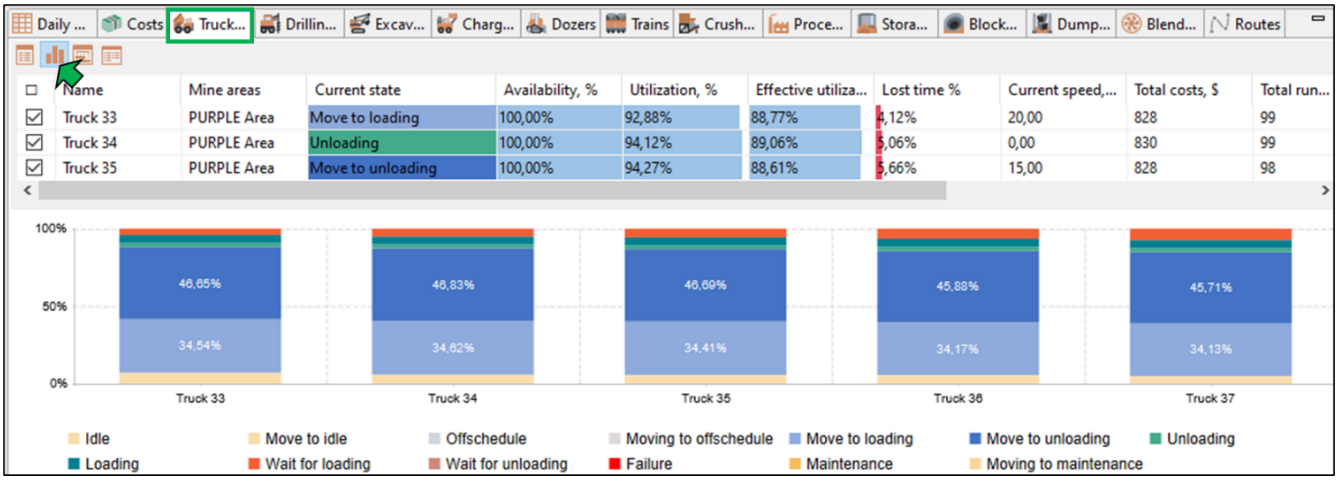
An example table of equipment operation data, shown for trucks, is provided in the figure.



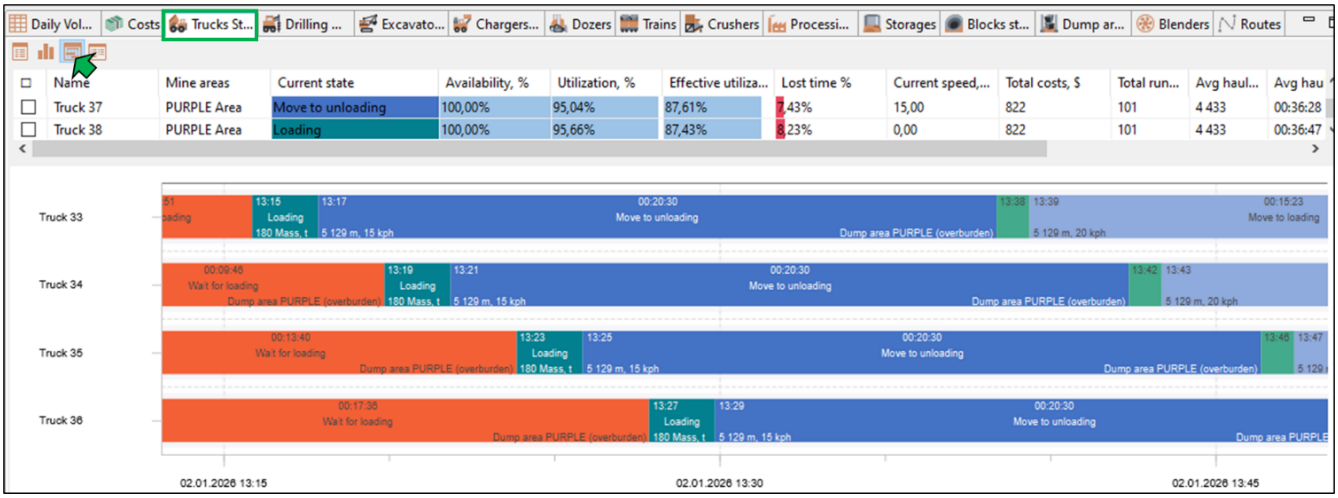
Name	Callout	Mine areas	Current state	Scheduled time, h	Availability, %	Utilization, %	Effective utiliza...	Lost time %	Total costs, USD	Mine areas wo...	Total run...	Avg haul...	Avg haul...	Total mo...	Fuel con...	Total hau...	Total hau...
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,79%	53,15%	53,12%	0,06%	0,00		190	3 107	00:23:28	24 700	9,93K	1,18K	153K
Komatsu HD1...		Mining and pr...	Move to loading	199,50	91,83%	53,41%	52,90%	0,95%	0,00		188	3 107	00:23:28	24 440	9,90K	1,17K	152K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,85%	53,44%	52,74%	1,31%	0,00		188	3 107	00:23:28	24 440	9,85K	1,17K	152K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,88%	53,66%	52,62%	1,94%	0,00		188	3 107	00:23:29	24 440	9,86K	1,17K	152K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,91%	53,68%	52,48%	2,24%	0,00		188	3 107	00:23:29	24 440	9,88K	1,17K	152K
Komatsu HD1...		Mining and pr...	Move to loading	199,50	91,85%	53,23%	53,06%	0,32%	0,00		189	3 114	00:23:30	24 570	9,92K	1,18K	153K
Komatsu HD1...		Mining and pr...	Loading	199,50	92,33%	51,93%	51,53%	0,77%	0,00		184	3 115	00:23:34	23 920	9,67K	1,15K	149K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,86%	52,39%	51,65%	1,40%	0,00		184	3 115	00:23:34	23 920	9,66K	1,15K	149K
Komatsu HD1...		Mining and pr...	Wait for loading	199,50	91,98%	52,60%	51,53%	2,02%	0,00		184	3 115	00:23:34	23 920	9,69K	1,15K	149K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	91,92%	52,67%	51,29%	2,62%	0,00		184	3 115	00:23:34	23 920	9,69K	1,15K	149K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	52,86%	50,89%	3,74%	0,00		184	3 108	00:23:29	23 920	9,69K	1,14K	149K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	52,86%	50,71%	4,07%	0,00		183	3 115	00:23:34	23 790	9,69K	1,14K	148K
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	0,00%	0,00%	0,00%	0,00		0	0	00:00:00	0	0,00	0,00	0,00
Komatsu HD1...		Mining and pr...	Wait for loading	199,50	92,43%	0,08%	0,07%	13,27%	0,00		0	0	00:00:00	0	14,9	0,00	0,00
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	0,00%	0,00%	0,00%	0,00		0	0	00:00:00	0	0,00	0,00	0,00
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	0,00%	0,00%	0,00%	0,00		0	0	00:00:00	0	0,00	0,00	0,00
Komatsu HD1...		Mining and pr...	Unplanned events	199,50	92,23%	0,00%	0,00%	0,00%	0,00		0	0	00:00:00	0	0,00	0,00	0,00
Caterpillar 793...		Empty dump, ...	Idle	199,50	92,81%	21,69%	18,92%	12,76%	0,00		81	2 447	00:23:36	17 820	5,45K	396	87,2K
Caterpillar 793...		Empty dump, ...	Unplanned events	199,50	92,23%	21,85%	18,84%	13,78%	0,00		80	2 447	00:23:37	17 600	5,42K	392	86,1K
Caterpillar 793...		Empty dump, ...	Unplanned events	199,50	92,23%	21,76%	18,71%	13,99%	0,00		80	2 447	00:23:40	17 600	5,41K	392	86,1K
Caterpillar 793...		Empty dump, ...	Idle	199,50	92,47%	21,65%	18,44%	14,83%	0,00		79	2 447	00:23:43	17 380	5,35K	387	85,1K
Caterpillar 793...		Empty dump, ...	Unplanned events	199,50	92,23%	21,59%	18,19%	15,74%	0,00		77	2 447	00:23:45	16 940	5,23K	377	82,9K
Caterpillar 793...		Empty dump, ...	Unplanned events	199,50	92,23%	20,34%	18,89%	7,11%	0,00		134	917	00:14:13	29 480	3,83K	246	54,1K
Caterpillar 793		Empty dump	Unplanned events	199,50	92,23%	20,34%	18,74%	7,84%	0,00		133	916	00:14:14	29 260	3,81K	244	53,6K

In addition, for certain types of equipment, additional specific statistics are displayed, such as the number of trips for trucks, the number of drilled holes for drill rigs, etc.

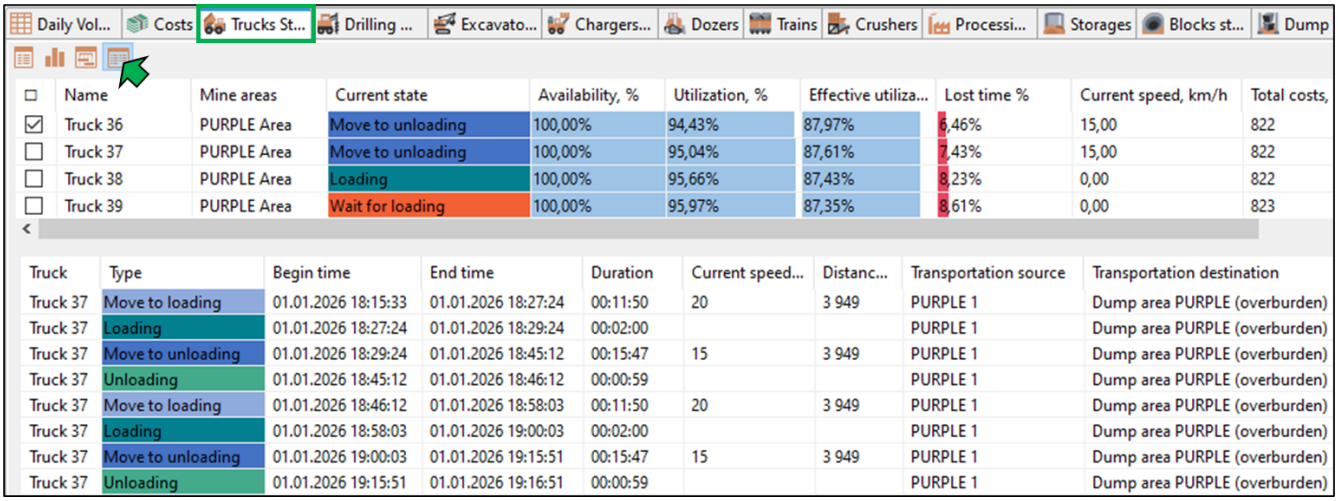
The button in the upper right corner of the table opens the display of equipment operation stats in the form of a bar chart.



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



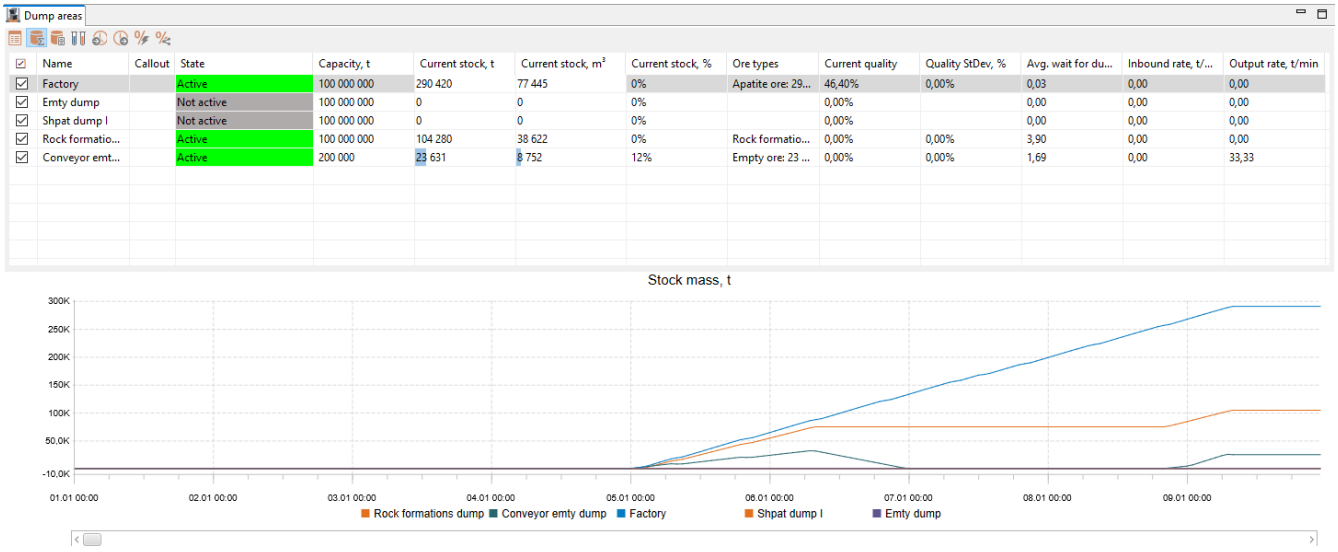
The button  in the upper right corner of the table opens a table with detailed information about the equipment states for the entire simulation period.



2.3.7. Dump areas and storages

Separate tables for ore dump areas and storages display information about their current status, such as occupancy, types and quality of ore, etc.

The **Dump areas** table is shown in the figure:



The following information is displayed for each dump area:

- **Callout** — allows you to display callout window for selected object
- **State** — inactive/unavailable, active, leveling required, dozer leveling, filled, and leveling completed
- **Capacity, t**
- **Current stock** — in tonnes, m^3, and % of capacity
- **Ore types** — amount of ore mass by type contained in the location
- **Current quality, %** — current grade of valuable component in the ore mass at the location
- **Quality StDev, %** — standard deviation of ore mass quality, %
- **Avg. wait for dumping time, min** - average waiting time before dumping at this location
- **Inbound rate, t/min** — ore mass inflow rate, t/min
- **Outbound rate, t/min** — ore mass outflow rate, t/min.

The buttons in the upper toolbar of the **Dump areas** and **Strages** windows open separate charts that display:

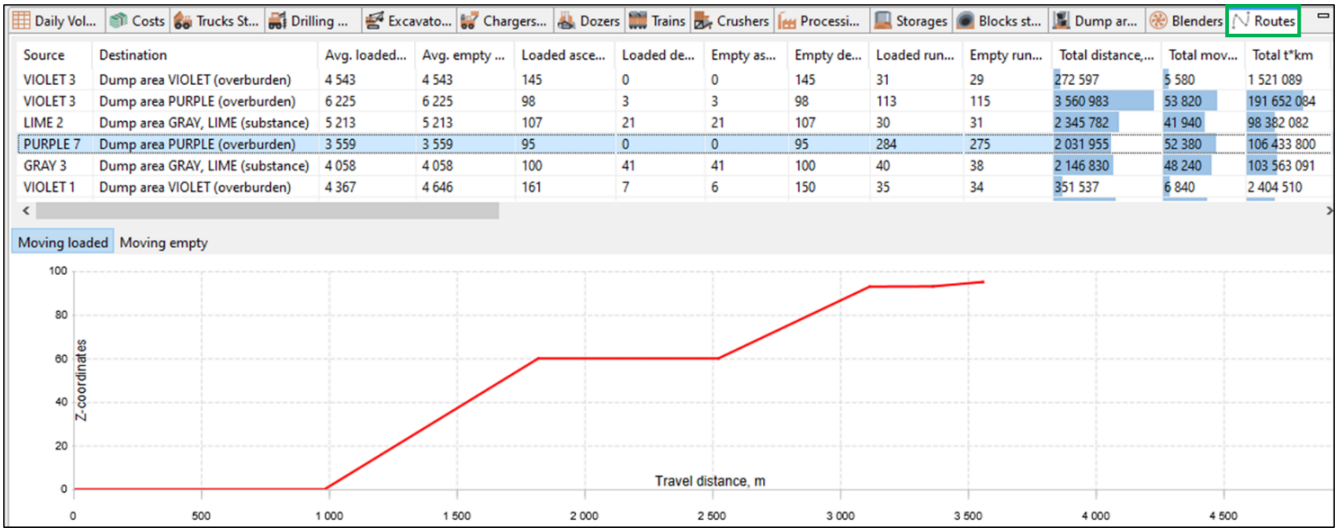
- Ore mass stock in dump areas, in tons
- Volume of ore mass stock in dump areas, in m3
- Change in the quality of the ore mass, in %
- Hourly inflow rate of ore mass entering the dump area, t/min
- Hourly outflow rate of ore mass from the dump area, t/min.
- Changes in the quality of ore fragments, %
- Quality variation, %.

2.3.8. Routes stats

The **Routes** table displays the following data for each route:

- Average haul distance loaded/empty, m
- Ascent loaded/empty, m
- Descent loaded/empty, m
- Number of loaded trips / return trips
- Total distance traveled, km
- Total tonnes hauled
- Total tonne-kilometers
- Average travel time loaded/empty, min
- Average travel speed loaded/empty, km/h
- Duration of the full loading–hauling–unloading cycle, min
- Percentage of time spent loading / unloading / waiting
- Quality of material hauled on the route, %
- List of equipment types and units that performed trips along the route

For each route a Z-axis profile of the route is displayed for loaded and empty route leg.



Source	Destination	Avg. loaded...	Avg. empty ...	Loaded asce...	Loaded de...	Empty as...	Empty de...	Loaded run...	Empty run...	Total distance,...	Total mov...	Total t*km
VIOLET 3	Dump area VIOLET (overburden)	4 543	4 543	145	0	0	145	31	29	272 597	5 580	1 521 089
VIOLET 3	Dump area PURPLE (overburden)	6 225	6 225	98	3	3	98	113	115	3 560 983	53 820	191 652 084
LIME 2	Dump area GRAY, LIME (substance)	5 213	5 213	107	21	21	107	30	31	2 345 782	41 940	98 382 082
PURPLE 7	Dump area PURPLE (overburden)	3 559	3 559	95	0	0	95	284	275	2 031 955	52 380	106 433 800
GRAY 3	Dump area GRAY, LIME (substance)	4 058	4 058	100	41	41	100	40	38	2 146 830	48 240	103 563 091
VIOLET 1	Dump area VIOLET (overburden)	4 367	4 646	161	7	6	150	35	34	351 537	6 840	2 404 510

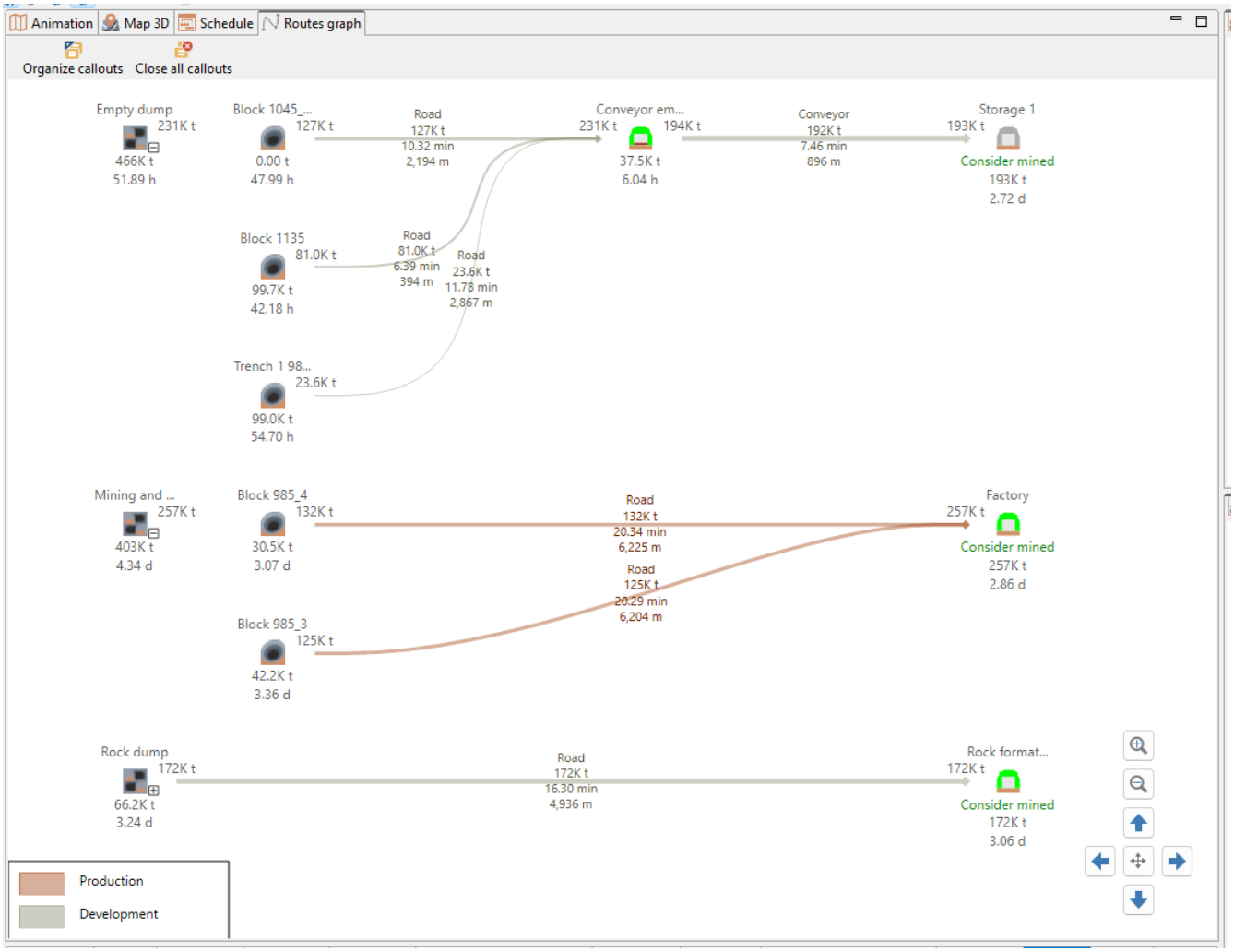
2.3.9. Routes graph

The **Routes graph** displays haulage routes in the form of a graph. It provides a visual overview of the route network used during the simulation.

The graph shows:

- Route points and related production objects, such as loading and unloading locations
- Connections between these points that form haulage routes
- The overall structure of the route network in the scenario

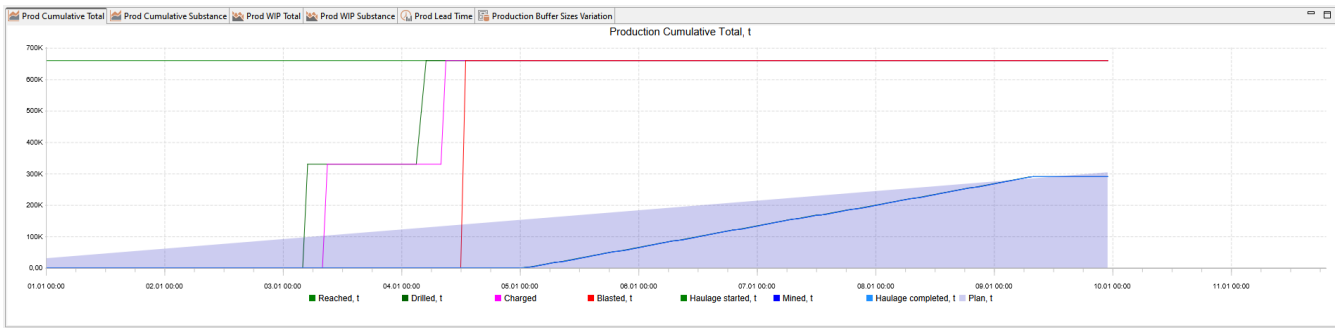
This view complements the **Routes** table and helps analyze route connectivity and understand how the haulage network is organized.



2.4. Graphs and charts

The MineTwin OpenPit visualization includes various graphs and charts for analyzing simulation results. By default, they are grouped into three windows on the right side of the screen.

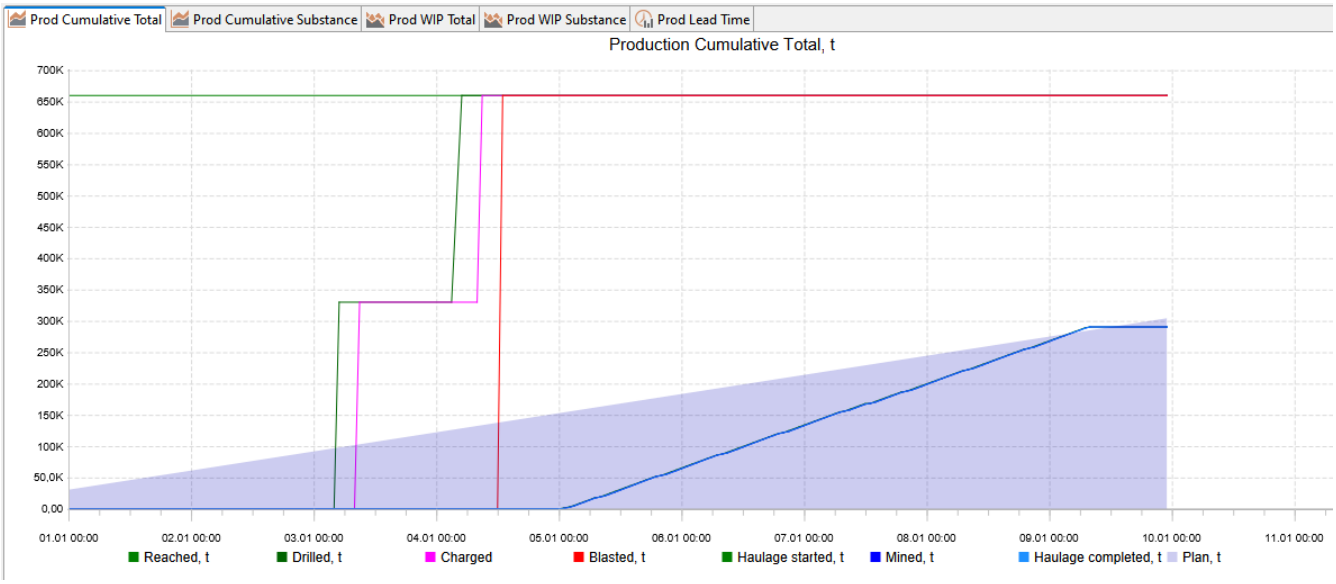
2.4.1. Charts for analyzing actual production mining



Several graphs in the upper right window are dedicated to the production mining. They are:

2.4.2. Production Cumulative Total Chart

The **Production Cumulative Total** chart displays the cumulative progress of mining operations over time, showing the total amount of ore mass (in tonnes) that has passed through each stage of the mining cycle.



This chart helps track how much ore mass has been reached, drilled, charged, blasted, hauled, and mined relative to the production plan. It allows users to visually compare actual progress against planned targets.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Cumulative tonnage (t)

Lines and Areas

- **Reached, t** — ore mass in blocks that have become accessible for drilling
- **Drilled, t** — ore mass in blocks where drilling has been completed
- **Charged, t** — ore mass in blocks where charging has been completed
- **Blasted, t** — ore mass in blocks that have been blasted and are ready for hauling
- **Haulage started, t** — ore mass currently being hauled
- **Mined, t** — ore mass, that was considered as mined
- **Haulage completed, t** — ore mass that has been delivered to dump locations
- **Plan, t** (filled area) — cumulative planned production target

How to Use:

- Monitor the buildup of tonnage through each stage of the production cycle.
- Verify that actual production (mined/haulage completed) is following the planned trajectory.
- Identify bottlenecks: flat lines indicate inactive stages where no progress occurred during the

period.

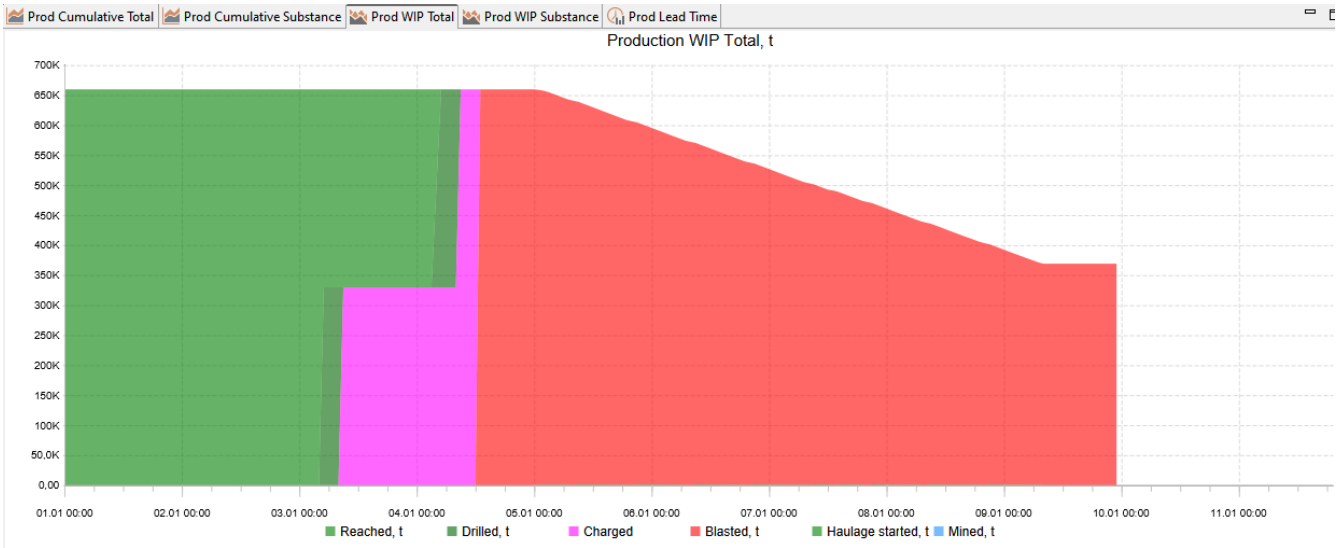
- Detect delays: if the mined line lags significantly behind the plan area, production is behind schedule.

2.4.3. Production Cumulative Substance Chart

The **Production Cumulative Substance** chart uses the same logic as **Production Cumulative Total** chart but for useful material, contained in ore mass.

2.4.4. Production WIP Total Chart

The **Production WIP (Work In Progress) Total** chart shows the amount of ore mass (in tonnes) that is currently in progress at each stage of the mining cycle over time.



This chart helps analyze where ore mass is “accumulating” in the production process at any given moment. It shows how much rock mass is waiting at each stage — drilled, charged, blasted, or awaiting haulage — and helps identify production bottlenecks.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Amount of ore mass currently in progress (t)

Stacked Areas:

- **Reached, t** — ore mass in blocks that have become accessible but not yet drilled
- **Drilled, t** — ore mass drilled but not yet charged
- **Charged, t** — ore mass charged but not yet blasted
- **Blasted, t** — ore mass blasted and awaiting haulage
- **Haulage started, t** — ore mass currently being hauled but is not yet considered as mined
- **Mined, t** — ore mass that was considered as mined, but which haulage is not yet completed

How to Use:

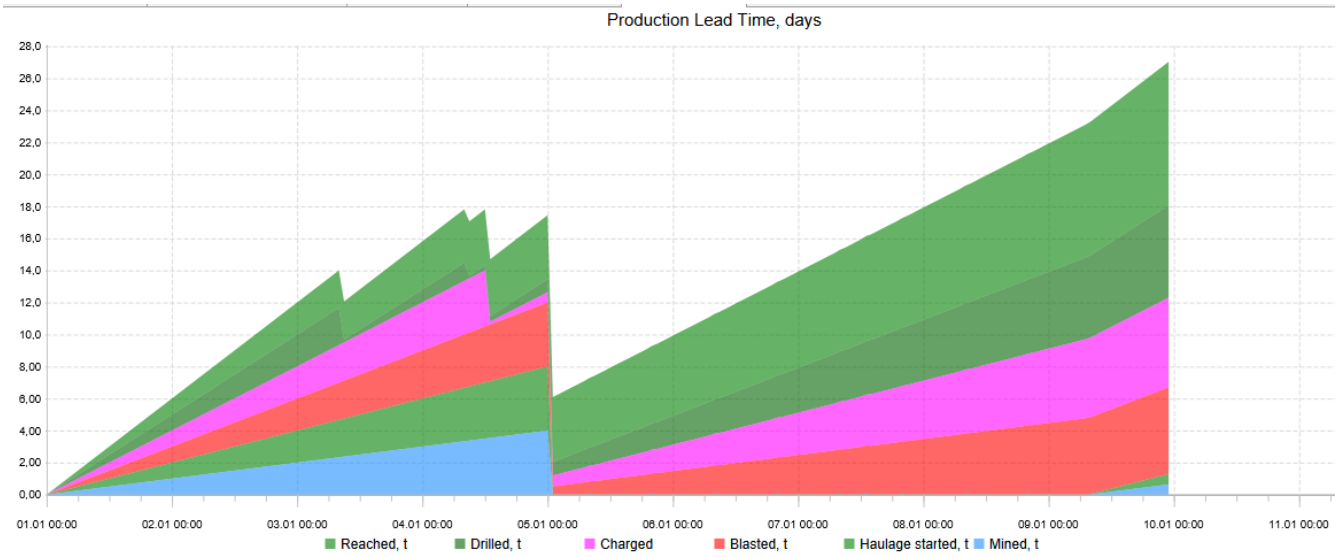
- Observe how material flows through different stages and where it accumulates.
- Detect production bottlenecks — if material builds up in one stage (for example, large red area = blasted but not hauled), it may indicate insufficient equipment capacity at the next stage.
- Verify process balance — steady material levels at all stages indicate a smooth production flow, while sharp spikes or drops show interruptions.
- Monitor the depletion of blasted material as it is gradually hauled away.

2.4.5. Production WIP Substance Chart

The **Production WIP Substance** chart uses the same logic as **Production WIP Total** chart but for useful material, contained in ore mass.

2.4.6. Production Lead Time Chart

The **Production Lead Time** chart shows how long ore mass (in days) spends in each stage of the mining process, calculated as how many days ore mass is staying in its current stage of the mining process at each point of time.



This chart helps analyze the overall efficiency of the production chain by showing how much time it takes for ore mass to pass through each stage — from becoming accessible to being hauled to the final destination. It helps identify delays or bottlenecks that increase the total cycle time.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Lead time in days

Stacked Areas (lead time contribution by stage):

- **Reached, d** — time ore mass spends between becoming accessible and drilling start
- **Drilled, d** — time ore mass spends between drilling and charging
- **Charged, d** — time between charging and blasting

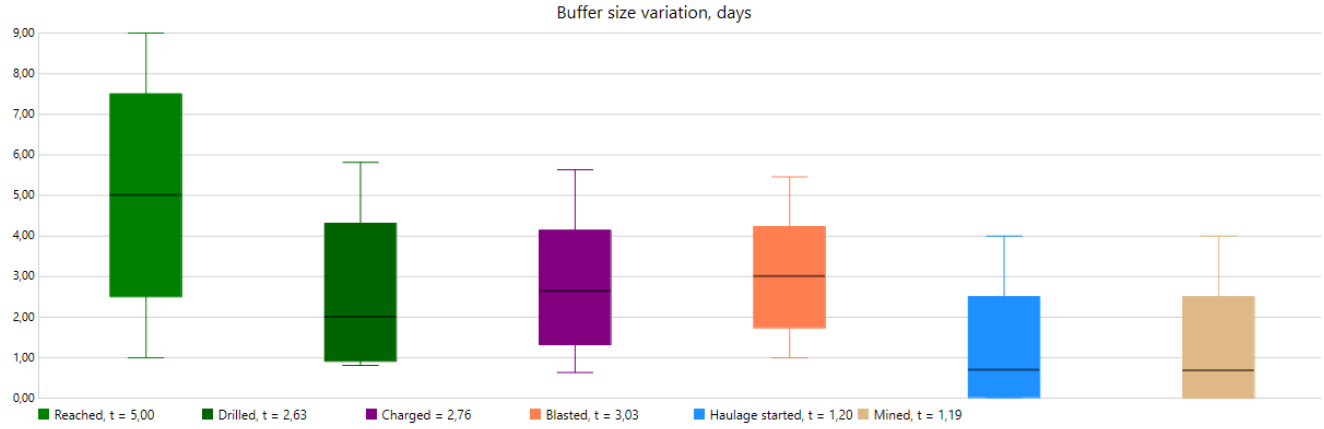
- **Blasted, d** — time between blasting and the start of haulage
- **Haulage started, d** — time from haulage start to being considered as mined
- **Mined, d** — time from being considered as mined to being hauled to the final destination

How to Use:

- Evaluate the total production cycle time: higher values indicate slower throughput.
- Identify stages that contribute most to delays — the thickest colored areas show where ore mass spends the most time.
- Track how lead time changes over the simulation period:
  - A growing slope means lead times are increasing (process is slowing down).
  - A declining or stable slope means throughput is improving or stable.
- Use this chart alongside the **WIP** and **Cumulative Total** charts to link time delays to ore mass accumulations.

2.4.7. Production Buffer Size Variation Chart

The **Production Buffer Size Variation** chart shows how long ore mass (in days) typically waits at each stage of the mining process before moving to the next stage. It visualizes the distribution of buffer sizes (work-in-progress inventories) for all production stages.



This chart helps assess the stability of production flow and detect where excessive ore mass accumulation or delays are occurring. It indicates how much waiting time builds up at each stage, revealing imbalances between process steps.

Chart Elements:

- X-axis (horizontal): Stages of the mining cycle
- Y-axis (vertical): Buffer size expressed as time in days

Box Plot Components for Each Stage:

- **Reached, d** — waiting time before drilling starts
- **Drilled, d** — waiting time before charging starts
- **Charged, d** — waiting time before blasting

- **Blasted, d** — waiting time before haulage
- **Haulage started, d** — time ore mass spends during haulage before it is considered mined
- **Mined, d** — time ore mass spends after it is considered mined before arriving to the final destination

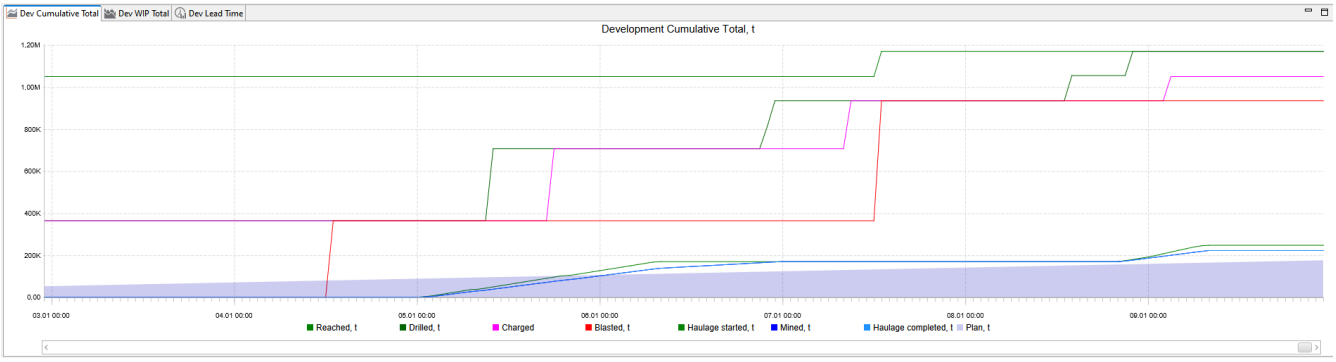
Each box shows:

- **Median line (black)** — typical buffer size in days
- **Box (colored)** — 25th to 75th percentile range (middle 50% of values)
- **Whiskers** — minimum and maximum values

How to Use:

- Identify stages where buffers are largest (tall boxes) — they indicate potential bottlenecks or idle queues.
- Check variation width — wide boxes or long whiskers mean unstable flow and uneven processing.
- Aim for balanced buffer times across stages to ensure smooth production and reduce idle times.
- Use together with the **WIP** and **Lead Time** charts to connect buffer sizes with delays in throughput.

2.4.8. Charts for analyzing development mining



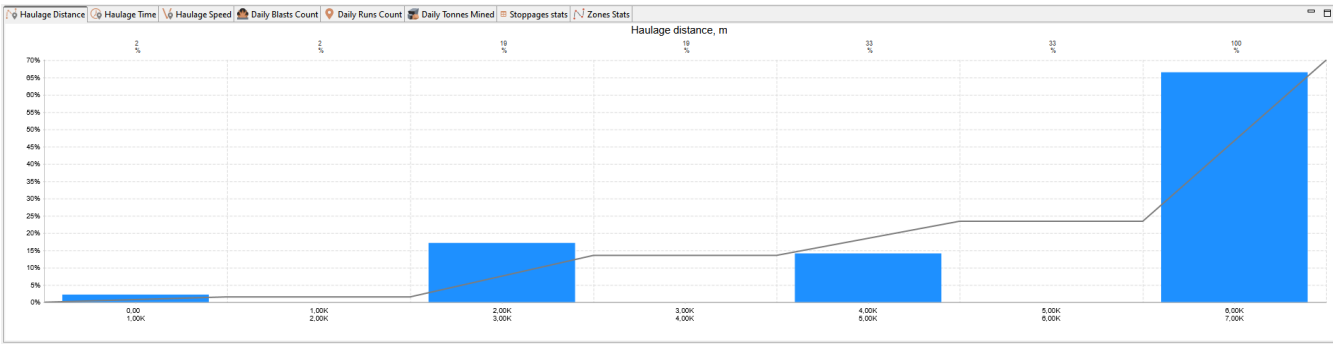
In the middle right window there are 3 charts for development mining:

- Development cumulative total
- Development WIP total
- Development lead time

They have the same logic as corresponding charts for production mining.

Note: On each chart, except box plot, you can click legend items to toggle the visibility of the corresponding data series. Clicking anywhere in the chart plot area will display the values of all visible data series at that point in time.

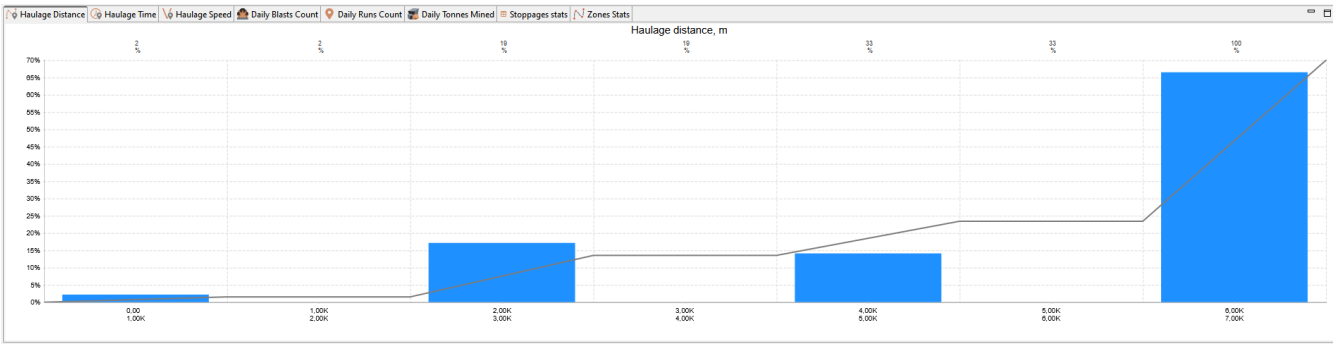
2.4.9. Other charts and tables



In the bottom-right window, several additional charts and tables are available, primarily focused on ore transportation statistics and other events.

2.4.10. Haulage Distance Chart

The **Haulage Distance** chart shows the distribution of haulage trip lengths (in meters) for all transportation runs completed during the simulation.



This chart helps analyze how far trucks or LHDs are traveling on average, identify typical haulage distances, and detect excessively long or inefficient routes that may reduce productivity.

Chart Elements:

- X-axis (horizontal): Haulage distance intervals (m)
- Y-axis (left vertical): Percentage of total trips in each distance interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

- **Blue bars** — show the share of trips within each distance interval (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as distance increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

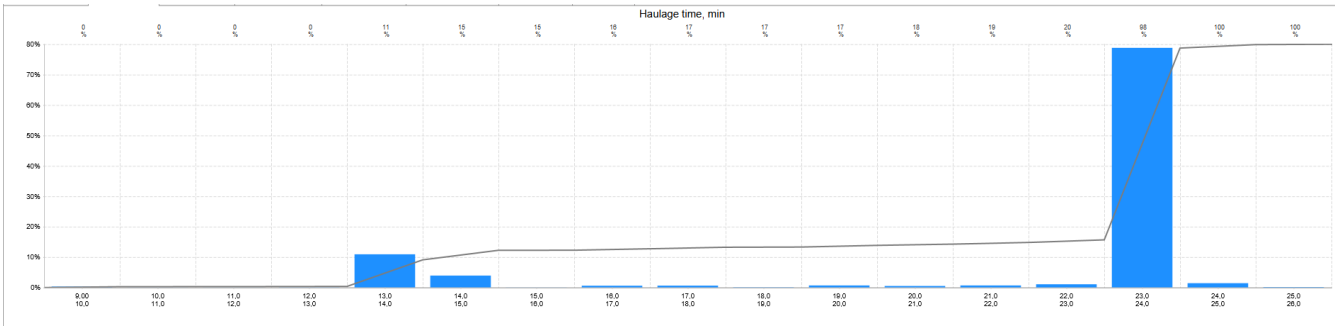
How to Use:

- Identify most common haulage distances — these appear as peaks in the histogram.
- Analyze distribution balance — if most trips are clustered at very short or very long distances, consider optimizing road layout or destination assignment.

- Track long-distance trips — high shares of long-distance hauling can indicate potential bottlenecks or inefficient routing.
- Use this chart together with **Haulage Time** and **Haulage Speed** charts to assess transport efficiency.

2.4.11. Haulage Time Chart

The **Haulage Time** chart shows the distribution of haulage trip durations (in minutes) for all transportation runs completed during the simulation.



This chart helps evaluate the efficiency of haulage operations by showing how long typical transportation cycles take. It helps identify unusually long or short trips, as well as detect delays that reduce fleet productivity.

Chart Elements:

- X-axis (horizontal): Haulage time intervals (minutes)
- Y-axis (left vertical): Percentage of total trips in each time interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

- **Blue bars** — show the share of trips within each time interval (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as time increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

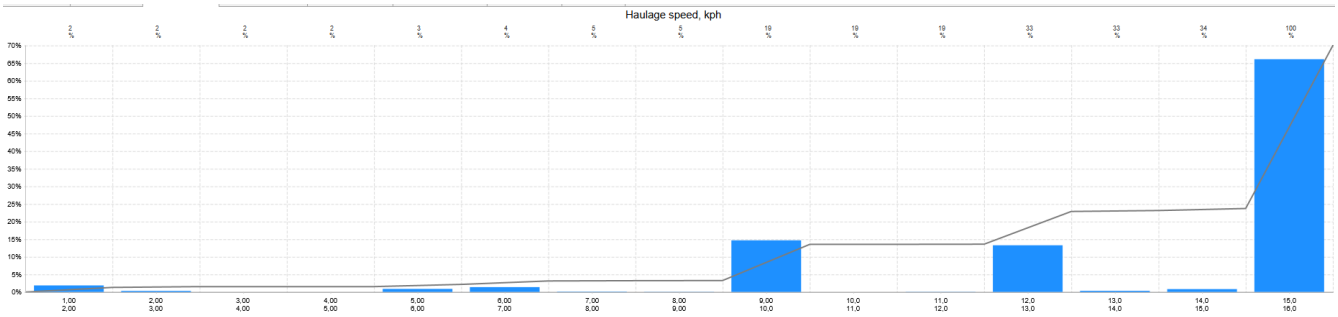
How to Use:

- Identify most common haulage times — these appear as peaks in the histogram.
- Detect abnormally long haulage times that may indicate delays, congestion, or breakdowns.
- Evaluate fleet performance stability — a tight distribution (narrow cluster of bars) indicates consistent operations, while a wide spread suggests unstable performance.
- Compare with the **Haulage Distance** and **Haulage Speed** charts to detect whether long times are due to longer routes or lower travel speeds.

2.4.12. Haulage Speed Chart

The **Haulage Speed** chart shows the distribution of average travel speeds (in kilometers per hour)

achieved during all haulage trips completed in the simulation.



This chart helps evaluate the efficiency of haulage operations by showing how fast equipment moves on average, and it helps detect cases where low speeds may indicate congestion, steep gradients, poor road conditions, or mechanical issues.

Chart Elements:

- X-axis (horizontal): Haulage speed intervals (km/h)
- Y-axis (left vertical): Percentage of total trips in each speed interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

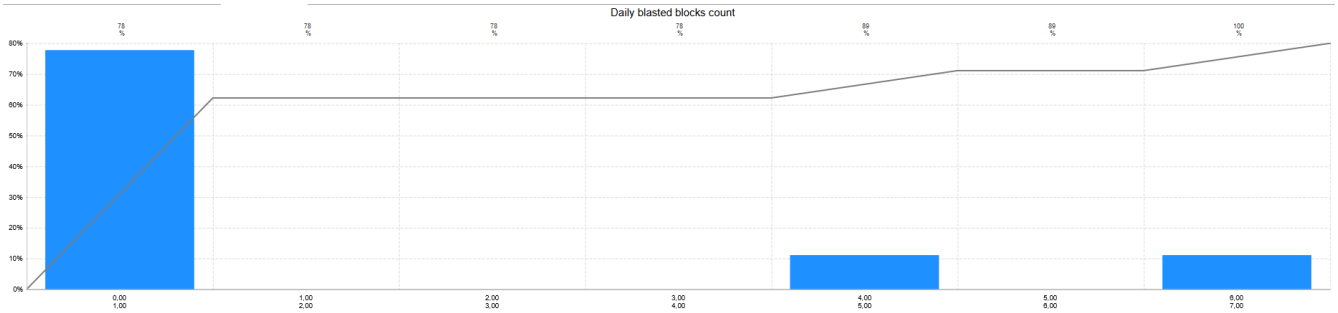
- **Blue bars** — show the share of trips within each average speed range (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as speed increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

How to Use:

- Identify most common travel speeds — these appear as peaks in the histogram.
- Detect low average speeds, which may indicate poor road conditions, queues or delays caused by traffic congestion.
- Evaluate speed consistency — a narrow cluster of speeds means stable performance, while a wide spread indicates variation between trips.
- Use together with **Haulage Time** and **Haulage Distance** charts to understand whether long travel times are caused by longer distances or lower speeds.

2.4.13. Daily Blasts Count Chart

The **Daily Blasted Blocks Count** chart shows the distribution of the number of blocks blasted per day during the simulation period.



This chart helps evaluate the intensity and regularity of blasting operations. It indicates how often blasting events occur and whether they are concentrated in large batches or evenly spread out over time.

Chart Elements:

- X-axis (horizontal): Number of blasted blocks per day
- Y-axis (left vertical): Percentage of simulation days that had this number of blasted blocks
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this number of blasts or fewer

Chart Components:

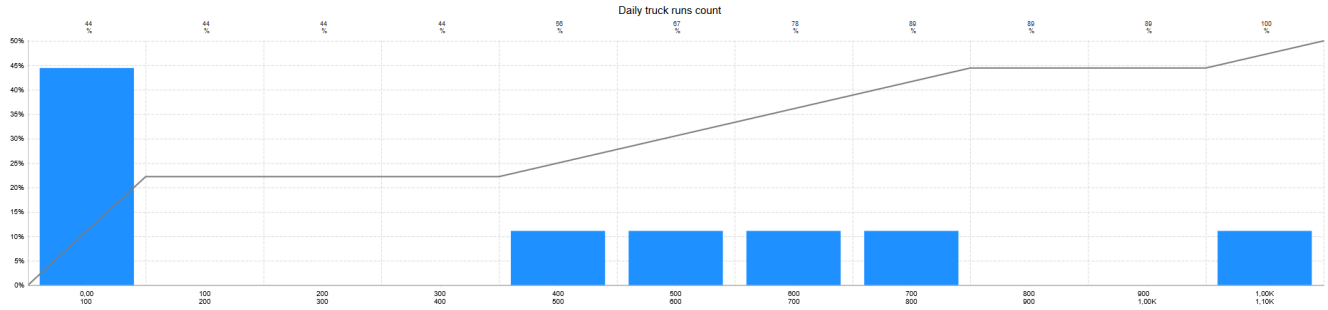
- **Blue bars** — show the share of days that had the specified number of blasted blocks
- **Gray cumulative line** — shows the cumulative percentage of all days that had this or fewer number of blasts
- **Labels above bars** — show the exact cumulative percentage of all days that had this or fewer number of blasts

How to Use:

- Identify typical blasting frequency — shown by the highest bar.
- Detect bursty vs. steady blasting:
- A single tall bar near zero means blasting happens infrequently.
- A wider spread of bars means more consistent daily blasting.
- Use this chart alongside **Daily Runs Count** and **Daily Tonnes Mined** charts to see how blasting activity influences production cycles.

2.4.14. Daily Runs Count Chart

The **Daily Runs Count** chart shows the distribution of the number of loaded haulage runs (trips with ore or waste) completed per day during the simulation period.



This chart helps analyze the intensity and consistency of haulage operations. It shows how many loaded trips are typically performed in a day and highlights whether hauling activity is steady or highly variable.

Chart Elements:

- X-axis (horizontal): Number of loaded runs per day
- Y-axis (left vertical): Percentage of simulation days that had this number of loaded runs
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this number of runs or fewer

Chart Components:

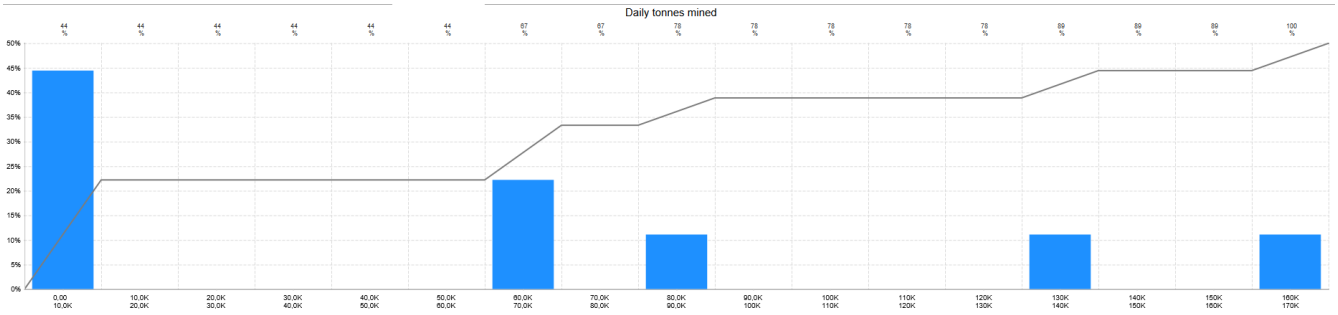
- **Blue bars** — show the share of days that had the specified number of loaded runs
- **Gray cumulative line** — shows the cumulative percentage of all days that had this or fewer number runs
- **Labels above bars** — show the exact cumulative percentage of days that had this or fewer number runs

How to Use:

- Identify the most common daily workload for haul trucks or LHDs (the tallest bar).
- Detect uneven hauling performance — a wide spread of bars indicates large fluctuations in daily output.
- Spot low-activity days — tall bars near zero show days with little or no hauling.
- Use this chart alongside the **Daily Blasted Blocks Count** and **Daily Tonnes Mined** charts to see how hauling activity aligns with blasting and production cycles.

2.4.15. Daily Tonnes Mined Chart

The **Daily Tonnes Mined** chart shows the distribution of the total amount of ore mass (in tonnes) considered as mined per day during the simulation period.



This chart helps evaluate the daily production performance of the mining operation. It shows how much ore mass is typically considered as mined in a day and whether production rates are stable or vary significantly between days.

Chart Elements:

- X-axis (horizontal): Total mined tonnage per day
- Y-axis (left vertical): Percentage of simulation days that had this amount of mined material
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this amount or less

Chart Components:

- **Blue bars** — show the share of days that had the specified daily mined tonnage
- **Gray cumulative line** — shows the cumulative percentage of all days as the mined tonnage increases
- **Labels above bars** — show the exact cumulative percentage of days up to the current bin

How to Use:

- Identify the typical daily production output — the tallest bar shows the most common production level.
- Detect low-production days — tall bars near zero may indicate downtime or operational disruptions.
- Check consistency of output — a narrow cluster of bars shows stable production; a wide spread indicates fluctuating performance.
- Use this chart alongside **Daily Runs Count** and **Daily Blasted Blocks Count** charts to understand how production aligns with hauling and blasting activity.

Note: In all histograms, the left boundary of each range is inclusive, while the right boundary is exclusive. This means that, for example, in the 0–1 range (with an integer number of blasts), only days with 0 blasts will be included.

2.4.16. Stoppage Stats Table

The **Stoppage Stats** table summarizes all downtime events that occurred during the simulation, grouped by equipment type and stoppage typen. It provides an overview of how much time equipment spent unavailable due to scheduled or unplanned stoppages.

Equipment type	Stoppage type	Stoppage description	Units count	Total events count	Total duration, hours	Time fraction per unit	Total costs
Conveyor	Unplanned events	Meteo	1	1	15,52	7,19%	0
Komatsu HD1500-7	Scheduled downtime period	Blast 1	17	10	7,50	0,20%	0
Komatsu HD1500-7	Unplanned events	Meteo	17	5	78,32	2,13%	0
Caterpillar 793F	Unplanned events	Meteo	27	8	123,09	2,11%	0
Liebherr R 9200	Scheduled downtime period	Blast 1	2	2	1,92	0,45%	0
Liebherr R 9200	Unplanned events	Meteo	2	2	29,90	6,92%	0
Liebherr R 9400 G6	Unplanned events	Meteo	3	1	14,63	2,26%	0
Atlas Copco DML	Scheduled downtime period	Blast 1	12	25	11,16	0,43%	0
Atlas Copco DML	Unplanned events	Meteo	12	4	62,78	2,42%	0
Volvo M1	Scheduled downtime period	Blast 1	1	2	2,00	0,93%	0
Volvo M1	Unplanned events	Meteo	1	1	15,17	7,02%	0

This table helps analyze the impact of various downtime reasons (such as weather, maintenance, or blasting) on equipment availability and productivity.

Table Columns:

- **Equipment type** — the type or model of equipment affected by the stoppages
- **Stoppage type** — the category of downtime
- **Stoppage description** — the specific name of the stoppage (for example, Blast 1 or Meteo)
- **Units count** — the number of equipment units of this type that experienced this stoppage
- **Total events count** — the total number of stoppage events of this type that occurred during the simulation
- **Total duration, hours** — total time (in hours) that equipment was unavailable due to this stoppage
- **Time fraction per unit** — share of total scheduled operational time that each affected unit spent in this stoppage state (shown as a percentage)
- **Total costs** — total costs associated with this stoppage (if cost parameters are configured)

How to Use:

- Identify which types of stoppages cause the largest downtime (look at Total duration, hours and Time fraction per unit).
- Distinguish between planned and unplanned stoppages to assess operational reliability.
- Use this data to refine schedules (e.g., plan maintenance better or reduce weather exposure) and improve equipment availability.
- If cost tracking is enabled, compare downtime-related costs across equipment types.

2.4.17. Zone Stats Table

The **Zone Stats** table provides a breakdown of transportation performance indicators by zone. Zones are user-defined areas of the haulage network, used to group road segments (arcs) for analysis.

Zone	Total length, km	Avg. loaded speed, kph	Avg. empty speed, kph	Total haulage, t*km
(none)	10,32	25,46	49,43	780 784
Road truck	13,73	25,48	49,32	1 784 429
Iron deposits	8,20	25,00	50,00	18 729
Empty dump road	5,91	27,50	47,30	16 727
Continuous conveyor for overburden	0,90	0,00	0,00	0

This table helps evaluate the efficiency of haulage operations within different parts of the mine by comparing travel distances, speeds, and transported volumes across zones.

Table Columns:

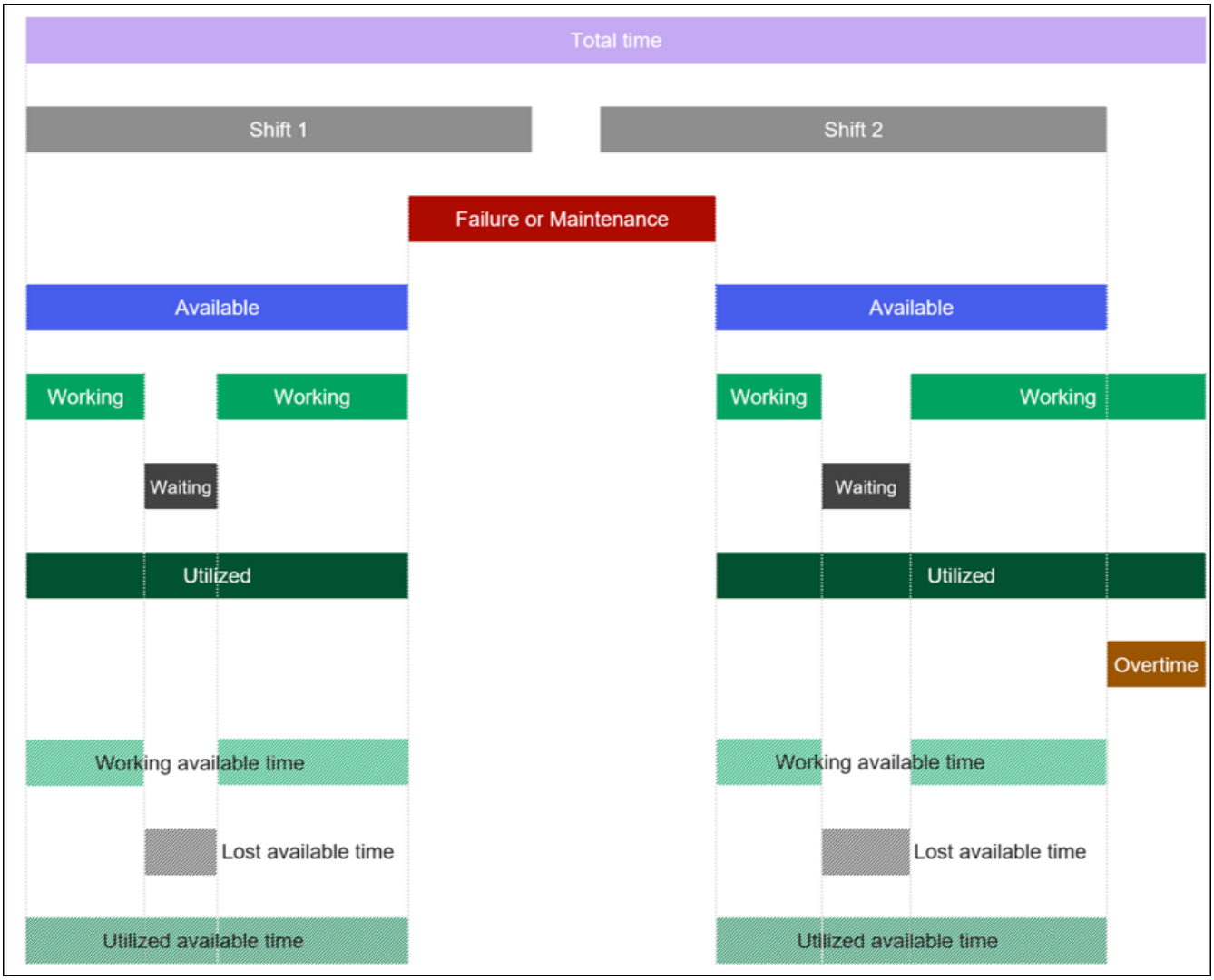
- **Zone** — the name of the zone assigned to road segments (or (none) if not assigned)
- **Total length, km** — the total combined length of all segments within this zone
- **Avg. loaded speed, kph** — the average speed of equipment moving with a load inside this zone
- **Avg. empty speed, kph** — the average speed of equipment moving without a load inside this zone
- **Total haulage, t*km** — the total haulage work performed in this zone, measured as **tonnes transported × kilometers traveled**

How to Use:

- Identify zones with high haulage workload — large values in **Total haulage, t*km** indicate areas where most transport effort is concentrated.
- Analyze travel speed differences between zones to detect possible bottlenecks (low speeds may signal steep gradients, congestion, or poor road conditions).
- Evaluate zone coverage — check **Total length** to see which areas dominate the road network.
- Use this data to optimize traffic organization and road maintenance priorities.

2.5. Availability and utilization calculation

Understanding equipment availability and utilization is crucial for optimizing mining operations and minimizing downtime. MineTwin's simulation tool provides a clear framework to track key metrics like total time, scheduled time, and utilized time, helping identify inefficiencies and improve equipment performance. These insights support better understanding of simulation results.

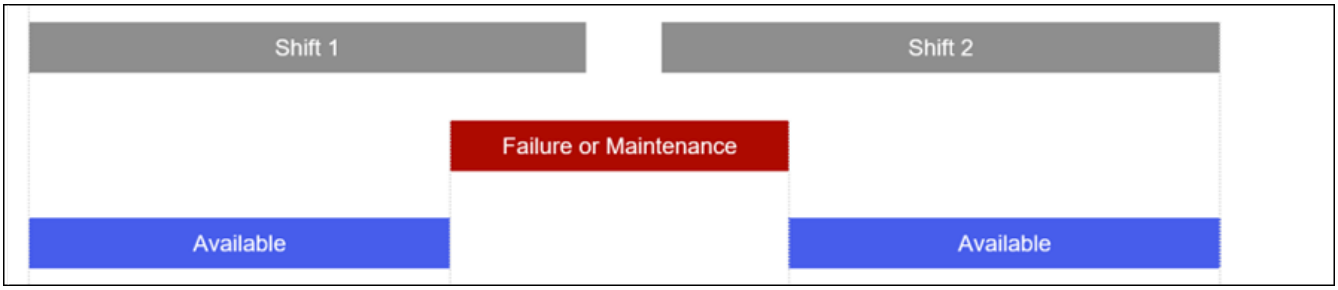


On the scheme above, there are the following categories of time periods and time usage:

Total time – total time since the beginning of the simulation.

Scheduled time – time there was a shift scheduled for the equipment. For equipment without shifts, scheduled time = total simulation time or total time between commissioning and decommissioning, if these are specified for this equipment.

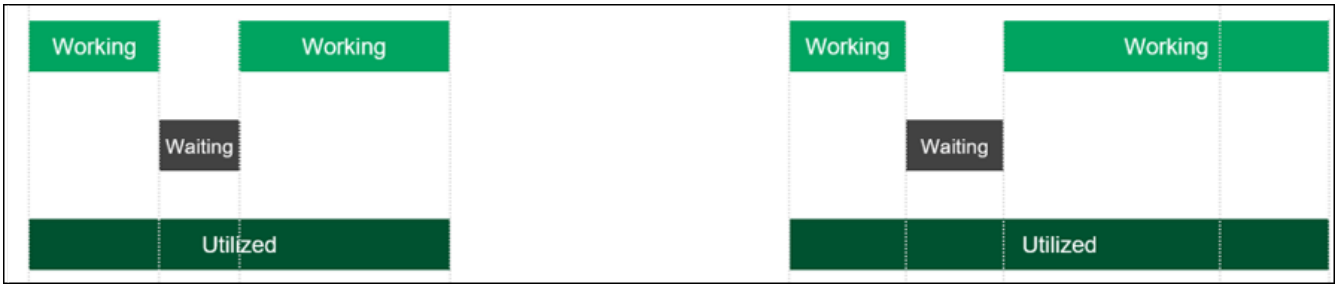
Unavailable time – duration of slots classified as UNAVAILABLE. Typically, failures and maintenances fall into this category.



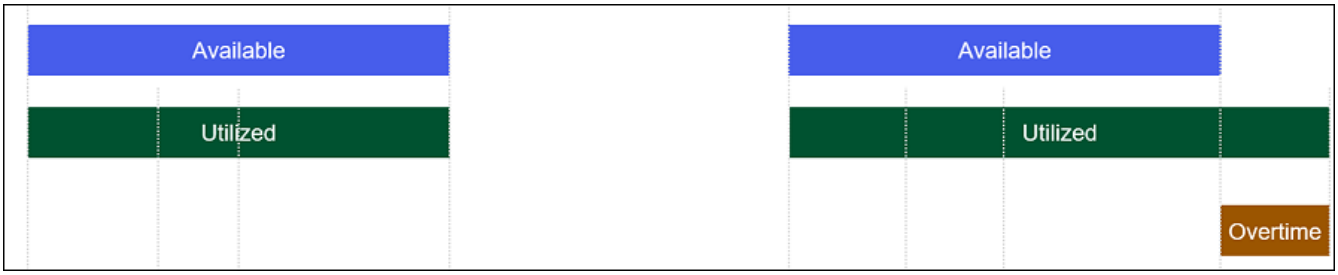
Available time is calculated as scheduled time excluding unavailable time.

Working time – duration of slots classified as ACTUAL_WORKING, doing actual useful work. For example, for trucks it would include moving to loading location, loading, moving loaded to unloading location, and unloading

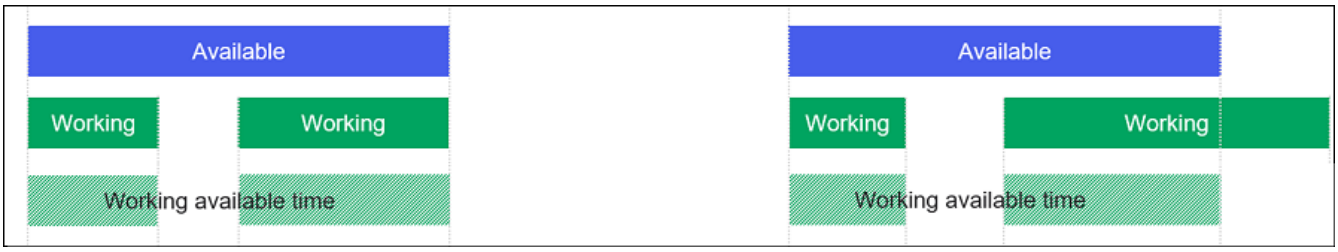
Lost time (also can be called **Waiting time**) – duration of slots classified as LOST_TIME, waiting for something or being blocked. For example, for trucks it would include waiting in front of an unloading point or queuing in front of an excavator.



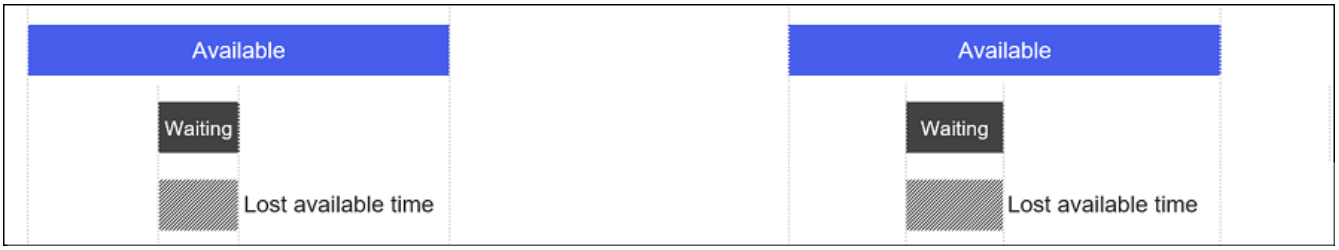
Utilized time is calculated as working time united with lost time.



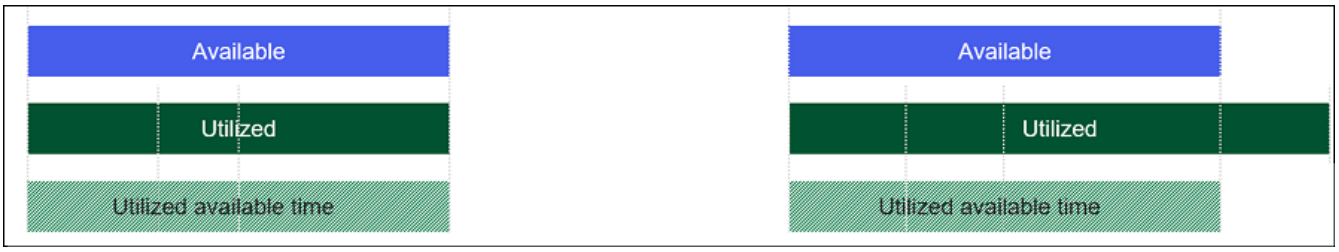
Overtime is calculated as utilized time excluding available time, should be negligibly small in real scenarios.



Working available time is calculated as working time intersected with available time.



Lost available time is calculated as lost time intersected with available time.



Utilized available time is calculated as utilized time intersected with available time.

The above time usage categories are used to calculate availability, utilization, effective utilization, and lost time fraction for individual equipment units and groups:

Availability is calculated as a fraction of scheduled time when the equipment was available:

$$\textbf{Availability} = \frac{Available\ time}{Scheduled\ time}$$

Utilization is calculated as a fraction of available time when the equipment was utilized (e.g. either working or actively waiting for something):

$$\textbf{Utilization} = \frac{Utilized\ available\ time}{Available\ time}$$

Effective utilization is calculated as a fraction of available time when the equipment was working (i.e., doing the useful work):

$$\textbf{Effective utilization} = \frac{Working\ available\ time}{Available\ time}$$

Lost time fraction is calculated as a fraction of utilized available time when the equipment was

actively waiting for something or was otherwise blocked:

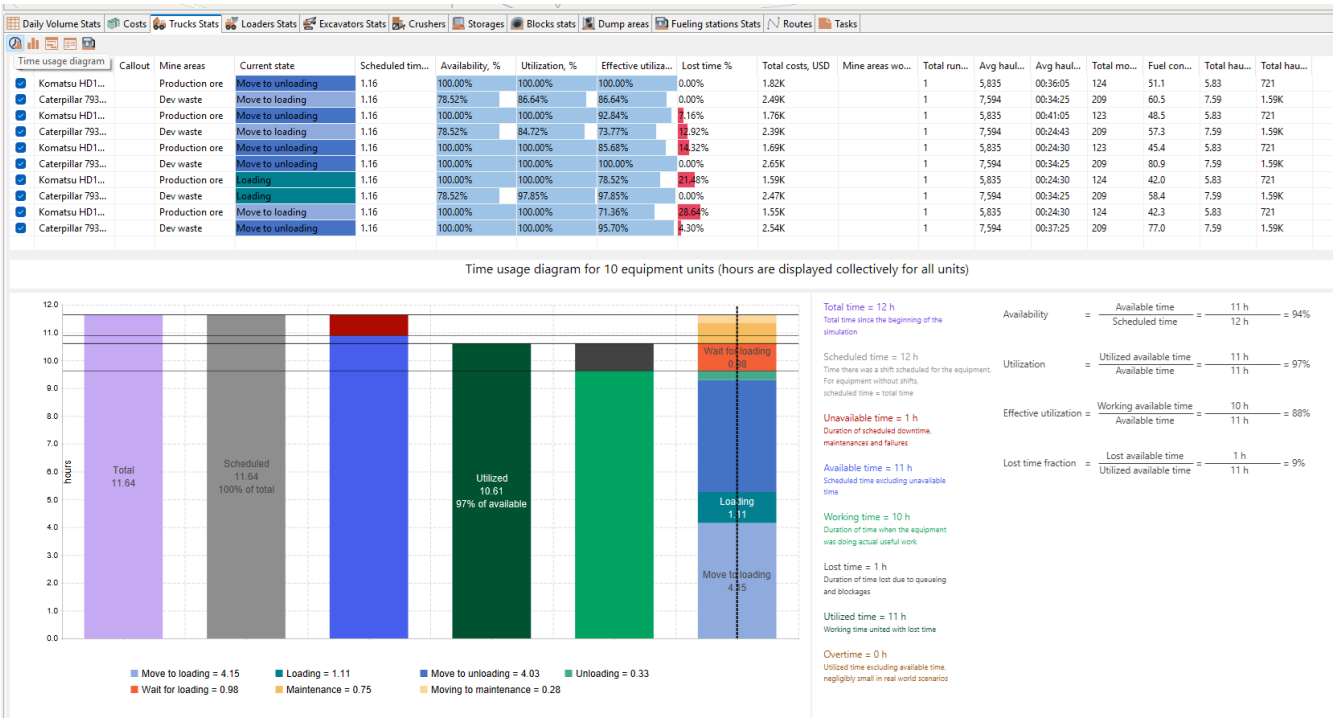
$$\textbf{Lost time fraction} = \frac{Lost\ available\ time}{Utilized\ available\ time}$$

2.5.1. Time usage diagrams

Time usage diagrams can be viewed in MineTwin to visualize how the time usage categories described above apply to individual equipment units during simulation. These diagrams provide a detailed breakdown of each unit's activity, making it easier to understand how availability, utilization, effective utilization, and lost time fraction values are derived.

To view a time usage diagram, open the desired stats tab (e.g. "Trucks Stats"). By checking and unchecking items in the list, users can select which units to show the statistics for. The diagram will then be displayed for the checked units.

Below is an example of a time usage diagram for trucks:



The time usage diagram is a bar chart where each bar corresponds to a certain time breakdown level. Each bar is divided into colored segments that indicate the time usage category — such as working time, lost time, unavailable time, and other states. This makes it possible to see at a glance when a truck was performing useful work, when it was waiting or blocked, and when it was unavailable due to maintenance or failure.

Time usage diagrams are especially helpful for:

- Analyzing simulation results at the level of individual equipment units
- Identifying bottlenecks and periods of excessive waiting

- Verifying that shift schedules, failures, and maintenances are modeled correctly

3. MineTwin Study Mode

3.1. Introduction

The **Study** mode is designed for conducting structured simulation experiments based on MineTwin scenarios. It allows users to analyze constraints, select an appropriate fleet configuration, and assess how sensitive results are to changes in model parameters.

This mode helps answer questions such as:

- which constraint has the strongest impact on achieving the plan;
- which fleet composition change would bring the result closer to the target plan;
- how results would change if the amount of equipment changes;
- which factors have the greatest influence on the final KPIs.

A study is created based on an open scenario. After creation, you can add steps, run automated study modes, execute calculations locally or on the server, compare results, and generate reports.

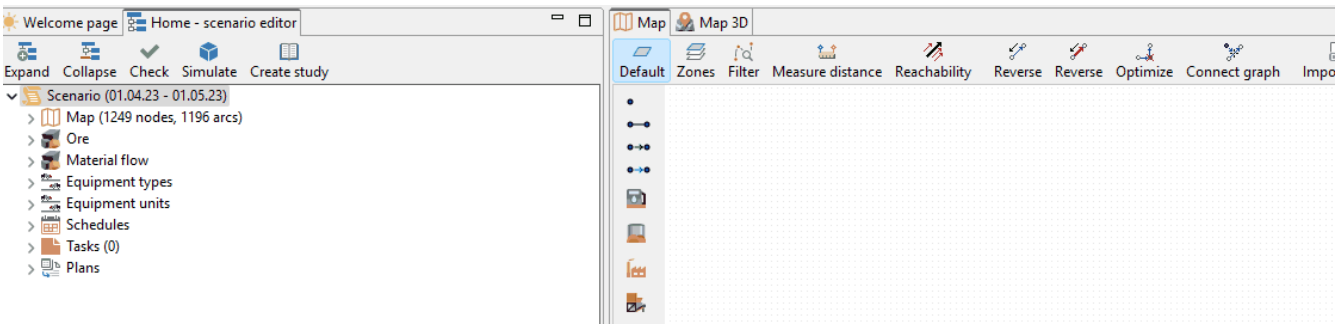
This structured approach improves analytical efficiency by making it easier to formulate and test hypotheses and quickly obtain well-grounded, reliable answers.

3.2. Creating a New Study

1. Open the required scenario.
2. Click **Create Study** on the toolbar.
3. The study opens in a new tab.
4. The current scenario becomes the study's **root step**. Child steps can be added to it.

The following commands are available for managing a study:

- **Rename** — a dedicated button on the study toolbar;
- **Save** and **Save As** — save the study as a ZIP archive;
- **Open Experiment** — open a previously saved study from the top menu in the **Menu** group.



3.3. Steps and Modifications

A study is built as a tree of steps. The base step contains the original scenario with no changes. Subsequent steps can:

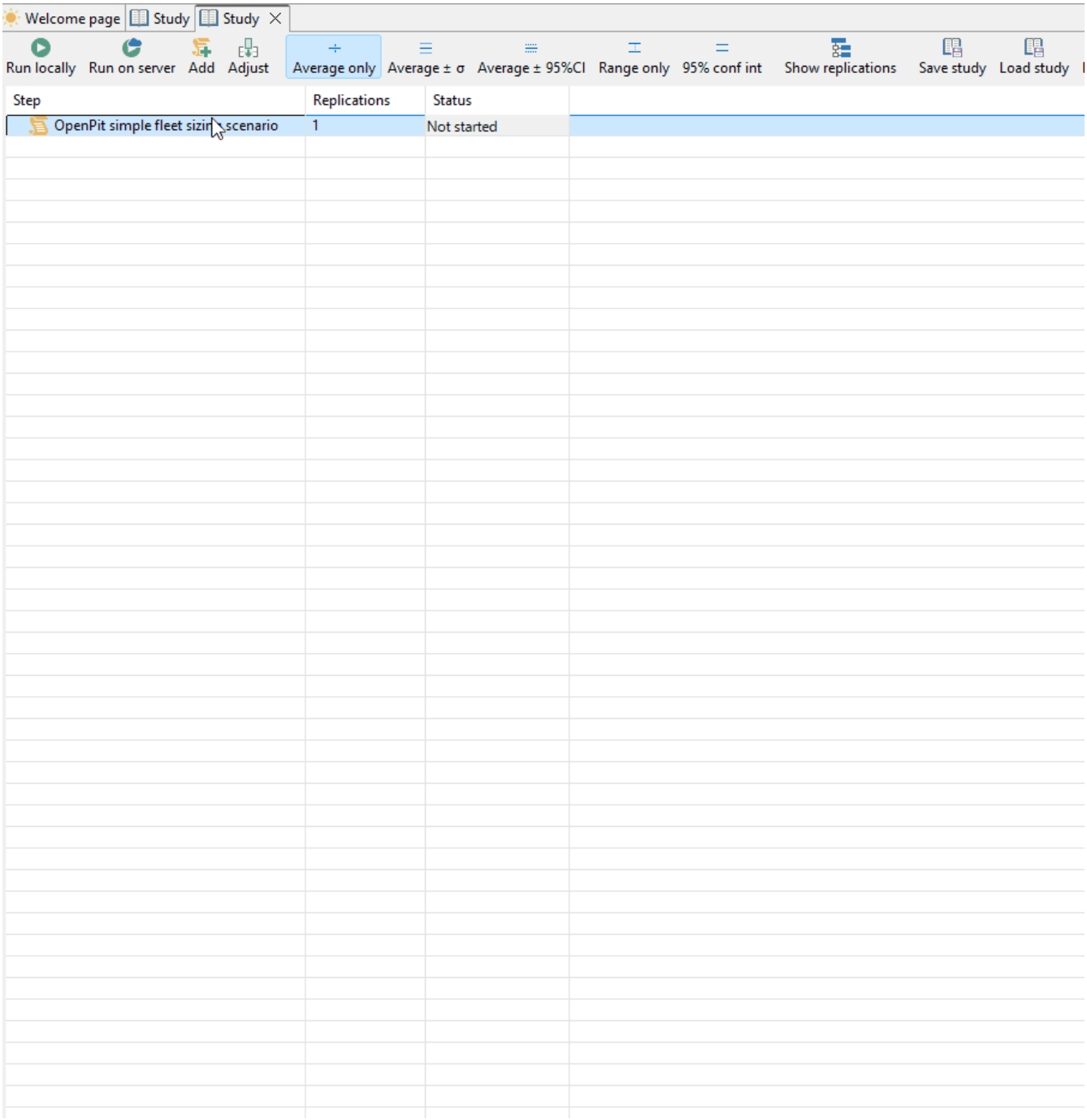
- inherit the scenario from the previous step and contain one or more modifications;
- be executed with multiple replications;
- be used as a basis for further experiments.

The user can:

- apply a modification to any study step;
- run an automated study for any step;
- create a new study from an intermediate step via right-click and the context menu;
- save any step as a separate scenario via right-click and the scenario save command;

3.3.1. Adding Modifications Manually

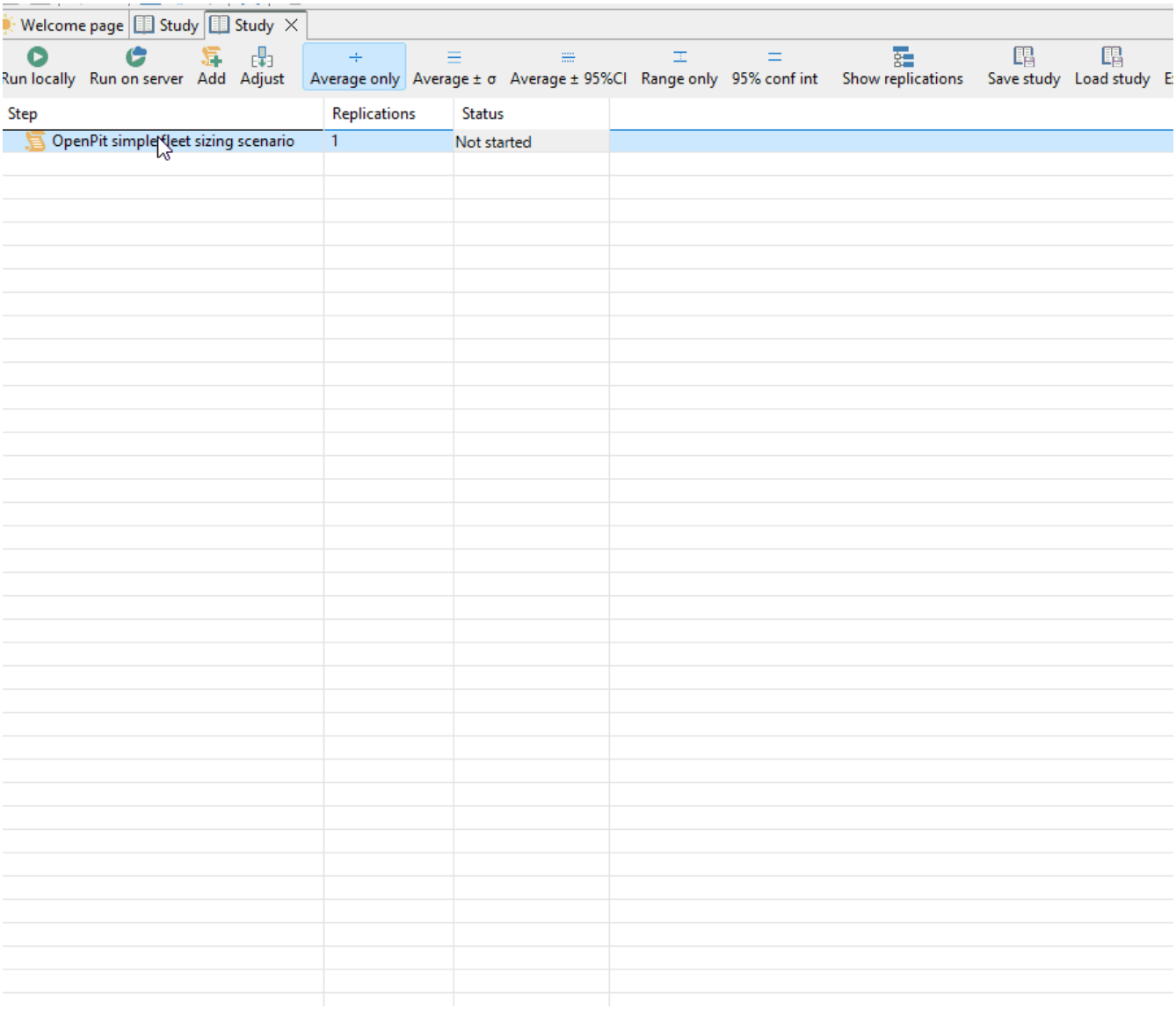
1. Select an existing step.
2. Right-click the step and select **"XX modifications available"** from the context menu. The total number of available modifications depends on the MineTwin version.



Modifications include:

- Removing maintenance downtime
- Removing equipment assignment to mining areas
- Doubling the number of trucks and excavators
- Allowing passage of unmined blocks
- Duplicating the target plan etc.

Any intermediate step can be used as the root step of a new study. This makes it possible to branch the analysis at the required moment and compare alternative scenarios.



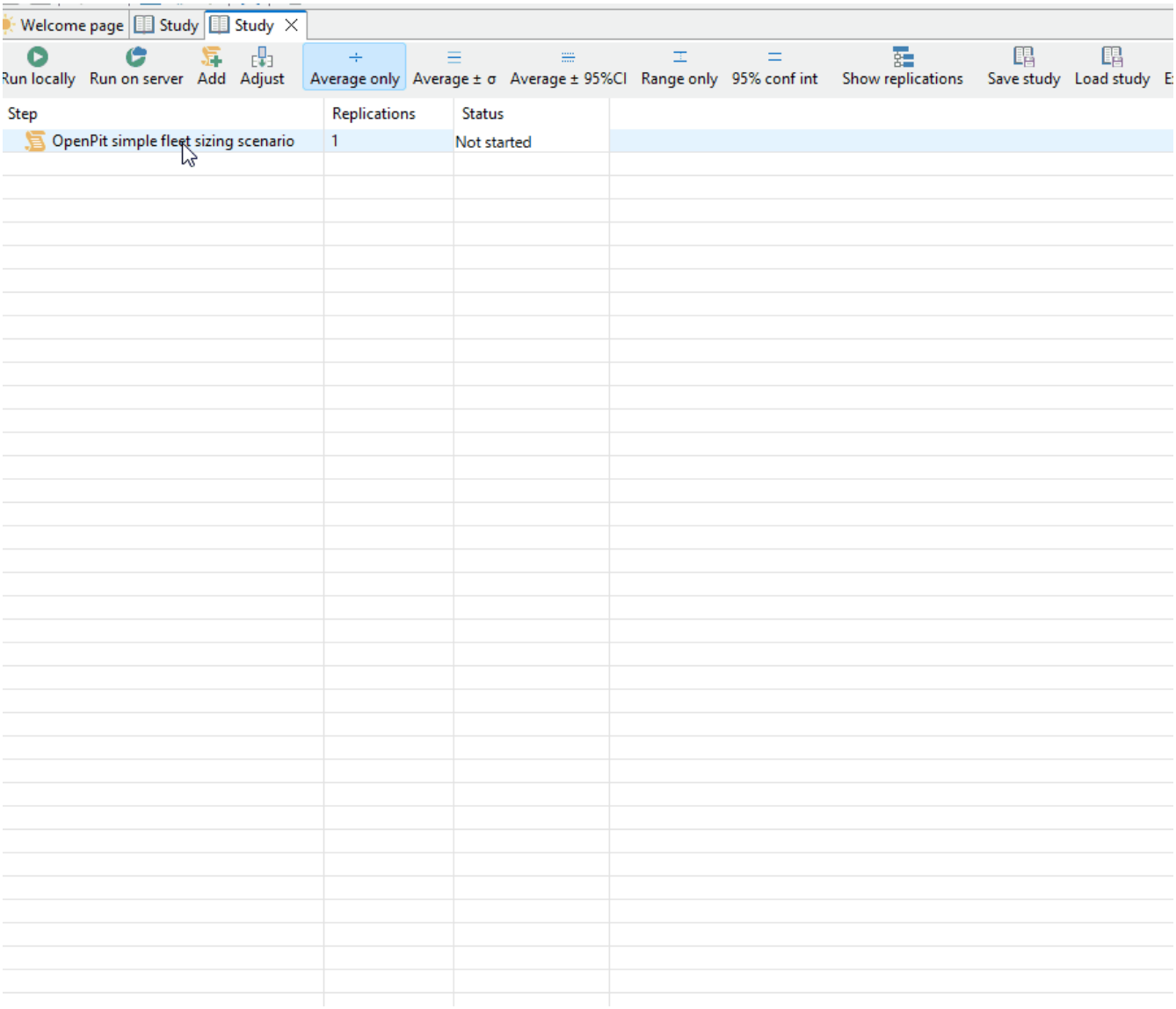
3.3.2. Automated Study Modes

Instead of adding individual modifications, you can run one of the automated study modes.

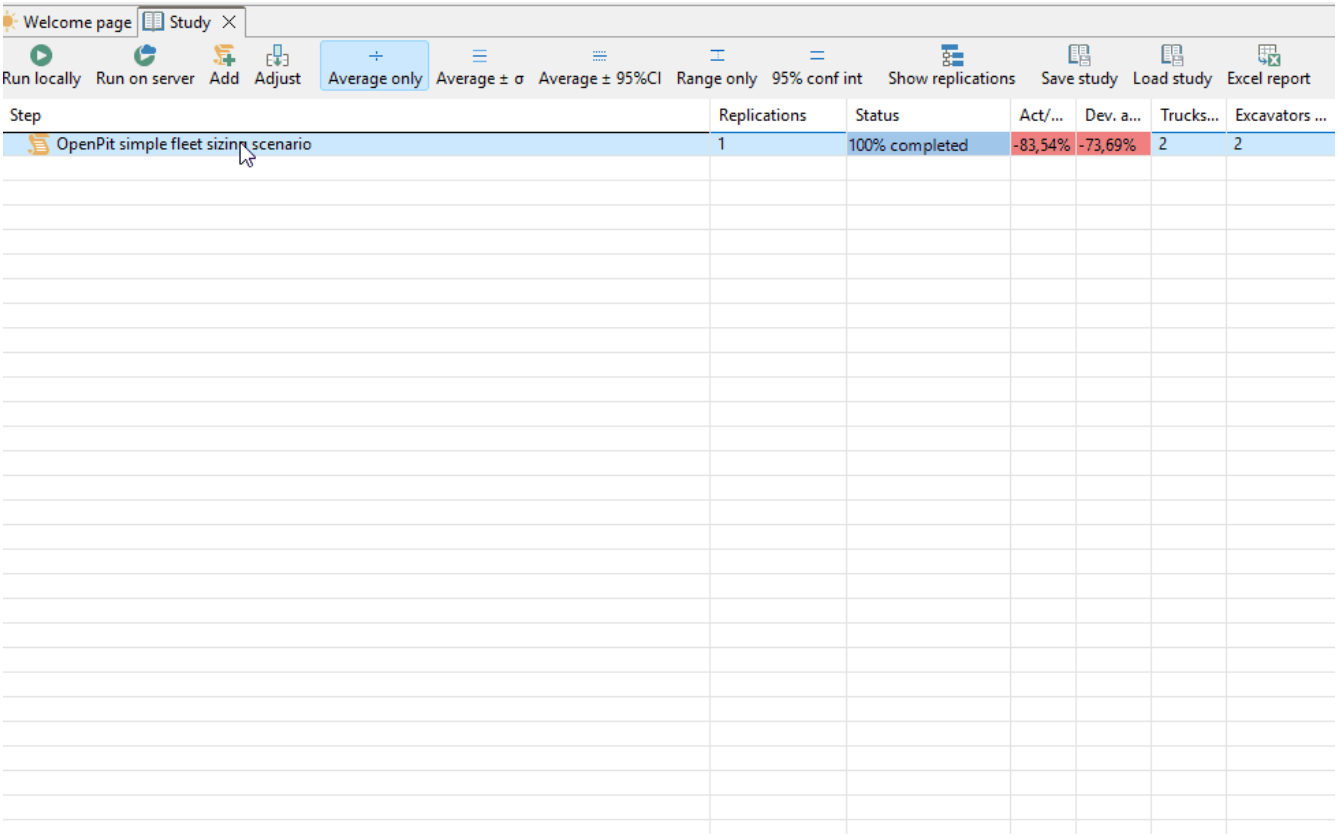
The following automated studies are available:

- Constraint Analysis
- Fleet Sizing
- Equipment Units Count Variation

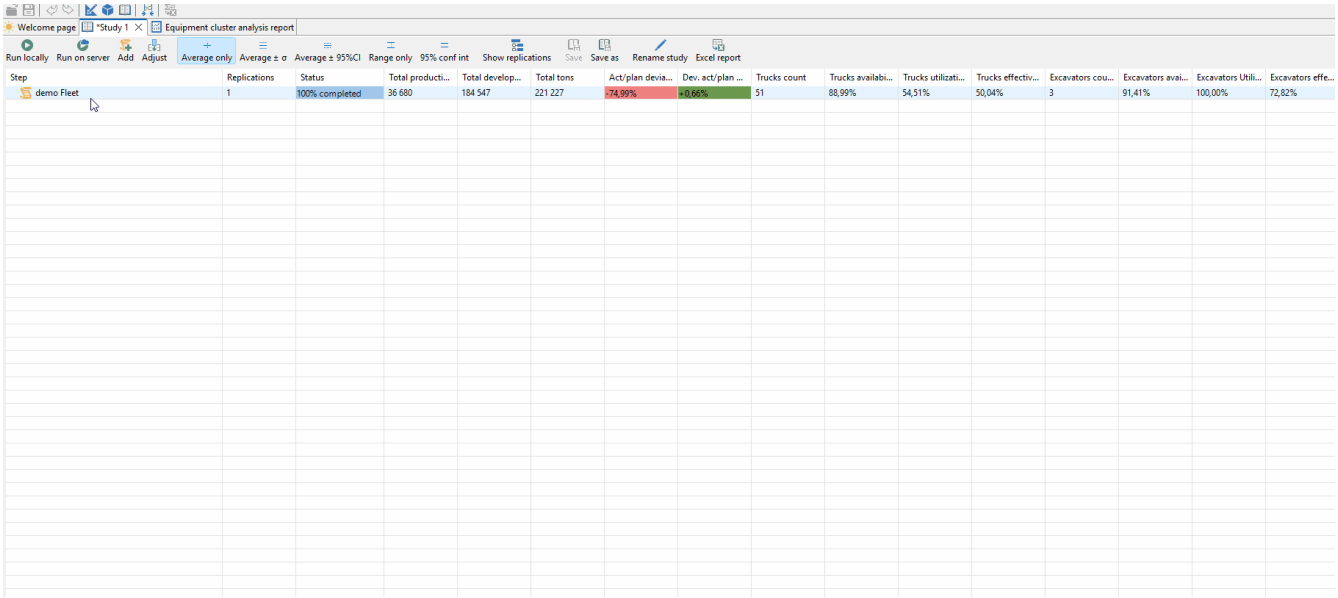
The **Constraint Analysis** mode is intended to identify scenario bottlenecks. When this analysis is run, MineTwin automatically launches the scenario simulation multiple times with available modifications applied, removing each major constraint in turn, and shows how much the mining plan fulfillment percentage would improve if that constraint did not exist: Instead of adding individual modifications, you can launch one of the automated study modes.



The **Fleet Sizing** study uses a sequential strategy to identify the minimum sufficient amount of equipment required to achieve the production target. During this study, instances of different equipment types are added or excluded step by step:

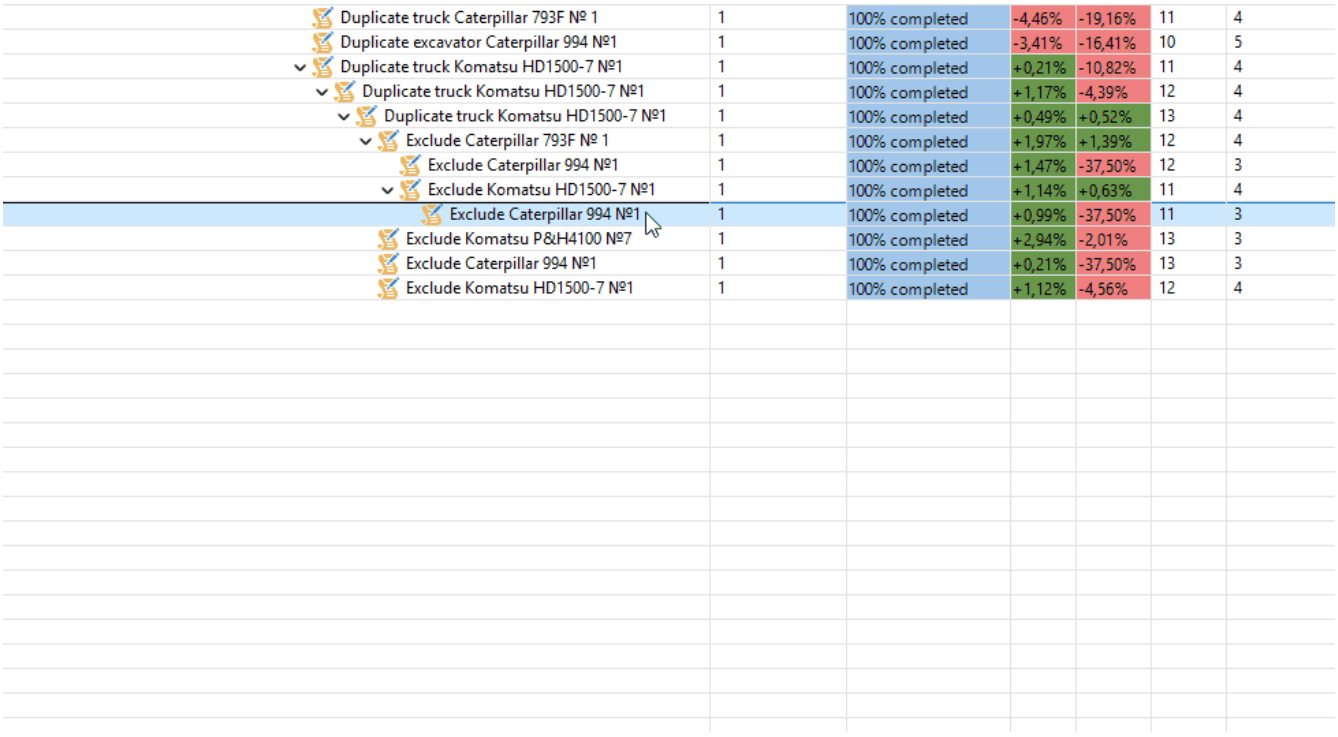


The **Equipment Units Count Variation** study allows users to configure and run one- and two-axis sensitivity analysis of a set of target KPIs against changes within a specified range in the amount of equipment and/or various operating parameters.

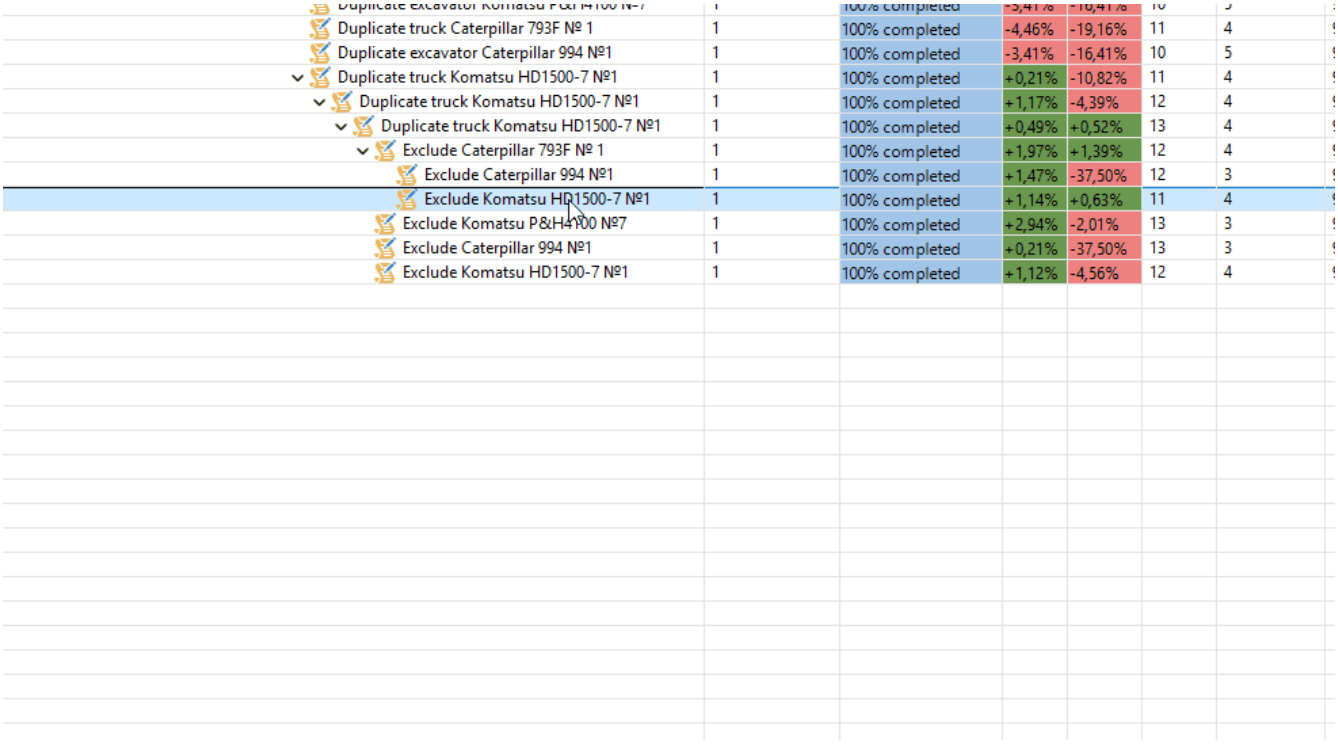


The following sections describe these modes in more detail.

Any step can be deleted through the context menu or by pressing **Delete** on the keyboard:

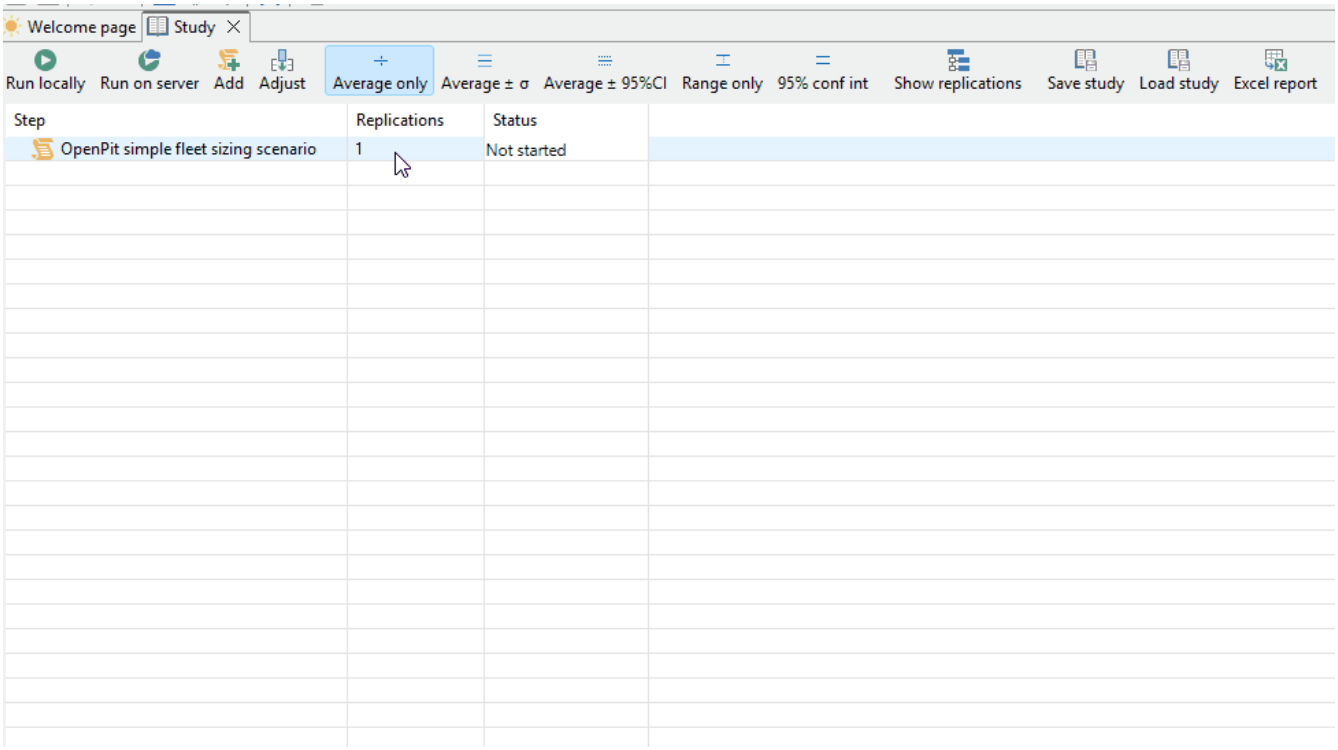


Any step can also be saved as a separate scenario for later use.



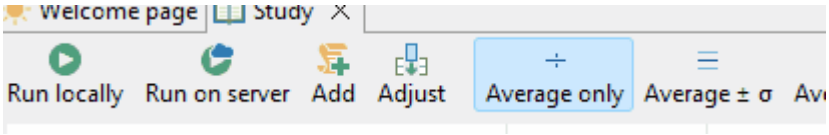
3.4. Setting the Number of Replications

1. Specify the number of replications (runs) for the selected step.
2. Each replication uses a different random number seed.
3. Enable **Show replications** to display individual run values.



3.5. Running Calculations

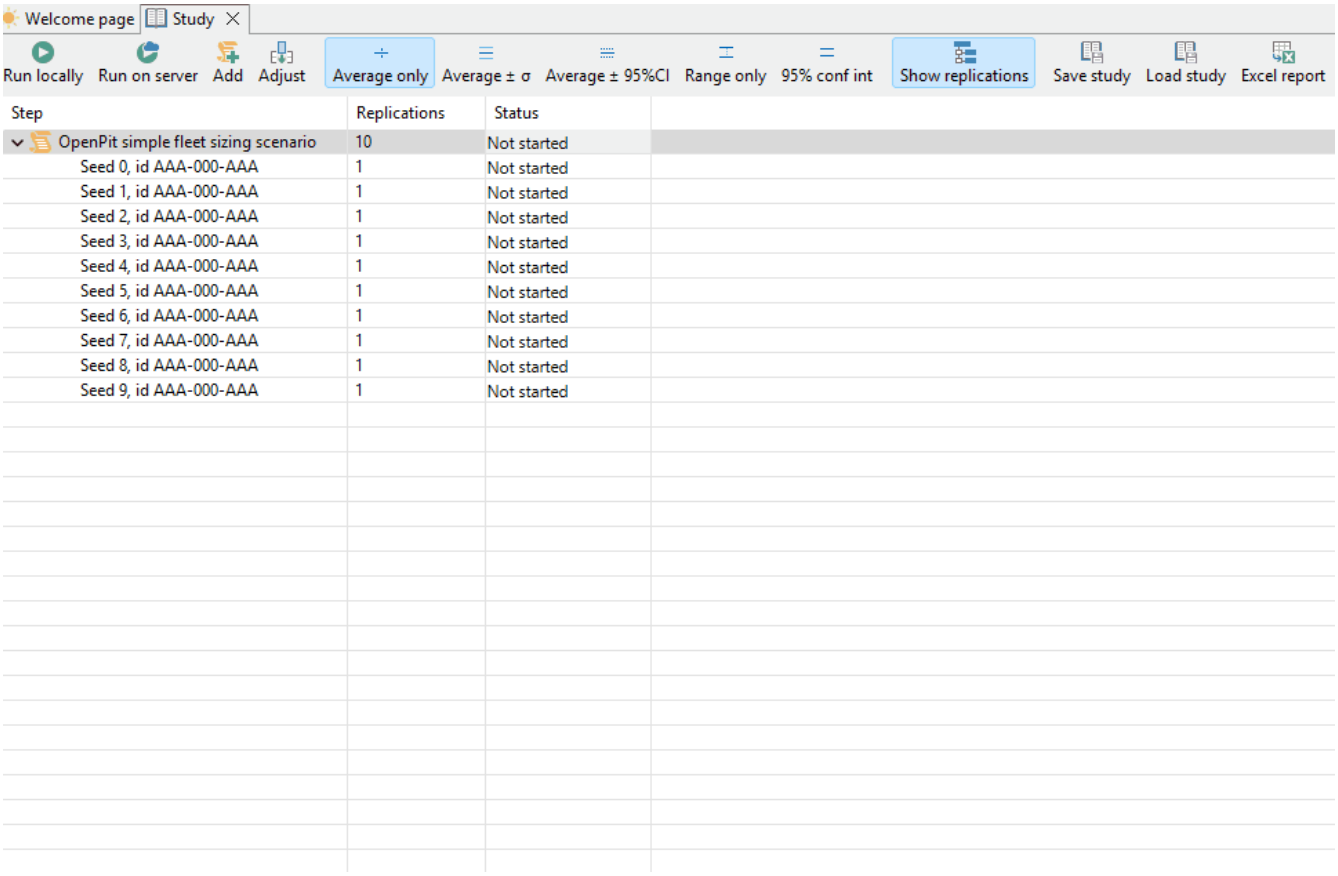
Choose how to run the calculations:



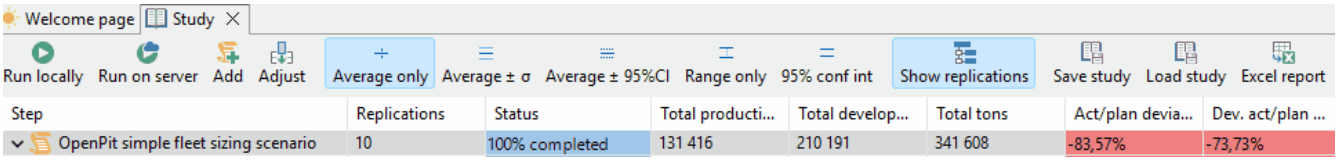
- **Run Locally** — execution on the local machine
- **Run on Server** — calculations on the MineTwin server

Server mode significantly reduces the load on the user's computer when the workload is large.

1. Click **"Run locally"** or **"Run on server"**.
2. Track the execution status in the corresponding table column.
3. You can switch to another mode (for example, scenario editing) without waiting for the calculations to finish. They will continue in the background, and the results will be available when you return.

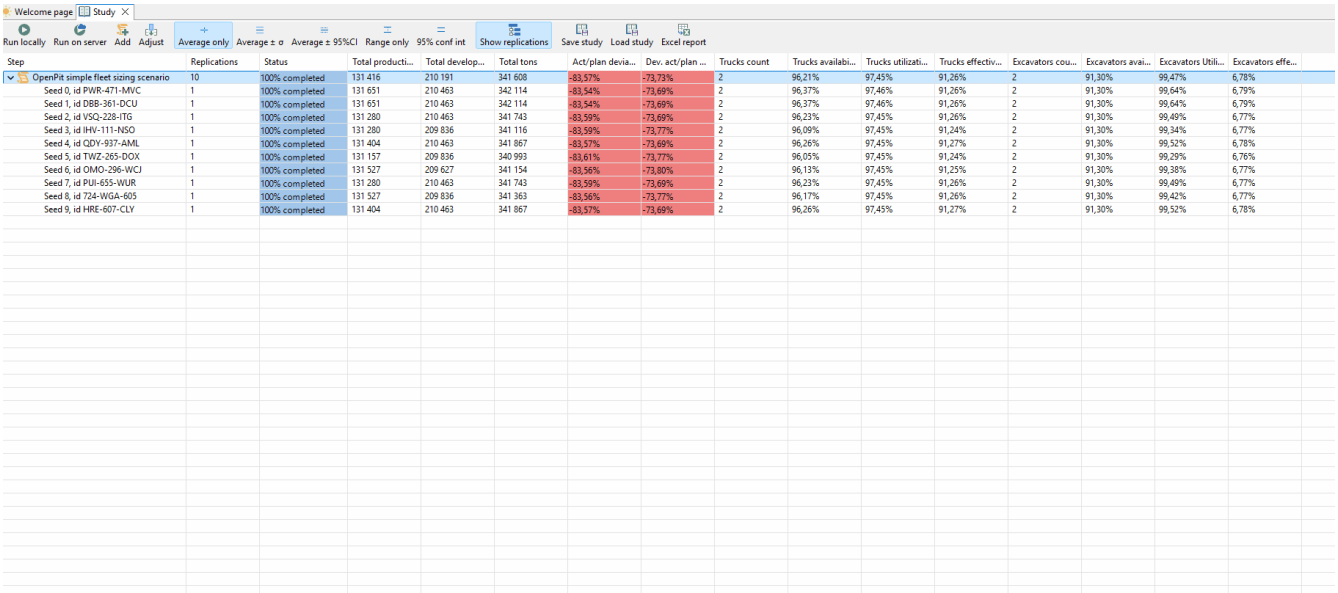


Any study can be saved and reopened later. If calculations are performed on the server, the study can be saved even before all step calculations are finished. After reopening, already calculated results will be automatically loaded from the server.



3.6. Viewing and Analyzing Results

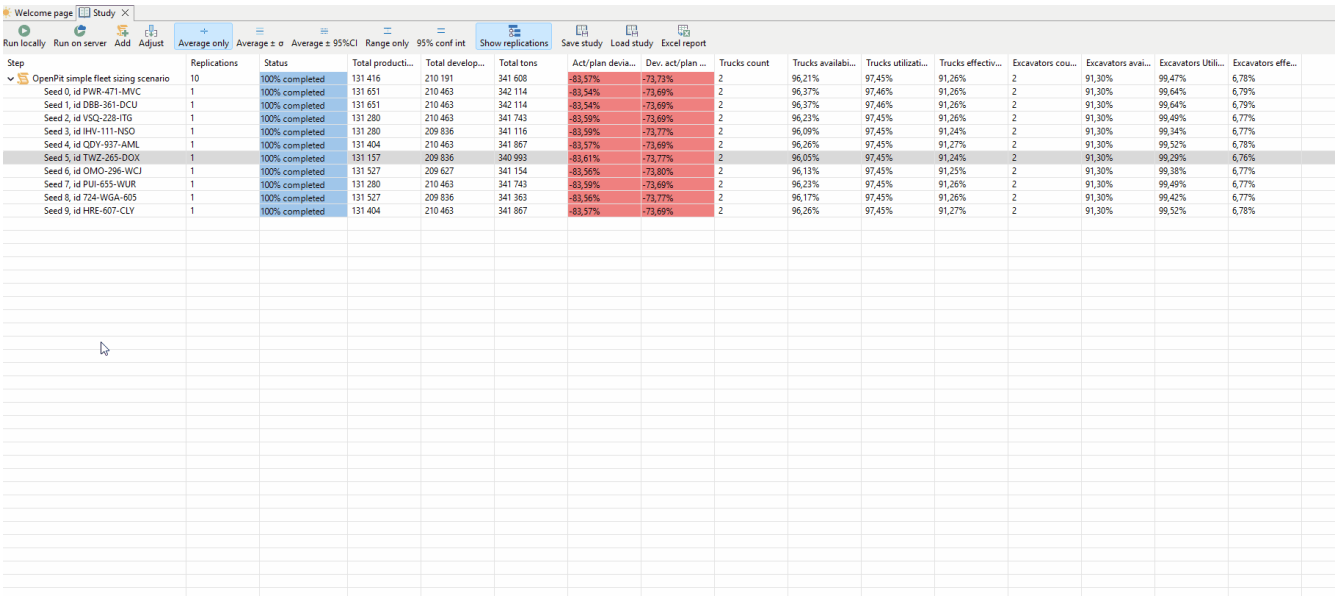
Results appear in the study step table. To customize which data columns are displayed in the table, click the **Adjust** button on the toolbar:



Step	Replications	Status	Total producti...	Total develop...	Total tons	Act/plan devia...	Dev. act/plan ...	Trucks count	Trucks availabi...	Trucks utilizati...	Trucks effectiv...	Excavators cou...	Excavators avai...	Excavators Utili...	Excavators effe...
OpenPit simple fleet sizing scenario	10	100% completed	131 416	210 191	341 608	-83,57%	-73,73%	2	96,21%	97,45%	91,26%	2	91,30%	99,47%	6,78%
Seed 0, id PWR-471-MVC	1	100% completed	131 651	210 463	342 114	-83,54%	-73,69%	2	96,37%	97,46%	91,26%	2	91,30%	99,64%	6,79%
Seed 1, id DBB-361-DCU	1	100% completed	131 651	210 463	342 114	-83,54%	-73,69%	2	96,37%	97,46%	91,26%	2	91,30%	99,64%	6,79%
Seed 2, id VSQ-228-ITG	1	100% completed	131 280	210 463	341 743	-83,59%	-73,69%	2	96,23%	97,45%	91,26%	2	91,30%	99,49%	6,77%
Seed 3, id IHV-111-NSO	1	100% completed	131 280	209 836	341 116	-83,59%	-73,77%	2	96,09%	97,45%	91,24%	2	91,30%	99,34%	6,77%
Seed 4, id QDY-937-AML	1	100% completed	131 404	210 463	341 867	-83,57%	-73,69%	2	96,26%	97,45%	91,27%	2	91,30%	99,52%	6,78%
Seed 5, id TWZ-265-DOX	1	100% completed	131 157	209 836	340 993	-83,61%	-73,77%	2	96,05%	97,45%	91,24%	2	91,30%	99,29%	6,76%
Seed 6, id OMO-296-WCJ	1	100% completed	131 527	209 627	341 154	-83,56%	-73,80%	2	96,13%	97,45%	91,25%	2	91,30%	99,38%	6,77%
Seed 7, id PUI-655-WUR	1	100% completed	131 280	210 463	341 743	-83,59%	-73,69%	2	96,23%	97,45%	91,26%	2	91,30%	99,49%	6,77%
Seed 8, id 724-WGA-605	1	100% completed	131 527	209 836	341 363	-83,56%	-73,77%	2	96,17%	97,45%	91,26%	2	91,30%	99,42%	6,77%
Seed 9, id HRE-607-CLY	1	100% completed	131 404	210 463	341 867	-83,57%	-73,69%	2	96,26%	97,45%	91,27%	2	91,30%	99,52%	6,78%

Data columns, including those added via the **Adjust** button, can be dragged by their headers to change their order.

You can right-click any step and choose **Show detailed results**:



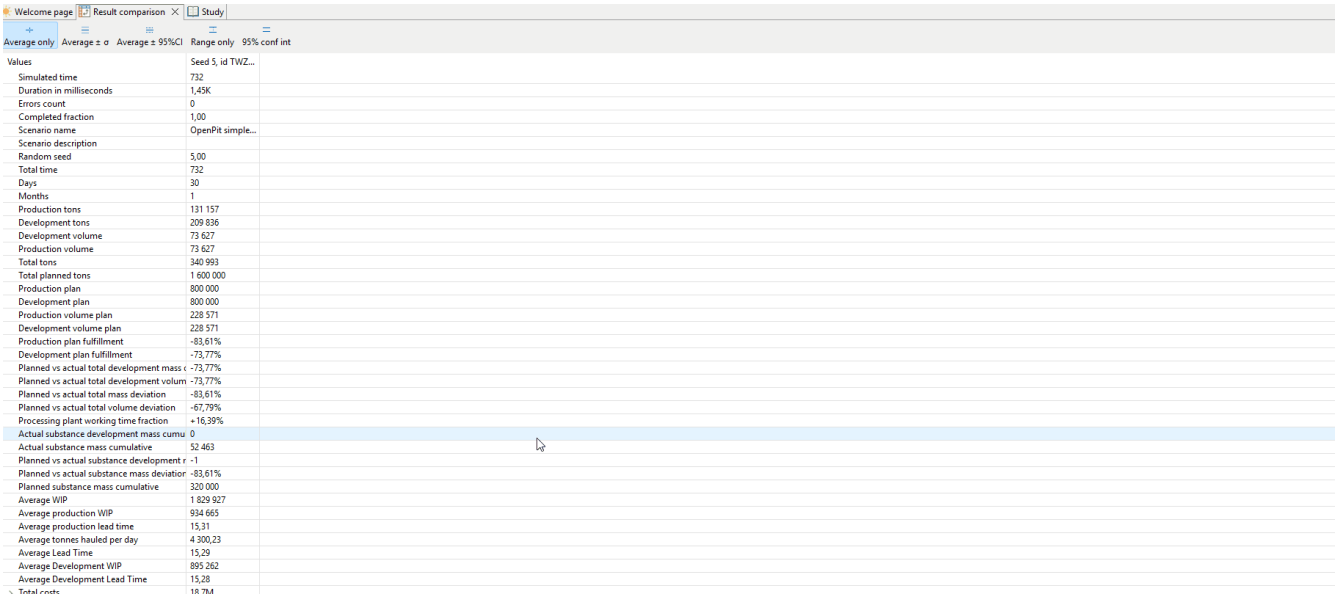
Step	Replications	Status	Total producti...	Total develop...	Total tons	Act/plan devia...	Dev. act/plan ...	Trucks count	Trucks availabi...	Trucks utilizati...	Trucks effectiv...	Excavators cou...	Excavators avai...	Excavators Utili...	Excavators effe...
OpenPit simple fleet sizing scenario	10	100% completed	131 416	210 191	341 608	-83,57%	-73,73%	2	96,21%	97,45%	91,26%	2	91,30%	99,47%	6,78%
Seed 0, id PWR-471-MVC	1	100% completed	131 651	210 463	342 114	-83,54%	-73,69%	2	96,37%	97,46%	91,26%	2	91,30%	99,64%	6,79%
Seed 1, id DBB-361-DCU	1	100% completed	131 651	210 463	342 114	-83,54%	-73,69%	2	96,37%	97,46%	91,26%	2	91,30%	99,64%	6,79%
Seed 2, id VSQ-228-ITG	1	100% completed	131 280	210 463	341 743	-83,59%	-73,69%	2	96,23%	97,45%	91,26%	2	91,30%	99,49%	6,77%
Seed 3, id IHV-111-NSO	1	100% completed	131 280	209 836	341 116	-83,59%	-73,77%	2	96,09%	97,45%	91,24%	2	91,30%	99,34%	6,77%
Seed 4, id QDY-937-AML	1	100% completed	131 404	210 463	341 867	-83,57%	-73,69%	2	96,26%	97,45%	91,27%	2	91,30%	99,52%	6,78%
Seed 5, id TWZ-265-DOX	1	100% completed	131 157	209 836	340 993	-83,61%	-73,77%	2	96,05%	97,45%	91,24%	2	91,30%	99,29%	6,76%
Seed 6, id OMO-296-WCJ	1	100% completed	131 527	209 627	341 154	-83,56%	-73,80%	2	96,13%	97,45%	91,25%	2	91,30%	99,38%	6,77%
Seed 7, id PUI-655-WUR	1	100% completed	131 280	210 463	341 743	-83,59%	-73,69%	2	96,23%	97,45%	91,26%	2	91,30%	99,49%	6,77%
Seed 8, id 724-WGA-605	1	100% completed	131 527	209 836	341 363	-83,56%	-73,77%	2	96,17%	97,45%	91,26%	2	91,30%	99,42%	6,77%
Seed 9, id HRE-607-CLY	1	100% completed	131 404	210 463	341 867	-83,57%	-73,69%	2	96,26%	97,45%	91,27%	2	91,30%	99,52%	6,78%

This opens the **Result comparison** tab with detailed metrics.

If a comparison tab already exists, use the command:

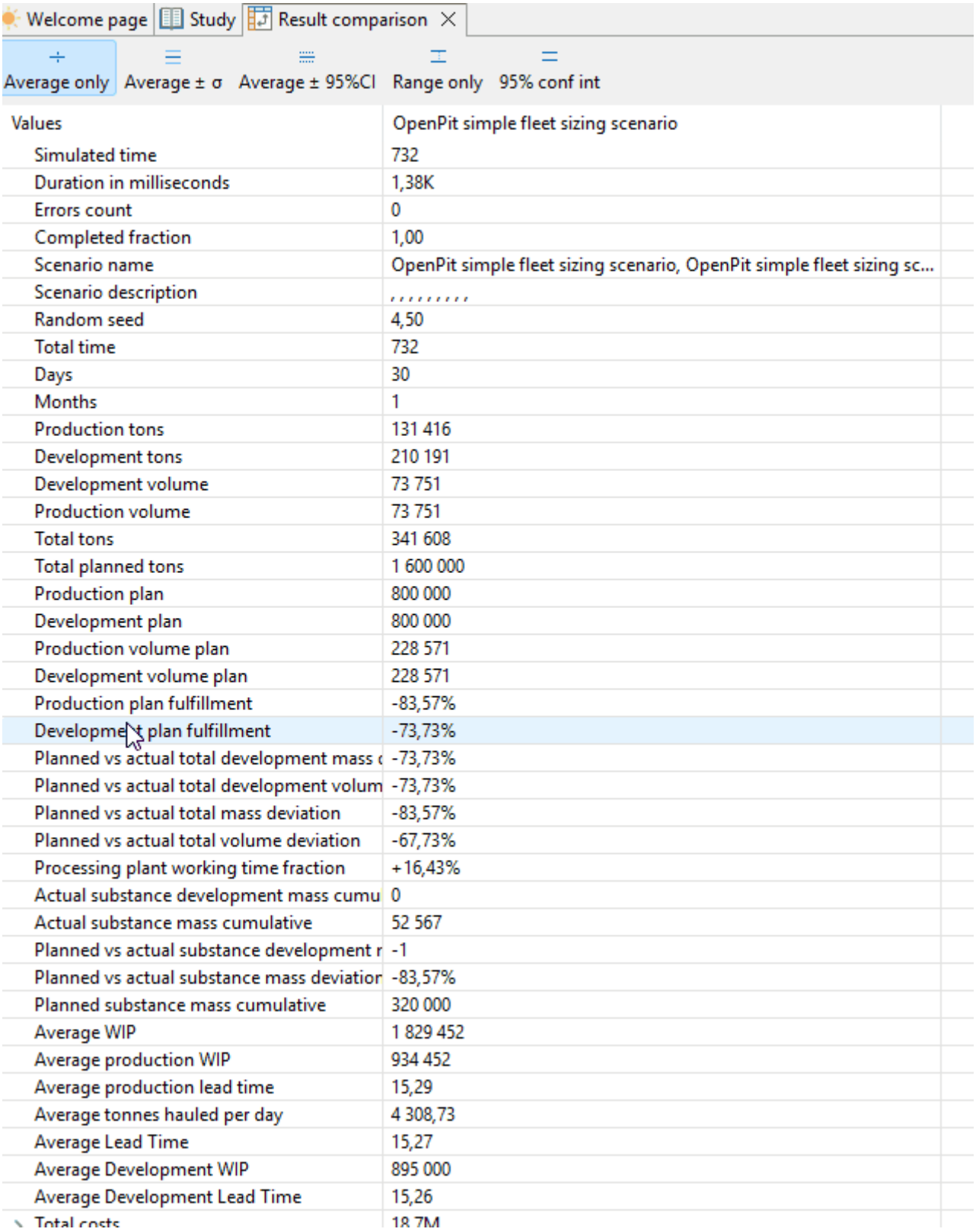
- **Add results to comparison**.

You can add other scenarios to the comparison tab and set one as a baseline. Differences will be calculated automatically:



Values	Seed 5, id TWZ...
Simulated time	732
Duration in milliseconds	1,45K
Errors count	0
Completed fraction	1,00
Scenario name	OpenPit simple...
Scenario description	
Random seed	5,00
Total time	732
Days	30
Months	1
Production tons	131 157
Development tons	209 836
Development volume	73 627
Production volume	73 627
Total tons	340 993
Total planned tons	1 600 000
Production plan	800 000
Development plan	800 000
Production volume plan	228 571
Development volume plan	228 571
Production plan fulfillment	-83,61%
Development plan fulfillment	-73,77%
Planned vs actual total development mass c	-73,77%
Planned vs actual total development volum	-73,77%
Planned vs actual total mass deviation	-83,61%
Planned vs actual total volume deviation	-67,79%
Processing plant working time fraction	+16,39%
Actual substance development mass cumu	0
Actual substance mass cumulative	52 463
Planned vs actual substance development r	-1
Planned vs actual substance mass deviation	-83,61%
Planned substance mass cumulative	320 000
Average WIP	1 829 927
Average production WIP	934 665
Average production lead time	15,31
Average tonnes hauled per day	4 300,23
Average Lead Time	15,29
Average Development WIP	895 262
Average Development Lead Time	15,28
Total costs	18 7M

If your scenario contains several replications you can use the toolbar to toggle how result values are aggregated:



Values	OpenPit simple fleet sizing scenario
Simulated time	732
Duration in milliseconds	1,38K
Errors count	0
Completed fraction	1,00
Scenario name	OpenPit simple fleet sizing scenario, OpenPit simple fleet sizing sc...
Scenario description	, , , , , , , , ,
Random seed	4,50
Total time	732
Days	30
Months	1
Production tons	131 416
Development tons	210 191
Development volume	73 751
Production volume	73 751
Total tons	341 608
Total planned tons	1 600 000
Production plan	800 000
Development plan	800 000
Production volume plan	228 571
Development volume plan	228 571
Production plan fulfillment	-83,57%
Development plan fulfillment	-73,73%
Planned vs actual total development mass c	-73,73%
Planned vs actual total development volum	-73,73%
Planned vs actual total mass deviation	-83,57%
Planned vs actual total volume deviation	-67,73%
Processing plant working time fraction	+16,43%
Actual substance development mass cumu	0
Actual substance mass cumulative	52 567
Planned vs actual substance development r	-1
Planned vs actual substance mass deviation	-83,57%
Planned substance mass cumulative	320 000
Average WIP	1 829 452
Average production WIP	934 452
Average production lead time	15,29
Average tonnes hauled per day	4 308,73
Average Lead Time	15,27
Average Development WIP	895 000
Average Development Lead Time	15,26
Total costs	18,7M

Available views:

- Mean value only
- Mean ± standard deviation
- Mean ± 95% confidence interval
- Value range only
- Confidence interval bounds only

How the confidence interval works:

The confidence interval allows you to determine the range in which the true average value of a metric is likely to fall with 95% probability (confidence level), based on your sample data. The calculation uses a special statistical method called the t-distribution, which accounts for the sample size. This is particularly important when the number of observations is relatively small. The confidence interval is calculated using the following formula:

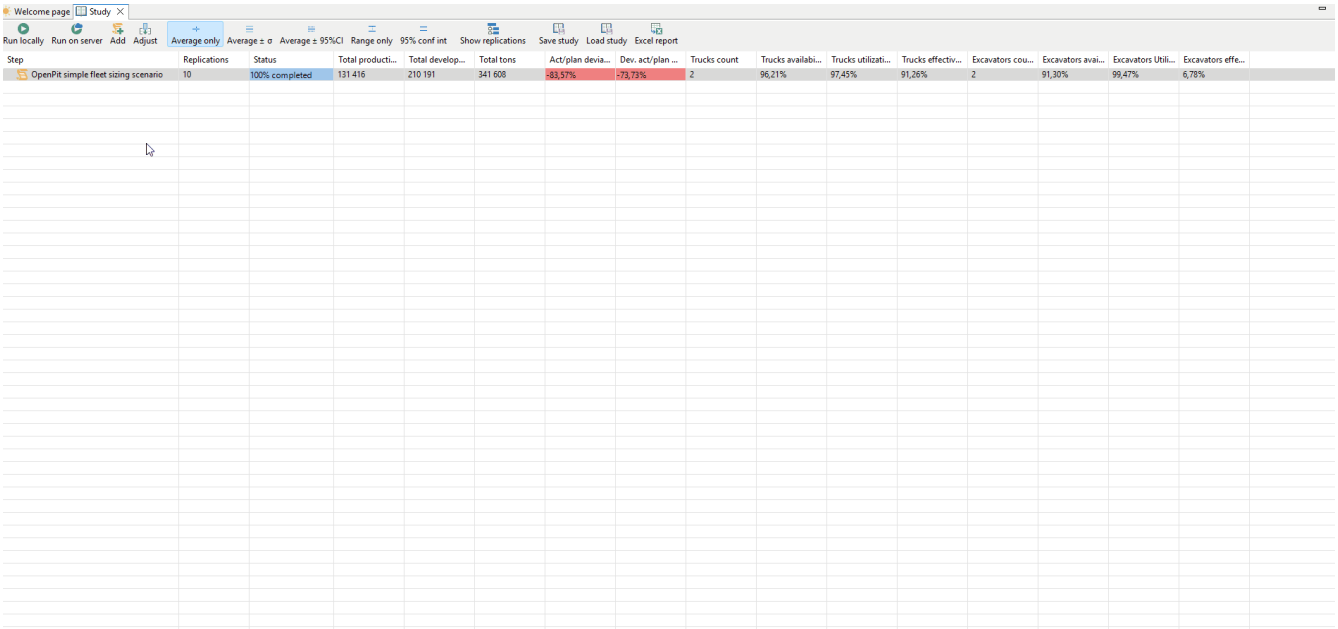
$$\text{Confidence Interval} = \left[\bar{x} - t^* \cdot \frac{s}{\sqrt{n}},\ \bar{x} + t^* \cdot \frac{s}{\sqrt{n}}\right]$$

where:

- $\bar{x}$ — the sample mean,
- s — the sample standard deviation,
- n — the number of observations,
- t^* — the critical t-value based on the confidence level and degrees of freedom.

3.7. Reports

Each step supports a **Scenario summary report**, generated from the context menu:



The report is generated as an HTML page and can be viewed in MineTwin. The report can also be opened in any browser (the **Open in Browser** button on the toolbar). This makes it possible to print it to PDF using browser tools.

Each automated study additionally generates its own report. To view it, select the corresponding item from the study context menu.

The study toolbar includes an **Excel Report** button.

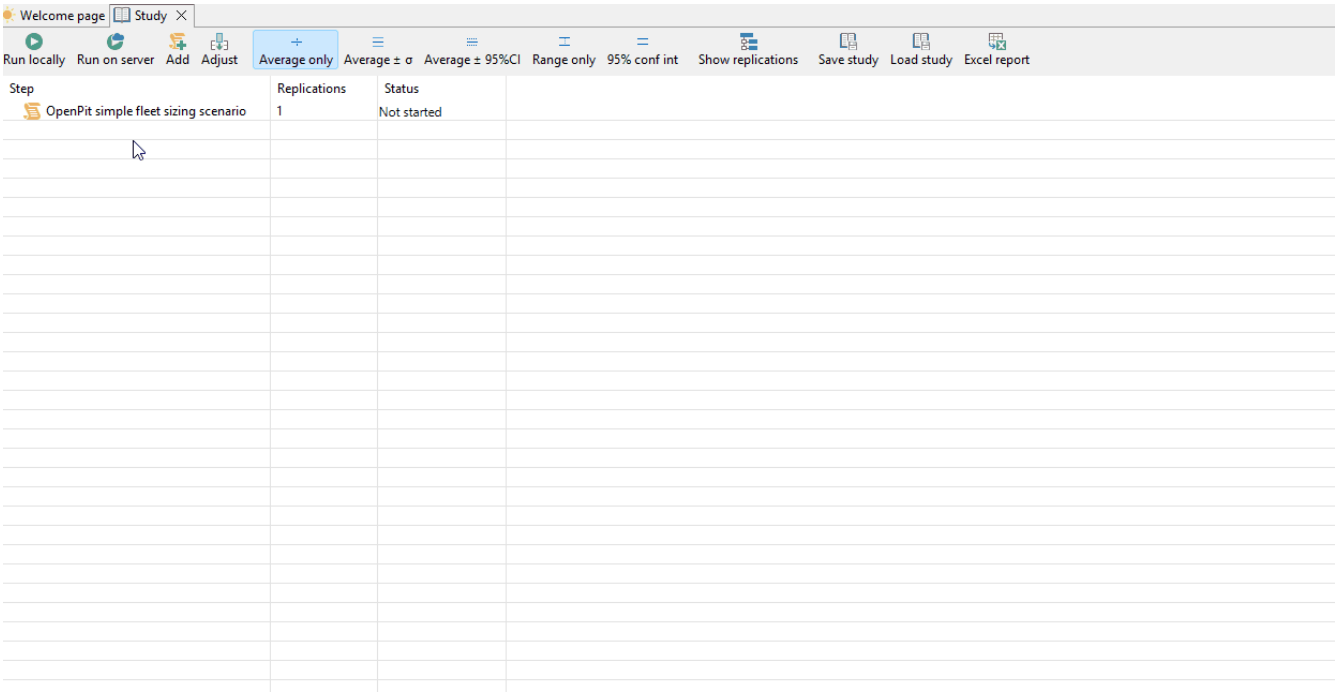
When clicked, the study table is saved to an Excel file and immediately opened in the corresponding application.

3.8. Study Examples

3.8.1. Study: Constraint Analysis

Constraint analysis mode is intended to identify scenario bottlenecks. When the analysis is run, MineTwin automatically launches the scenario simulation multiple times, removing each major constraint in turn, and shows how much the mining plan fulfillment percentage would improve if that constraint did not exist.

Each constraint is modeled through a separate modification, and the results are compared with the baseline scenario. The visual representation makes it easy to identify the most critical bottlenecks.



The following modifications are available:

- **Remove equipment maintenance**;
- **Remove assignment of all equipment units to mine areas**;
- **Duplicate tons in blocks**;
- **Duplicate the number of trucks**;
- **Duplicate the number of excavators**;
- **Duplicate unloading points count at dump areas**;
- **Allow passage of unmined blocks**;
- **Duplicate target plan**;
- **Allow bypassing for all roads**.

The exact set of available modifications may vary depending on the software version.

A right-click command, **Constraint Analysis Report**, opens the HTML report in a separate tab.

The report contains:

- a **Methodology** section describing the study methodology;
- a **Results** section;
- a table with the following columns:
  - **Modification**;
  - **Total production and development tons mined**;
  - **Relative difference to the baseline scenario**;
  - **Modification description**.

Such theoretical experiments help validate modeling assumptions. This **Constraint analysis** is typically the first step toward exploring real-world strategies for performance improvement. It provides a holistic view of system limitations and reveals complex interdependencies in mining operations.

3.8.2. Study: Fleet Sizing

This mode is designed to select the mobile equipment configuration minimally required to achieve the target production and development plans.

After launch:

1. the **No Modifications** scenario is calculated;
2. **equipment clusters** are identified — combinations of equipment class and type, as well as the areas to which they are assigned;
3. the first **Equipment Cluster Analysis** is performed;
4. within the cluster analysis, the following scenarios are created:
   - **Duplicating equipment units in all clusters**;
   - variations of this scenario where equipment is duplicated in all clusters except one;
5. the system determines which cluster increase gives the greatest effect;
6. calculates how many equipment units need to be added;
7. generates a new scenario with additional equipment;
8. then repeats the cluster analysis.

The cycle continues until a configuration is found that allows the plan to be fulfilled for both production and development mining.

After the plan is achieved, the stage of excluding the least utilized equipment units begins:

- after each exclusion, a new scenario is generated;
- if the plan is no longer fulfilled, that branch is discarded;

- if the plan is still fulfilled, the study continues deeper into that branch with further equipment exclusions;
- the process continues until a dead end is reached.

The entire process is displayed as a hierarchical table with branching study steps.

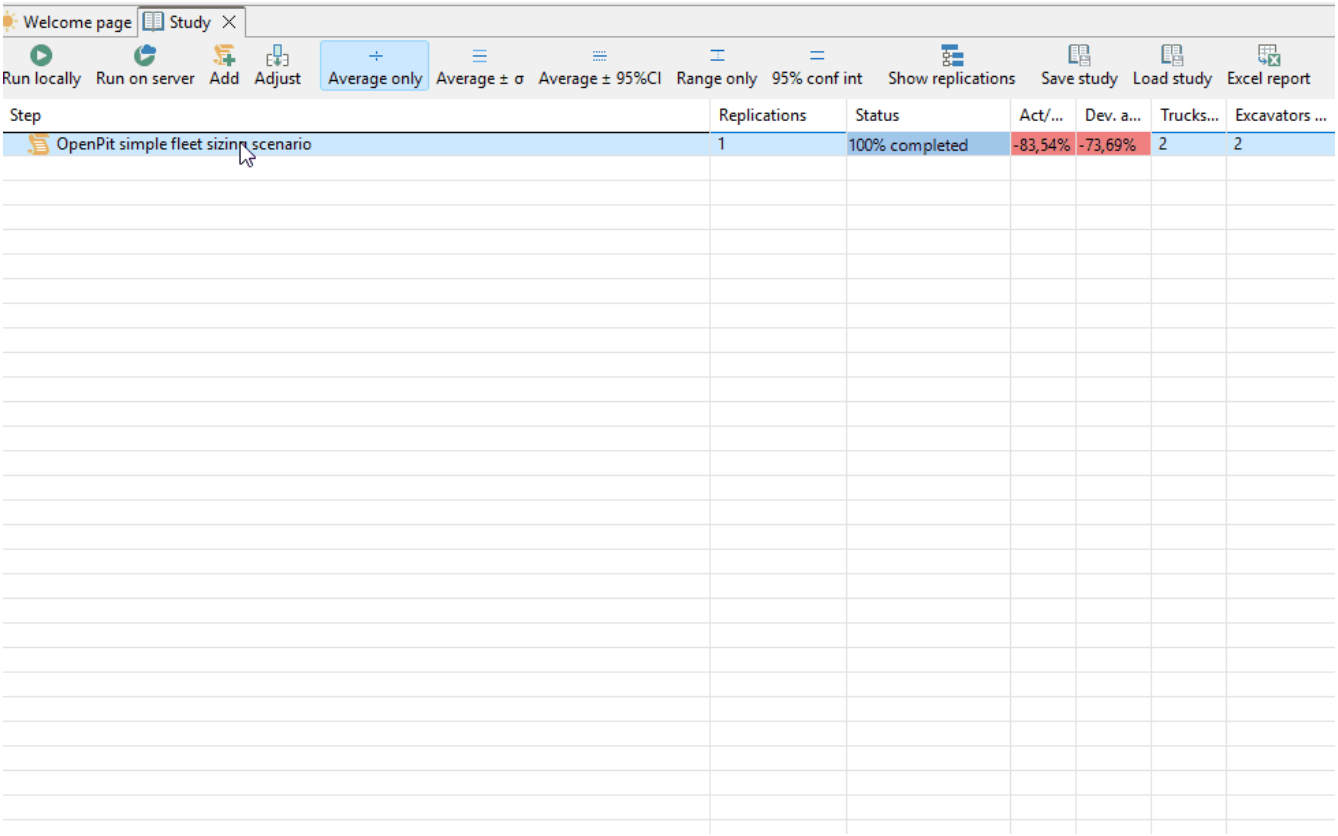
Each **Equipment Cluster Analysis** generates a separate HTML report. The report contains:

- the baseline limiting plan fulfillment;
- the theoretical maximum achieved by duplicating equipment in all clusters;
- a list of clusters;
- the number of units in each cluster;
- an estimate of absolute improvement potential;
- an estimate of improvement potential per unit;
- a final recommendation for fleet changes.

The entire study for determining the optimal fleet size also generates a separate final HTML report.

The final report contains:

- comparison of the **Baseline Scenario** and the **Best Fleet Configuration**;
- target KPI achievement status;
- **Total tonnes mined**;
- **Ore tonnes mined**;
- **Development or waste tonnes mined**;
- **Total cost**;
- **Cost per ton**;
- **Number of trucks**;
- **Number of excavators**;
- waterfall charts showing the step-by-step effect of fleet changes on total mining volume and cost per ton.



3.8.3. Study: Equipment Units Count Variation

The **Equipment Units Count Variation** mode is intended to determine how changes in equipment quantity and/or operating parameter values affect a set of target KPIs.

The mode is launched from the context menu.

After launch, a dialog box opens where the following can be specified:

- equipment to vary;
- minimum quantity;
- maximum quantity;
- variation step.

The dialog also shows how many scenarios will be generated.

After clicking **OK**, the required scenarios are created automatically. This launch creates a **one-axis study**.

Variation axes are available for different types of equipment, including:

- trucks;
- excavators;
- drills;
- charging machines;
- loaders; etc.

Adding a Second Variation Axis

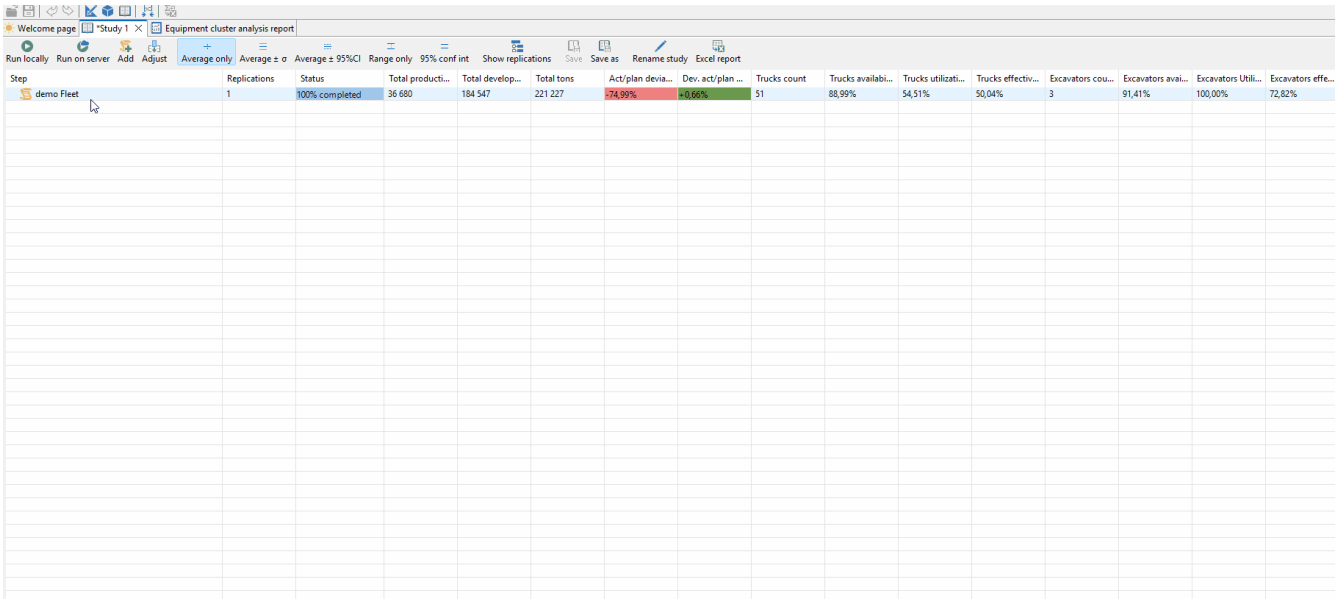
To add a second and subsequent axes for another equipment type, right-click the study and select **Add variation axis** from the context menu. A dialog box similar to the one used for the one-axis study will appear.

To add a second axis for another parameter, or to create an axis for a parameter not related to equipment quantity, you need to:

1. switch to editor mode;
2. open the tab where the required parameter is located;
3. click the book icon button to the right of the parameter;
4. in the window that opens, specify the variation range and step;
5. choose whether to apply the changes to all equipment units or only to a specific unit;
6. if necessary, enable the flag to use the parameter as the second axis;
7. select from the dropdown list the existing one-axis study to which the new axis will be added.

Thus:

- the first axis can be created via the **Study** mode as an equipment quantity study, or via the editor for varying parameter values not related to equipment quantity;
- the second axis can be added from the **Study** mode for varying equipment quantity, or from the editor through object parameters for varying its value.



Reports for Variation Studies

Different HTML reports are generated for one-axis and two-axis studies.

The one-axis report contains:

- description of the parameter under study;
- total number of experiments and replications;

- a correlation table with the following columns:
  - **Independent parameter**;
  - **Dependent KPI**;
  - **Sufficient data**;
  - **Correlation type**;
  - **Spearman correlation coefficient**;
- textual conclusions on the identified relationships;
- dependency charts for KPIs where correlation was found or its absence was confirmed.

The two-axis report contains:

- description of the two varied parameters;
- total number of experiments and replications;
- tables and visualizations in the form of a heat map showing the influence of parameters on key KPIs.

The following are analyzed in two-axis reports:

- **Impact on total tons**;
- **Impact on production tons**;
- **Impact on production plan fulfillment**;
- **Impact on trucks effective utilization**;
- **Impact on excavators effective utilization**.

3.9. Conclusion

The **Study** mode offers a powerful framework for evaluating operational strategies, identifying constraints, and making informed data-driven decisions.

By enabling structured experimentation and visual comparison of scenarios, Study mode transforms simulation into a practical decision-support tool. It helps engineers, analysts, and managers test assumptions, quantify outcomes, and prioritize actions that have the greatest operational and financial impact.

This not only accelerates the decision-making cycle but also improves confidence in strategic choices, ensuring that mine planning is based on evidence rather than intuition.

3.9.1. Summary of Key Workflows

The Study mode supports a range of structured workflows, including:

- **Creating studies** from existing scenarios
- **Adding manual or automated modifications** to explore operational changes

- **Running simulations locally or on the server**, with background execution
- **Viewing individual or aggregated results**, including statistical metrics
- **Comparing results** across different steps or scenarios using baseline mode
- **Generating reports** for each step or entire study
- **Saving any step as a reusable scenario** or continuing analysis from any step

These workflows are designed to maximize analytical flexibility while reducing manual overhead.