

MineTwin Undergound

User guide





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1. Introduction

1.1. Purpose of the document

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

1.2. System description

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

MineTwin Underground consists of the following modules:

- 1. Editor
- 2. Scheduler
- 3. Simulation model

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

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

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

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

1.3. System requirements

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

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



2. Scenario creation and editing

2.1. Preparing the input file

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

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

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

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

2.2. Launching the application, loading the editing mode

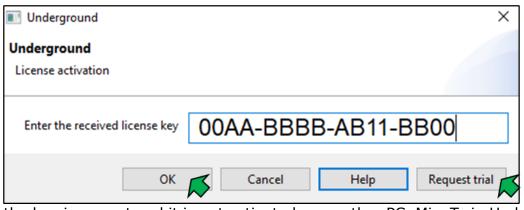
To install the MineTwin Underground application on your computer, you need to unzip the **"MineTwin 0.1.0"** folder and save it on your local computer.

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

MineTwin Underground							
MineTwin Underground license activation							
No active license has been found for this PC and product							
OK Cancel Help							

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





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

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

opens when you click on Help



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



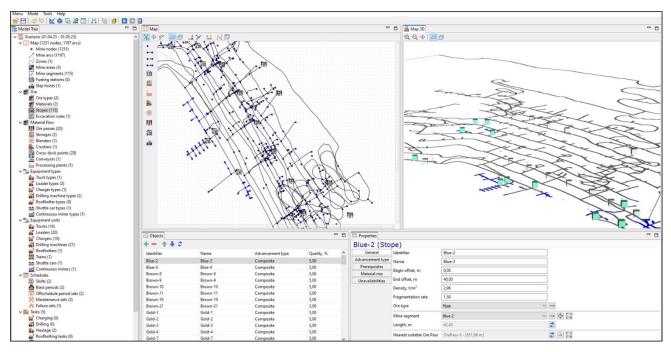
Mode Tools Help w 👂 🔂 🖉 🔛 🛤 👯					
/e D:\Amalgama 2.0\r	ninetwin\scenarios\Underground\MineTwin Underg ninetwin\scenarios\Underground\Simple undergrou ninetwin\scenarios\Underground\MineTwin Underg				
t Other	K				
	🕽 Открытие				×
	🔶 🔶 🐘 🕇 🦲 « Новый то	ом (D:) > Amalgama 2.0 > minetwin > scenarios	> Underground ~	Ö Поиск в: Undergrou	und 🔎
	Упорядочить 👻 Новая папи	:a		BEE	- 🔳 🕜
	🖊 Загрузки	^ Имя	Дата изменения	Тип	Размер ^
	📰 Изображения	Demo example.xlsx	06.04.2023 10:16	Лист Microsoft Ex	137 KE
	👌 Музыка	Demo-scenario-real.xlsx	06.04.2023 10:16	Лист Microsoft Ex	121 KE
	🧊 Объемные объекты	Demo-scenario-real-quality.xlsx	06.04.2023 10:16	Лист Microsoft Ex	161 K5
	Рабочий стол	Excavation dependency.xlsx	06.04.2023 10:16	Лист Microsoft Ex	57 КБ 🗸
	<u>И</u> мя файла:	Demo-scenario-real.xlsx		~ *.*	~
				Открыть	Отмена

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

				—	
Scenario	loading errors				
Some pro	oblems detected during scenario loadi	ng			
Туре	Message	Excel Sheet	Row	Column name	
Error	Empty cell is illegal	FuelingStation	1	fuelingPosition	
Error	Empty cell is illegal	FuelingStation	1	queuingPosition	
Error	Empty cell is illegal	Charger	1	baseNode	
Error	Empty cell is illegal	Charger	1	chargerType	
Error	Empty cell is illegal	Charger	1	chargerType	ОК

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





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

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

2.3. Elements of the scenario editor

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

2.3.1. Toolbar

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



Me	nu Mode Tools Help ' 🔡 🞺 🏷 📐 🎓 🐯 🖉 [≝ 💐 💥 😻 🗲 ∋ 🗐	
Menu Mode Tools □ New □ Open > □ Save Ctrl+S □ Save as	Mode Tools Help Image: Simulation Image: Second comparison Image: Second comparison Image: Second compari	Tools Help Image: Second se	Help License

The "Menu" button contains the following functions:

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

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

- Editor (🔽)
- Simulation (▶)
- Scenario Comparison (💷)
- Sensitivity Analysis (²²)
- Constrains Analysis (^[]]).

The "Tools" button contains the function:

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

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

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

The button $\stackrel{\scriptstyle{\scriptstyle{\boxtimes}}}{=}$ synchronizes graphs in the simulation mode.

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



The button ³ allows to import files in .dxf format.

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

The button 🗐 searches any scenario element by its name.

2.3.2. Model tree

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

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



Model Tree	- 6	3
✓ Scenario (01.04.23 - 01.05.23)	,	_
✓ Ⅲ Map (548 nodes, 591 arcs)		
 Mine nodes (548) 		
Mine arcs (591)		
V Zones (0)		
Mine areas (1)		
Mine segments (25)		
Fueling stations (0)		
Skip hoists (0)		
V 🛒 Ore		
Ore types (2)		
Materials (2)		
Stopes (25)		
Excavation rules (1)		
✓ Material flow		
Ore passes (5)		
Storages (0)		
Blenders (0)		
Crushers (0)		
Cross-dock points (0)		
Conveyors (0)		
Processing plants (0)		
✓ ^{max} / _{em} Equipment types		
Truck types (1)		
Loader types (4)		
🙀 Charger types (1)		
Drilling machine types (2)	
Roofbolter types (1)		
Shuttle car types (0)		
Continuous miner types	(0)	
✓ [™] → Equipment units		
👸 Trucks (1)		
😽 Loaders (4)		
🙀 Chargers (2)		
🔐 Drilling machines (3)		
Roofbolters (1)		
Trains (1)		
Shuttle cars (0)		
🗺 Continuous miners (0)		
✓		
Shifts (3)		
Blast periods (1)		
Offschedule period sets (1)	
💥 Maintenance sets (0)		
🔥 Failure sets (0)		
✓ ■ Tasks (0)		
Charging (0)		
🔐 Drilling (0)		
Haulage (0)		
Roofbolting tasks (0)		
Cross-docking tasks (0)		
Continuous mining tasks	; (0)	
Skip hoisting tasks (0)		
Shuttling tasks (0)		
V Plans		
Stopes plan (0)		
Target plan (0)		
		~



2.3.3. Objects

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

✓ 🚉 Equipment types 등 Truck types (1) ↓ Loader types (4)	Objects + - C	2 🕒			- 8
Charger types (1)	Identifier	Name	Capacity, t	Volume, m ³	Loading
Drilling machine types (2)	SANDVIK LH409E	SANDVIK LH409E	12,50	40,00	0,50
Roofbolter types (1)	SANDVIK LH514	SANDVIK LH514	14,00	40,00	0,50
Continuous miner types (0)	R1600G	R1600G	10,20	40,00	0,50
Equipment units	R1700G	R1700G	14,00	40,00	0,50

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



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

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

Objects				_	Objects				Objects		
+ - 🗈 🛧	+				+ - 🗈 🛧	+			+- 🗈 🕇	+	
Identifier	Name		Quality	l	Identifier	Nam lime		Ц	Identifier	Name •	Quality
LIME 1	LIME 1		1.0		LIME 1	LIME 1	1.0		LIME 1	LIME 1	1.0
LIME 2	LIME 2	T 7	11	٦	LIME 2	LIME 2	1.0	Ш	LIME 2	LIME 2	1.0
LIME 3	LIME 3		ME 2		LIME 3	LIME 3	1.0	Ш	LIME 3	LIME 3	1.0
GRAY 1	GRAY 1	🄏 ≠ LI	ME 2		GRAY 1	GRAY 1	1.0	Ш			
GRAY 2	GRAY 2	🌃 Con	tains		GRAY 2	GRAY 2	1.0	Ш			
GRAY 3	GRAY 3	Сор			GRAY 3	GRAY 3	1.0	Ш			
PURPLE 1	PURPLE 1		-		PURPLE 1	PURPLE 1	0.0	Ш			
PURPLE 2	PURPLE 2	GE Ope	n in Excel		PURPLE 2	PURPLE 2	0.0	Ш			
PURPLE 3	PURPLE 3	20 li	nes		PURPLE 3	PURPLE 3	0.0	11			
PURPLE 4	PURPLE 4	_	0.0		PURPLE 4	PURPLE 4	0.0	11			

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

Objects		
+- 🖻 🛧 🖣	•	
Identifier	Name •	Quality
LIME 1	LIME 1	1.0
LIME 2	LIME 2	🌇 = LIME 1
LIME 3	LIME 3	¥ LIME 1
		K Contains
		K Remove filter
		Copy all
		Open in Excel
		3/20 lines

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



2.3.4. Properties

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

Objects			- 0	Properties		
+ - 🗈 🛧 🖣	2 13			SANDVIK L	H409E (Loader type)	
Identifier	Name	Capacity, t	Volume, m ³	General	Identifier	SANDVIK LH409E
SANDVIK LH409E	SANDVIK LH409E	12,50	40,00	Speeds	Name	SANDVIK LH409E
SANDVIK LH514	SANDVIK LH514	14,00	40,00	Fuel consumption	Maintenance	~ >
R1600G	R1600G	10,20	40,00		Maintenance	
R1700G	R1700G	14,00	40,00		Failure set	~ >
					Capacity, t	12,50
					Volume, m ³	40,00
					Loading duration, min	0,50
					Unloading duration, min	0,50

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

Properties			
Mine arc 21	(Mine arc)		
General	Identifier	Mine arc 21	
Structure	Name	Mine arc 21	
Mine segments	ls bidirectional	\square	
	Requires bypass		
	Road quality	1,00	
	Туре	Road	(
	Zone	Road Rail	$\times \neg$
	Calculate values	Conveyor	
	Length, m	74,24	
	Average gradient, degree	0,00	

To update the data, use the button $\stackrel{\frown}{\simeq}$.

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



Properties						
SANDVIK LI	H514 (1) (Loader)					
General	Identifier	SANDVIK LH514 (1)				
Maintenance runs	Name	SANDVIK LH514 (1)				
Unavailabilities	Included					
	Base node	Mine node 1) ~	-	
	Mine area	Mine area 1		~	\rightarrow \times	
	Loader type	SANDVIK LH514		~		
	Empty speed, km/h	Properties				
	Loaded speed, km/h	Mine node 1	L (Mine	e node)		
	Fuel tank volume, liters	General	Identifier	Mine node 1		
	Empty fuel consumption rate, liters/hour	Input connectors	Name	Mine node 1		
	Loaded fuel consumption rate, liters/hour	Output connectors	x	418,75		
U			Y	-248,00		
			z	0,00		

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

		<u><u> </u></u>
	<mark>8</mark>	
		● ••• ● •• ● ••• ● ••• ••• ••• ● ••••••
		· · · · · · · · · · · · · · · · · · ·
Properties		
SANDVIK LI	1514 (1) (Loader)	
General	Identifier	SANDVIK LH514 (1)
Maintenance runs	Name	SANDVIK LH514 (1)
Unavailabilities		
	Included	
	Base node	Mine node 1 $\checkmark \rightarrow \bigotimes $
	Mine area	Mine area 1 \checkmark \rightarrow \times
	Loader type	SANDVIK LH514 ✓ →

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



Properties			
SANDVIK LI	H514 (1) (Loader)		
General	Identifier	SANDVIK LH514 (1)	
Maintenance runs	Name	SANDVIK LH514 (1)	
Unavailabilities	Included		- \
	Base node	Mine node 1	- → 💠 🔯
	Mine area	Mine area 1	$\sim \rightarrow \times$
	Loader type	SANDVIK LH514	\sim \rightarrow

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

Properties]	
Fueling stat	tion 1 (Fuelin	g station)				
General	Identifier		Fueling station 1			
	Name		Fueling station 1			
	x		0,00			
	Υ		0,00			
	z		0,00			
	Fueling position		Mine node 101	 -> O + O 		
	Queuing position	Properties		\sim		
		Fueling stat	ion 1 (Fueling station)			
		General	Identifier	Fueling station 1		
			Name	Fueling station 1		
			x	2 625,57		
			Y	2 073,51		
			Z	60,00		
			Fueling position	Mine node 101) ~ [-	» 🔶 🔶 🖸
			Queuing position	Mine node 129	~ -	> 🔶 🔶 🖸

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



Properties							1
	pe 1 (Charger type)						
General	Identifier		Charger type 1				
	Name		Charger type 1				
	Maintenance					~ X	
	Failure set					~ X	
	Velocity, km/h		15,00				
	Setup duration before charging, min		triangular(0,00; 1	,00; 2,00)			4
	Well charging duration, min					r	×
	Explosives loading duration, min	Select distr	ibution esired distribution and fill i	n its paramete	ers		
		Type Constant Truncated r Normal Uniform Triangular	iormal	Min Likely Max	0.0	10.0% 9.0% 8.0% 6.0% 5.0% 4.0% 3.0% 2.0% 1.0%	

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).

💁 Blast periods				
+ - 🖻 🕇	++			
Identifier	Name	Duration, min	Period	
Blast period	Blast period	60.0	Every 1 days at 14:00	l
5	elect time series Select the desired time series and fill in the required fields Every N days Every month Every month last day Every week Every N days Single	X Select time serie Select the desired required fields Every N days Instant time N days	es It time series and fill in the 14:00	
	OK Car	ncel	OK Cancel	

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

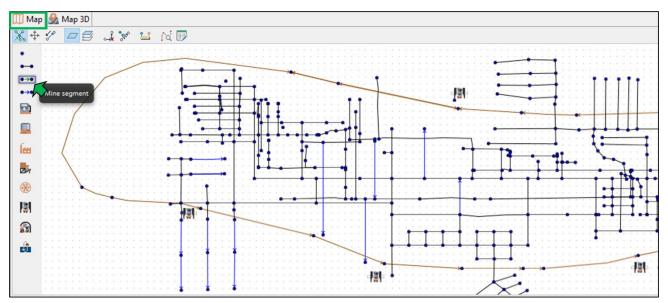
OK Cancel



🔲 Объекты				
+- 🖻 🛧 🕂				
Идентификатор LoaderType-0	Название SANDVIK LH409E			
LoaderType-1 LoaderType-2 LoaderType-3	SANDVIK LH514 R1600G R1700G	₩ ₩ ₩	= SANDVIK LH514 ≠ SANDVIK LH514 Contains Copy all Open in Excel	
			4 lines	

2.3.5. Map

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



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

The button $\overset{\text{M}}{\longrightarrow}$ in the upper left corner allows to display on the map the input and output connections of the elements of the system ensuring the material flow.

The button Φ allows you to center the map.



The button $\overset{\checkmark}{\sim}$ allows you to quickly change the direction of the stope.

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

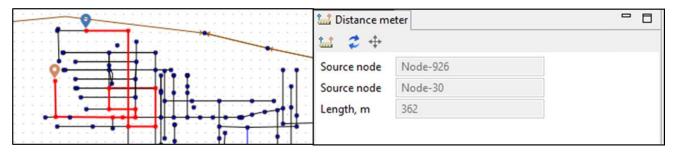
The button solution optimizes arc inflection points - removes inflection points that are on the same line between two consecutive inflection points, of selected mine arcs or all arcs of the scenario, if no arc is selected (Clause 2.5.2).

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

The button 🕍 allows to determine the shortest distance between two nodes of the mine

field. After clicking on this button, a label 💡 appears, which must be placed on the

node of the beginning of the path and clicked with the mouse. Then the second label will appear, which must be set on the destination node. After that, the route between the nodes will be highlighted on the map, and information about the distance between the selected mine nodes will appear in the "Distance meter" window that opens.



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

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



Setting mine nodes Z-range					
Set Z-range parameters and confirm selection					
Min value	-140	X			
Max value	-120	X			
	ОК	Cancel			

The button 🔯 enables/disables viewing of the selected area.

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

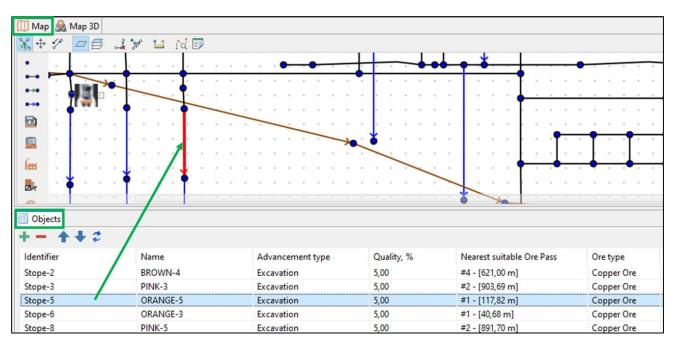
To add any mine object, except for arcs and segments, you need to left-click on the object on the palette, and then on the place of the plan where you want to add the object.

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

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

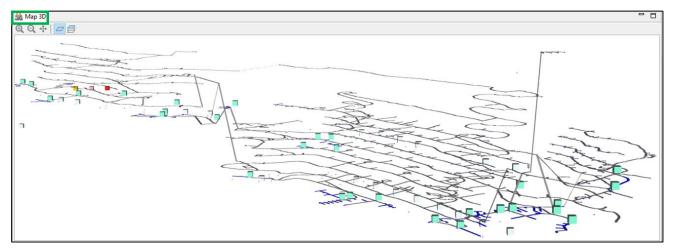
When you select the object unit in the "Objects" window, the corresponding object is highlighted on the map.





2.3.6. Map 3D

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



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

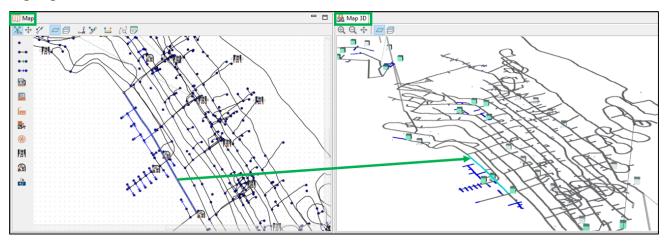
The button $\stackrel{\text{\tiny{def}}}{=}$ in the upper left corner allows you to center the map 3D.

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

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



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



2.3.7. Errors

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

Tools	Help	
😨 V	alidate Scenario	

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.

D Errors				
🗢 Re	cords: 5			
#	Object	Description		
81	Loader type 1	Value should be a positive number (Capacity, m ³)		
82	Loader type 1	Value should be a positive number (Empty speed, km/h)		
83	Loader type 1	Value should be a positive number (Loaded speed, km/h)		
84	Loader type 1	Value should be a positive number (Loading duration, min)		
85	Loader type 1	Value should be a positive number (Unloading duration, min)		

Error messages can be of two types:

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

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



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

2.4. Scenario

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

Properties			
West.xlsx	(Scenario)		
General	Identifier	West	
	Name	West.xlsx	
	Begin date	01.04.2023 00:00	8
	End date	01.05.2023 00:00	8
	Scheduling mode	By tasks 🗸	·
		By tasks By stopes By target By target regardless of quality	

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

- Unique identifier and name of the scenario.
- Date and time of start and end of scheduling and simulation.
- One of the possible scheduling modes:
 - by tasks only tasks created by the user manually in the stopes
 ^w Tasks (2)
 of the model tree are scheduled (Clause 2.9.1)
 - by stopes scheduling is carried out in accordance with the plan by stopes
 (Stopes plan (20)) (Clause 2.9.2.1)
 - by target scheduling is carried out in accordance with the plan by target (^{Target plan (2)}) (Clause 2.9.2.2).
 - by target regardless of quality scheduling is carried out in accordance with the plan by target regardless of quality of the ore.

2.5. Underground mine parameters

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

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



- Fueling stations
- Skip hoists.

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

- Ore types
- Materials
- Stopes
- Excavation rules.

2.5.1. Mine node

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

Properties							
Mine node :	Mine node 1 (Mine node)						
General	Identifier	Mine node 1					
Input connectors	Name	Mine node 1					
Output connectors	x	418,75					
	Υ	-248,00					
	z	0,00					

The mine node is characterized by the following parameters:

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

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

2.5.2. Mine arc

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



Properties	I Properties						
Mine arc 21	Mine arc 21 (Mine arc)						
General	Identifier	Mine arc 21					
Structure	Name	Mine arc 21					
Mine segments	ls bidirectional	\square					
	Requires bypass						
	Road quality	1,00					
	Туре	Road 🗸					
	Zone	~	$\times \rightarrow$				
	Calculate values	2					
	Length, m	74,24					
	Average gradient, degree	0,00					

The mine arc is characterized by the following parameters:

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

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



Properties					
Mine arc 32	(Mine arc)				
General	Source node		Mine node 1		-> 🔶 🖸
Structure	х		-126,50		
Mine segments	γ		1,00]
	Z		0,00]
	Dest node		Mine node 32		-> 🔶 🖸
	х		-125,50]
	Y		-169,00]
	Z		0,00]
	12 - 4				
	X	Y		Z	
	-118,25	-85,75		0,00	

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

Properties						
Mine arc 11	(Mine arc)					
General	Identifier	Name	Mine area	Mining front		
Structure	Mine segment 1	Mine segment 1	MineArea-0	Bottom center block	->	
Mine segments						

2.5.3. Zone

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



🔟 Map 🔬 Map 3D		
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		teres e se se se se se se se se la se se la∐e φ se se se e¶ se se la matrix T s [s se se] s ⊕ φ se se se
Properties		
Clearing (Z		
General	Identifier	Clearing
Mine arcs	Name	Clearing
	Color	0, 255, 0

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

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

Properties							
Clearing (Zone)							
General	•						
Mine arcs	ldentifier	Name	Source node	Dest node			
	ROAD-149	ROAD-149	ROAD-149-b	MN-146			
	ROAD-104	ROAD-104	ROAD-13-b	ROAD-14-b			

Here you can add arcs by selecting them on a mine field using the button $\textcircled{\Phi}$ or remove an arc from the list (\blacksquare).

2.5.4. Mine area

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

Properties			
Area #1 (Min	e are	a)	
General	lentifier [1	
N	lame [Area #1]

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



2.5.5. Mine segment

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

Properties								
Brown-7 (M	Brown-7 (Mine segment)							
General	Identifier	Brown-7						
Mine arcs	Name	Brown-7						
	Length, m	9,06	2					
	Mine area	2 ~	→					
	Stope	Brown-7 ~	+					

The mine segment is characterized by the following main parameters:

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

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

Properties				
Brown-7 (I	Mine segment)			
General	- • -			
Mine arcs	Identifier	Name	Source node	Dest node
	MineArc-1030	MineArc-1030	Node-954	Node-973

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

Fueling station 2.5.6.

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



Properties							
Fueling station 1 (Fueling station)							
General	Identifier	Fueling station 1					
	Name	Fueling station 1					
	x	0,00					
	Υ	0,00					
	Z	0,00					
	Fueling position	~ ~	-> 🔶 🔶 💈	О,			
	Queuing position	~	-> 🔶 🔶 🛛	О,			

The fueling station is characterized by the following parameters:

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

2.5.7. Skip hoist

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

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



Properties			
Skip hoist (west) (Skip hoist))	
General	Identifier	Skip hoist (west)]
Maintenance runs	Name	Skip hoist (west)]
Unavailabilities	Included		
	Mine area	Mine area 1 🗸 🗸 🗸	\rightarrow \times
	Maintenance	~	\times
	Failure set	~	\times
	X	69 109,00]
	γ	40 929,50]
	Z	-318,00]
	Mine node	Node-9 ~	$\rightarrow \diamondsuit \Leftrightarrow \square$
	Skip capacity, t	0,00]
	Cycle time, s	0,00]
	Loading and dumping time, s	0,00]
	In flow connector	OrePass-11 ~	$2 \rightarrow \oplus \times \square$
	Out flow connector	~	$\mathcal{Z} \to \oplus \times \mathbb{N}$

The skip hoist is characterized by the following main parameters:

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

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

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



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

2.5.8. Ore type

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

Properties						
Copper Ore (Ore type)						
General	Identifier	Copper Ore				
	Name	Copper Ore				
	Mining type	Production ~				

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

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

2.5.9. Material

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

Properties			
Copper (Ma	terial)		
General	Identifier	Copper	
	Name	Copper	
	Material type	Substance V	

The following properties must be set for each material:

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

2.5.10. Stope

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



2.5.10.1 General parameters

Properties			
Red-8 (Stop	be)		
General	Identifier	Red-8	
Advancement type	Name	Red-8	
Prerequisites	Begin offset, m	0,00	
Material mix Unavailabilities	End offset, m	84,32	
	Density, t/m³	2,80	
	Fragmentation rate	1,50	
	Ore type	Порода 🗸 🗸	
	Mine segment	Red-8 ~	$\rightarrow \Leftrightarrow \square$
	Length, m	84,32	2
	Nearest suitable Ore Pass	OrePass-5 - [4 169,57 m]	🔹 -> 🖸

The stope is characterized by the following main parameters:

- Unique identifier and name
- Begin offset, m distance from the begin of the stope that was already developed at the start of planning/simulation, determines the working place in the stope
- End offset, m distance from the begin of the stope, determines the end of the stope for development
 For example, the length of the stope is 60 meters, begin offset is 20m, end offset

is 55 m. It means, that the equipment will work in the stope only on the length from 20 to 55 m, because 20 m is already finished, last 5 m is not available for works.

- Density, t/m³ ore mass per unit volume minus the volume of pores, voids and cracks, in t/m³
- Fragmentation rate coefficient characterizing the increase in the volume of ore mass during destruction (blasting or cutting by continuous miner)
- Ore type one of the possible types of ore mass in the scenario
- Mine segment reference to the mine segment that corresponds to the stope
- Length in meters is equals to the length of the mine segment, which corresponds to the stope
- Nearest suitable ore pass the closest ore pass to the stope that can take on the ore type of the stope. The nearest suitable ore pass is determined automatically.

2.5.10.2 Advancement type

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



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

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

Properties															
Red-8 (Stop	Red-8 (Stope)														
General	Max possible length, m	84,32	2												
Advancement type	Advancement type	Excavation 🗸													
Prerequisites		10.00													
Material mix	Empty length, m	10,00]												
Unavailabilities	Bolted length, m	10,00													
	Drilling and charging cycle started														
	Length with ore, m	1,00	\$ \$												
	Ore mass to haul, t	180,00]												
	Drilled wells count	0,00]												
	Charged wells count	0,00]												
	Width, m	4,87]												
	Height, m	5,09]												
	Excavation rule	Rule ~													
	Drilling depth, m	4,00													
	Max unbolted length, m	100,00]												
	Bolts per m2 roof	4,00]												
	Drilling wells per m2 face	2,30													

2.5.10.3 Excavation

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

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



- Length with ore, m the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required
- Ore mass to haul, t
- Number of drilled wells
- Number of charged wells
- Width of the stope, m
- Height of the stope, m.
- Excavation rule one of the possible rules containing additional information about the drilling rules (maximum drilling depth, number of wells per m² face, etc.) (Clause 2.5.11).

Properties														
Blue-4 (Stope)														
General	Max possible length, m	2												
Advancement type	Advancement type	Cleaning ~												
Prerequisites Material mix	Section area, m2	30,00]											
Unavailabilities	Drilling ring length, m	2,00]											
	Vertical wells per ring	15,00]											
	Vertical well depth, m	10,00]											
	Cleaned length, m	0,00]											
	Length with ore, m	0,00	35											
	Ore mass to haul, m	0,00]											
	Drilling and charging cycle started													
	Drilled wells count	0,00]											
	Charged wells count	0,00]											

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

- Section area, m² average section area of the stope during cleaning
- Drilling ring length, m distance between two drill rings
- Number of vertical wells per one ring
- The average depth of a vertical well, m
- Cleaned length the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- Length with ore, m the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required



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

2.5.10.5 Composite

Properties							
Green-30 (S	Stope)						
General	Max possible	length, m	12,37		2		
Advancement type	Advancement	type	Composite		~		
Prerequisites							
Material mix	Drilling ring le	ength, m	2,50				
Unavailabilities	Ore mass to h	iaul, m	0,00				
	+ 🕒 -	- 🐺 🐔 🖊					
	Area, m2	Well depth, m	Wells count	Ore type	Material mix	Identifier	Name
	264,69	13,00	15	Copper ore	Copper (5%), Overburden (95%)	/ Section 298	Section 298
	264,69	13,00	15	Copper ore	Copper (5%), Overburden (95%)	Section 299	Section 299
	264,69	13,00	15	Copper ore	Copper (5%), Overburden (95%)	Section 300	Section 300
	264,69	13,00	15	Copper ore	Copper (5%), Overburden (95%)	/ Section 301	Section 301
	-						

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

- Drilling ring length, m distance between two drill rings
- Ore mass to haul, t
- For each drill ring must be set:
 - \circ Section area, m² average section area of the stope during cleaning
 - The average depth of a vertical well, m
 - Number of vertical wells
 - Ore type
 - Material mix

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

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

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



2.5.10.6 Continuous

Properties			
Gold-1 (Sto			
General	Max possible length, m	61,02	2
Advancement type	Advancement type	Continuous 🗸	
Prerequisites	Autoneemene type	continuous	
Material mix	Empty length, m	0,00	
Unavailabilities	Width, m	4,50	
	Thickness, m	6,00	
	Max unbolted length, m	5,00	
	Bolts per m2 roof	4,00	
	Conveyor performance, t/min	2,00	
	Conveyor speed, m/min	10,00	

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

- Empty length, m the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- Width of the stope, m
- Thickness of ore mass cutting by a continuous miner, m
- Maximum unbolted length, m the maximum length of the stope on which the continuous miner is allowed to work without strengthening the stope roof
- Number of bolts per m² of the stope roof
- Performance of the conveyor serving the stope, t /min
- Speed of the conveyor serving the stope, m/min.

2.5.10.7 *Prerequisites*

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



_																						1																
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les	1.1										1	*					S	to	pe-	11	1	1			1		*			Ŀ	*	*			Ł		*	*
		*	*		*	*	*			*	*	*	*		×	c+.	0	20	0	1	2	• •	*		۲.		*		1	6	*	*		*	Ł			
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(Gene	ral			Φ	÷	•	-																														
Advan	cem	ent	type	2	Id	anti	fier							N																								
Prerequisites									Name																													
Stope-2 Stope-2																																						
				-	St	ope	-36							St	ope	-36																						
Una	vailal	biliti	es																																			

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

The button 单 allows you to select on a 2D map and add related stopes, the button 🖿

allows you to add related stopes from the list. The button \square removes related stopes from the list.

2.5.10.8 Material mix

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

Properties												
Stope-11 (S	itope)											
General	+ - /											
Advancement type	Material 📈	Fraction			— 🗆 X							
Prerequisites	Copper	0,050	Changing the composition of	materials								
Material mix Unavailabilities	Overburden	0,950	Enter new values									
onavanabilities			Material	Fraction, %								
			Copper	5.0	%							
			Overburden	95.0	%							
				OK	Canad							
				OK	Cancel							

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

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

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



2.5.10.9 Unavailabilities

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

Properties									
Stope-11 (Stope)									
General	+ -								
Advancement type	Begin date		End date		Description				
Prerequisites	04.04.2023 12:00		08.04.2023 20:00		·				
Material mix									
Unavailabilities									

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

2.5.11. Excavation rule

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

Properties Rule (Excavation rule)							
General	Identifier	Rule					
	Name	Rule					
	Drilling depth, m	4,00					
	Max unbolted length, m	100,00					
	Bolts per m2 roof	4,00					
	Drilling wells per m2 face	2,30					

The excavation rule contains the following information about drilling:

- Unique identifier and name of the rule
- Maximum drilling depth in meters
- Maximum unbolted length, m the maximum length of the stope on which the drilling machine is allowed to work without strengthening the stope roof
- Number of bolts per m² of the stope roof
- Number of wells per m² of the stope face

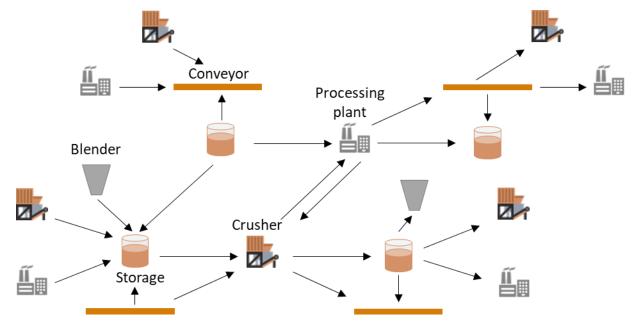
The element of the tree of objects " Excavation rules" contains a list of all the rules that can be used in planning and simulation.

2.6. Parameters of the system elements ensuring the material flow

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



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



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

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

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

2.6.1. Ore pass

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



Properties		
OrePass-11	(Ore pass)	
General	Identifier	OrePass-11
Ore types	Name	OrePass-11
Connectors	Included	
	х	70 294,00
	Υ	39 786,00
	Z	-440,00
	Volume, m ³	6 000 000,00
	Outbound mine node	Node-1197 $\lor \rightarrow \diamondsuit \bigoplus \square$
	• –	
	Inbound mine node	
	Node-335	

The ore pass is characterized by the following main parameters:

- Unique identifier and name
- Included parameter that indicates whether the equipment unit will be used for scheduling/simulation
- X-, Y-and Z-coordinates
- Volume, m³ the maximum quantity of ore that can accommodate the ore pass
- Outbound mine node reference to the mine node where the equipment unit is located while receiving the ore mass from the ore pass
- Inbound mine node reference to the mine node where the equipment unit is located while dumping the ore mass into the ore pass.

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

Properties			
OrePass-11	(Ore pass)		
General			
Ore types Connectors	Ore type		
Connectors	Empty rock		
	Copper ore	\checkmark	

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



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

Properties			
OrePass-11	(Ore pass)		
General	Out flow connector	Skip hoist (west)	✓ ✓ ♦ ♦
Ore types Connectors	In flow connectors		
	ldentifier Conveyor (E)		

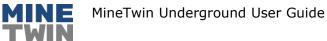
2.6.2. Storage

Storage - a place for intermediate storage of ore mass.

Properties			
Storage BCS	5 (Storage)		
General	Identifier	Storage BCS	
	Name	Storage BCS	
	х	69 203,00	
	Y	41 035,50	
	Z	-320,00	
	Volume, m ³	50 000,00	
	In flow connector	Processing plant 1	~ 🏞 → 🕀 🗙 🖸
	Out flow connector	Blender K1	× 💈 → 🔶 🗙 🖾

The storage is characterized by the following properties:

- Unique identifier and name
- X-, Y- and Z-coordinates
- Volume, m³ the maximum quantity of ore that can accommodate the storage
- In flow connector reference to the equipment unit from which the ore mass enters the storage: blender, crusher, processing plant or skip hoist
- Out flow connector reference to the equipment unit to which the ore mass enters from the storage: blender, crusher, processing plant or skip hoist.



2.6.3. Blender

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

Properties								
Blender K1 (Blender)								
General	Identifier	Blender K1						
Connectors	Name	Blender K1						
	Target grade	1,00						
	Performance, t/min	10,00						

The mixer is characterized by the following main parameters:

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

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

Properties			
Blender K1	(Blender)		
General	Out flow connector	Storage 810	\sim \bigcirc \rightarrow \Leftrightarrow \times \bigcirc
Connectors	In flow connectors		
	$=$		
	Identifier		
	Storage BCS		

2.6.4. Crusher

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



Properties	(Crucher)		
Crusher PZ	O (Crusher)		
General	Identifier	Crusher PZO	
Unavailabilities	Name	Crusher PZO	
	х	69 262,00	
	Y	41 041,00	
	Z	-320,00	
	In flow connector	Conveyor 1 [Conveyor (B)] V	$2 \rightarrow 0 \times \mathbb{R}$
	Out flow connector	Processing plant 1 V	$2 \rightarrow \oplus \times \mathbb{Q}$

The crusher is characterized by the following main parameters:

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

You can set periods of unavailability for the crusher.

Propertie:				
Crusher PZC	O (Crusher)			
General	+ -			
Unavailabilities	Begin date	End date	Description	
	11.04.2023 08:00	 11.04.2023 11:00	 Maintenance	

The buttons 🔳 💻 allow you to add/remove crusher unavailabilities.

2.6.5. Cross-dock point

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



D		· · · · · · · · · · · · · · · · · · ·
,¤		<mark>> ∞ </mark>
2.		
181 1		
Properties		
CDP-10 (Cr	oss-doc	k point)
General	Identifier	CDP-10
Ore types	Name	CDP-10
	Included	
	х	70 405,00
	Υ	39 229,00
	z	-402,00
	Volume, m³	300,00
	Mine node	Node-846 $\lor \rightarrow \diamondsuit \bigoplus \bigodot$

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

- Unique identifier and name
- Included parameter that indicates whether the equipment unit will be used for scheduling/simulation
- X-, Y-and Z-coordinates
- Volume, m³ niche volume for temporary storage of ore mass at the cross-dock point
- Mine node reference to the mine node where the cross-dock point is located

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

Properties							
CDP-10 (Cross-dock point)							
General							
Ore types	Ore type						
	Empty rock	\checkmark					
	Copper ore	\checkmark					

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



2.6.6. Conveyor

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

Properties			
Conveyor 1	(Conveyor)		
General	Identifier	Conveyor 1	
Mine arcs	Name	Conveyor 1	
Unavailabilities	Performance, t/min	50,00	
	Speed, m/min	20,00	

The conveyor is characterized by the following main parameters:

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

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

Properties				
Conveyor 1 General	(Conveyor)			
Mine arcs Unavailabilities	ldentifier MineArc-conveyor	Name MineArc-conveyor	Source node Conveyor (B)	Dest node Conveyor (E)

Mine	arcs	are	added	by	selecting	them	on	the	minefield	using	the	button	÷	and
remo	ved fi	rom	the con	ivey	or using t	he but	ton	-						

You can set periods of unavailability for the conveyor.

Properties			
Conveyor 1 (Conveyor)		
General	+ -		
Mine arcs	Begin date	End date	Description
Unavailabilities	10.04.2023 12:00	 10.04.2023 16:00	 Ремонт

The buttons 📑 💻 allow you to add/remove conveyor unavailabilities.



2.6.7. Processing plant

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

Properties									
Processing	Processing plant 1 (Processing plant)								
General	Identifier	Processing plant 1							
Unavailabilities	Name	Processing plant 1							
	x	69 305,50							
	Υ	40 992,00							
	Z	0,00							
	Performance	2 000,00							
	In flow connector	Crusher PZO 🗸	$ \rightarrow \leftrightarrow \times $						
	Out flow connector	Storage BCS 🗸 🗸	\bigcirc \rightarrow \Leftrightarrow \times \bigcirc						

The processing plant is characterized by the following main parameters:

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

You can set periods of unavailability for the processing plant.

Properties							
Processing plant 1 (Processing plant)							
General							
Unavailabilities	Begin date	End date	Description				
	18.04.2023 08:00	19.04.2023 08:00	Line repair				

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

2.7. Parameters of mobile equipment

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



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

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

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

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

dentifier		Name	Time per bolt,	Speed, km/h	Maintenance	Failure se	et		
								— 🗆	×
	Dic	tionary							
		lect objects to import from t	the dictionary						
			and dictionary						
		Identifier	Name	Speed, kn	n/h Time per	bolt, min	Monthly fixed	Cost per 1 km	Cost
		Atlas Copco Boltec M	Atlas Copco Boltec M	5,00	constant	0,50)	0,00	0,00	0,00
		Atlas Copco Boltec S	Atlas Copco Boltec S	5,00	constant	0,50)	0,00	0,00	0,00
	\checkmark	Atlas Copco Boltec MC	Atlas Copco Boltec M	C 5,00	constant	0,50)	0,00	0,00	0,00
		Sandvik DS411	Sandvik DS411	6,00	constant	0,50)	0,00	0,00	0,00
	<								>

2.7.1. Truck types

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



Properties			
Sandvik (Ti	ruck type)		
General	Identifier	Sandvik	
Speeds	Name	Sandvik	
Fuel consumption	Maintenance	Truck maintenance \checkmark	\times
	Failure set	Failure ~	\times
	Capacity, t	45,00	
	Volume, m3	24,00	
	Dumping duration, min	1,00	
	Angle based speeds		
	Empty speed, km/h	13,77	
	Loaded speed, km/h	9,92	
	Fuel tank volume, liters	0,00	
	Angle based fuel consumption		
	Empty fuel consumption rate, liters/hour	0,00	
	Loaded fuel consumption rate, liters/hour	0,00	
	Idling fuel consumption rate, liters/hour	0,00	
	Monthly fixed cost, \$	0,00	
	Cost per active shift, \$	0,00	
	Cost per working hour, \$	0,00	
	Cost per 1 km traveled, \$	0,00	

The following properties must be set for each truck type:

- Unique identifier and name
- Capacity of trucks of this type in tons
- Volume, m³ the maximum quantity of ore that can accommodate the truck of this type in m³
- Dumping duration, min
- Truck speed without load, km/h
- Truck speed with load, km/h
- A parameter that shows whether the speed of this type of trucks depends on the angle of the road. If the speed is independent of the slope angle, it is determined by the constant speed values set on this tab. If the speed depends on the angle of the road, it is calculated taking into account the parameters set on the "Speeds" tab (Clause 2.7.1.1)
- Fuel tank volume of trucks of this type, in liters
- Fuel consumption rate when driving without load, I/h
- Fuel consumption rate when driving with load, I/h
- Fuel consumption rate without movement, I/h



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

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

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

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

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

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

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

Properties				
Sandvik (Tr	ruck type)			
General	Vehicle run speed factor distribution	n triangular(0,80; 1,00; 1,20)		
Speeds	+ -			
Fuel consumption				
	Min angle, degrees	Max angle, degrees	Empty speed, km/h	Loaded speed, km/h
	0,00	5,00	15,00	12,00
	5,00	10,00	14,00	11,00
	10,00	15,00	13,00	10,00

2.7.1.2 *Fuel consumption*

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



Properties				
Sandvik (Tr	uck type)			
General	+ -			
Speeds	Min angle, degrees	Max angle, degrees	Empty fuel consumption rate, I/h	Loaded fuel consumption rate, I/h
Fuel consumption	0,00	5,00	15,00	20,00
	5,00	10,00	17,00	25,00
	15,00	15,00	19,00	27,00

2.7.2. Loader types

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

Properties			
Atlas Copco	(Loader type)		
General	Identifier	Atlas Copco	
Speeds	Name	Atlas Copco	
Fuel consumption	Maintenance	Loader maintenance 🗸	\times
	Failure set	Failure	X
	Capacity, t	14,00	
	Volume, m ³	6,40	
	Loading duration, min	1,10	
	Unloading duration, min	0,20	
	Angle based speeds		
	Empty speed, km/h	9,70	
	Loaded speed, km/h	7,80	
	Fuel tank volume, liters	0,00	
	Angle based fuel consumption		
	Empty fuel consumption rate, liters/hour	0,00	
	Loaded fuel consumption rate, liters/hour	0,00	
	Idling fuel consumption rate, liters/hour	0,00	
	Monthly fixed cost, \$	0,00	
	Cost per active shift, \$	0,00	
	Cost per working hour, \$	0,00	
	Cost per 1 km traveled, \$	0,00	

The following properties must be set for each loader type:

• Unique identifier and name



- Capacity of load-carrying bucket of loaders of this type in tons
- Volume, m³ the maximum quantity of ore that can accommodate the loadcarrying bucket of loaders of this type in m³
- Loading duration, min
- Unloading duration, min
- Speed without load, km/h
- Speed with load, km/h
- A parameter that shows whether the speed of this type of loaders depends on the angle of the road. If the speed is independent of the slope angle, it is determined by the constant speed values set on this tab. If the speed depends on the angle of the road, it is calculated taking into account the parameters set on the "Speeds" tab (Clause 2.7.1.1)
- Fuel tank volume of loaders of this type, in liters
- Fuel consumption rate when driving without load, I/h
- Fuel consumption rate when driving with load, I/h
- Fuel consumption rate without movement, I/h
- A parameter that shows whether the fuel consumption of loaders of this type depends on the angle of the road. If fuel consumption does not depend on the angle of inclination, it is determined by the constant flow rates set on this tab. If fuel consumption depends on the angle of inclination of the road, its calculation is performed taking into account the parameters set on the "Fuel consumption" tab (Clause 2.7.1.2).

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

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

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

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

2.7.3. Charger types

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



Properties								
Charmec (Charger type)								
General	ldentifier	Charmec						
	Name	Charmec]					
	Maintenance	~	\times					
	Failure set	~ ~	\times					
	Setup duration before charging, min	constant(1,00)						
	Well charging duration, min	constant(1,00)						
	Explosives loading duration, min	constant(30,00)						
	Speed, km/h	60,00]					
	Monthly fixed cost, \$	0,00						
	Cost per active shift, \$	0,00]					
	Cost per working hour, \$	0,00]					
	Cost per 1 km traveled, \$	0,00]					

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

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

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

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

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

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

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

2.7.4. Drilling machine types

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



Properties									
Atlas Copco	Atlas Copco Simba (Drilling machine type)								
General	Identifier	Atlas Copco Simba							
	Name	Atlas Copco Simba]						
	Maintenance	DM maintenance \vee	\times						
	Failure set	Failure ~	\times						
	Drills count	1]						
	Max drilling depth, m	40,00]						
	Max drilling performance, m/min	0,60]						
	Setup time per drill, min	constant(0,30)							
	Setup time before drilling session, min	constant(109,00)							
	Speed, km/h	5,00]						
	Drill type	Vertical \checkmark							
	Monthly fixed cost, \$	0,00]						
	Cost per active shift, \$	0,00]						
	Cost per working hour, \$	0,00]						
	Cost per 1 km traveled, \$	0,00]						

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

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

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

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

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



• Costs per 1 kilometer run, in USD.

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

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

2.7.5. Roofbolter types

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

Properties							
Atlas Copco Boltec MC (Roofbolter type)							
General	Identifier	Identifier Atlas Copco Boltec MC					
	Name	Atlas Copco Boltec MC					
	Maintenance	~	\times				
	Failure set						
	Time per bolt, min	constant(0,50)					
	Speed, km/h	5,00					
	Monthly fixed cost, \$	0,00					
	Cost per active shift, \$	0,00					
	Cost per working hour, \$	0,00					
	Cost per 1 km traveled, \$	0,00					

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

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

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

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

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

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

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



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

2.7.6. Shuttle car types

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

Properties			
5BC15M (Sł	nuttle car type)		
General	Identifier	5BC15M	
Speeds	Name	5BC15M	
Fuel consumption	Maintenance	~	\times
	Failure set	~	\times
	Unloading rate, t/h	15,00	
	Capacity, t	15,00	
	Volume, m3	20,00	
	Angle based speeds		
	Empty speed, km/h	12,00	
	Loaded speed, km/h	8,00	
	Fuel tank volume, liters	0,00	
	Angle based fuel consumption		
	Empty fuel consumption rate, liters/hour	0,00	
	Loaded fuel consumption rate, liters/hour	0,00	
	Idling fuel consumption rate, liters/hour	0,00	
	Monthly fixed cost, \$	0,00	
	Cost per active shift, \$	0,00	
	Cost per working hour, \$	0,00	
	Cost per 1 km traveled, \$	0,00	

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

- Unique identifier and name
- Performance of ore mass unloading in tons per minute
- Capacity of shuttle cars of this type in tons
- Volume, m³ the maximum quantity of ore that can accommodate shuttle cars of this type in m³
- Speed without load, km/h
- Speed with load, km/h



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

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

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

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

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

2.7.7. Continuous miner types

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



Properties			
Komatsu (Jo	y) (Continuous mi	iner type)	
General	Identifier	Komatsu (Joy)]
	Name	Komatsu (Joy)]
	Maintenance	~	\times
	Failure set	~	\times
	Speed, km/h	4,00]
	Performance, t/h	780,00]
	Time per bolt, min	constant(0,50)	
	Capacity, t	180,00]
	Volume, m3	200,00]
	Unloading rate to shuttle car, t/h	400,00]
	Working with	Shuttle car 🗸]
	Monthly fixed cost, \$	0,00]
	Cost per active shift, \$	0,00]
	Cost per working hour, \$	0,00]
	Cost per 1 km traveled, \$	0,00]

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

- Unique identifier and name
- Constant speed of this type of continuous miners in km/h
- Performance of ore mass cutting in tons per minute
- Duration of one bolt installation in minutes
- Capacity of a bunker of continuous miners of this type in tons
- Volume, m³ the maximum quantity of ore that can accommodate a bunker of continuous miners of this type in m³
- Performance of transloading from bunker to shuttle cars in tons per minute
- Parameter that indicates whether continuous miners of this type work with shuttle cars or with conveyors.

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

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



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

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

2.7.8. Mobile equipment

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

2.7.8.1 General parameters

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

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



Properties									
Atlas Copco 1-4 (Loader)									
General	Identifier	Atlas Copco 1-4							
Maintenance runs	Name	Atlas Copco 1-4							
Unavailabilities	Included	\bigtriangledown							
	Base node	Node-1245 V		Ð	0				
	Mine area	Mine area 1 🗸 🗸							
	Loader type	Atlas Copco 🗸 🗸							
	Empty speed, km/h	9,70							
	Loaded speed, km/h	7,80							
	Fuel tank volume, liters	0,00							
	Empty fuel consumption rate, liters/hour	0,00							
	Loaded fuel consumption rate, liters/hour	0,00							
	Idling fuel consumption rate, liters/hour	0,00							
	Capacity, t	14,00							
	Volume, m³	6,40							
	Loading duration, min	1,10							
	Unloading duration, min	0,20							

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

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

2.7.8.2 *Train*

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



Properties								
Train 1 (Train)								
General	ldentifier	Train 1						
Maintenance runs	Name	Train 1						
Unavailabilities	Included							
	Base node	~	→ � 🖸					
	Speed, km/h	10,00						
	Loading duration, min	5,00						
	Unloading duration, min	5,00						
	Rail car capacity, t	3,00						
	Rail car length, m	3,00						
	Rail cars count	6						

The following basic parameters are set for a train:

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

2.7.8.3 *Maintenance runs*

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

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



Properties			- 0
R1700G (#4	4) (Loader)		
General	Maintenance runs:		
Maintenance runs	Time	12 000,00	
Unavailabilities	Working time	300,00	
	Distance	10 000,00	

2.7.8.4 Unavailabilities

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

Properties				- 8
R1700G (#4	4) (Loader)			
General	+ -			
Maintenance runs	Begin date	End date	Description	
Unavailabilities	05.01.2026 07:00	 09.01.2026 18:00	 Major repair	

2.8. Schedules

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

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

2.8.1. Shifts

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

😰 Shifts			
+- 🖻 ++			
Shift index	Duration, min	Period	
1	600,00	Every 1 days at 01:00	
2	600,00	Every 1 days at 13:00	

Parameters are set for each shift:

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



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

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

2.8.2. Blast periods

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

Blast periods + − 🗈 ↑ ↓				
Identifier	Name	Duration, min	Period	
Blast period	Blast period	60.0	Every 1 days at 14:00	
Mine areas				
<u> </u>				
Identifier	Name			
GRAY Area	GRAY Area	1		
LIME Area	LIME Area	~		
VIOLET Area	VIOLET Area			
VIOLETAICO				

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

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

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

2.8.3. Off-schedule periods

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



Offschedule periods	- E	🛛 😰 Offs	chedule perio	d records			- 1
+ - 🗈 🕂		+ -	Ē 🛧	۲.			
Identifier	Name	Descri	ption	Priority	Period	Duration, hours	
Excavator maintenance	Excavator maintenance	Bearin	g lubrication	0	On last day at 08:30	0,45	
Truck maintenance	Truck maintenance	Filter o	- hange	0	Every monday at 08:30	0,20	
<	>						
not state the seriod of the series of the series and the series of the s	Inments						
L L							
Identifier	Name						
Excavator LIME 1	Excavator LIME 1		1				
Excavator LIME 2	Excavator LIME 2		√				
Excavator LIME 3	Excavator LIME 3		\checkmark				
Excavator PURPLE 1	Excavator PURPLE 1		\checkmark				
Excavator PURPLE 2	Excavator PURPLE 2		\checkmark				
Excavator PURPLE 3	Excavator PURPLE 3		\checkmark				
Excavator PURPLE 4	Excavator PURPLE 4		\checkmark				
Excavator PURPLE 5	Excavator PURPLE 5		\checkmark				
Excavator PURPLE 6	Excavator PURPLE 6		\checkmark				
Excavator PURPLE 7	Excavator PURPLE 7		\checkmark				
	Excavator PURPLE 8		1				

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

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

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

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

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



2.8.4. Maintenances

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

🔆 Maintenances			券 Mainte	nance records				- 8
+- 🖻 🛧 🕂			+ -	è ↑ ↓				
Identifier	Name		Descripti	on	Basis	Duration	Interval	
Daily maintenance	Daily maintenance		Oil chang	je	Working time	0,50	250,00	
Medium repair	Medium repair		Retaining	parts change	Distance	1,00	1 000,00	
Major repair	Major repair							
漪 Maintenance assignr	ments							- 8
	neno							
C								
Identifier	Name							
TH-540	TH-540			✓				
SANDVIK DL 411-15	SANDVIK DL	411-15						
Charmec	Charmec							
R1700G	R1700G			√				
12м3	12м3			✓				
5м3	5м3			✓				
T-170	T-170			✓				

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

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

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

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

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



2.8.5. Failure sets

Failure sets are used to simulate emergency equipment failures.

👌 Failure sets			枔 Failure set record	s		
+ - 🗈 🛧	ŧ		+- 🗈 🛧	÷		
Identifier	Name		Description	Time between failures, h	Repair duration, h	
Failure set 1	Failure set 1		Engine failure	triangular(300,00; 350,00; 400,00)	constant(4,00)	
			Small failures	truncated normal(100,00; 10,00; 50,00; 150,00)	triangular(1,50; 2,00; 2	,50)
🏷 Failure set assignn	nents					
-	ments Name					
ц <u>р</u>		1	✓			
L L	Name TH-540		✓ ✓ ✓			
Identifier TH-540	Name TH-540					
Identifier TH-540 SANDVIK DL 411-15	Name TH-540 SANDVIK DL 411-15					
Identifier TH-540 SANDVIK DL 411-15 Charmec	Name TH-540 SANDVIK DL 411-15 Charmec		1			
Identifier TH-540 SANDVIK DL 411-15 Charmec R1700G	Name TH-540 SANDVIK DL 411-15 Charmec R1700G		1			

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

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

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

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

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

2.9. Transaction data: tasks and plans

2.9.1. Tasks

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



-

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

ี Drilling tasks							
+ - 🗈							
Begin date	End date	Wells count	Stope	2	Drilling machi	ine	
01.01.2019 00:00	02.01.2019 00:00	460,00	Blue-	2	Atlas Copco Boomer 3-1		
01.01.2019 00:00	02.01.2019 00:00	240,00	Gold-	-9	Atlas Copco S	imba 10-2	
Charging tasks							
+ - 🗈							
Begin date	End date	Wells count	Stope	e	Charger		
01.01.2019 00:00	02.01.2019 00:00	460,00	Blue-	2	Charmec-2-6		
01.01.2019 00:00	02.01.2019 00:00	240,00 Gold-9		9	Charmec-3-4		
😽 Haulage tasks							
Begin date	End date	Runs count	Source stop	pe Loade	er	Destination	
01.01.2019 00:00	02.01.2019 00:00	12.0	Gold-16	Atlas	Copco 1-4	CDP-4	
01.01.2019 00:00	02.01.2019 00:00	24.0	Brown-10	Atlas	Copco 3-6	OrePass-15	
Roofbolting tasks							
+ - 1							
Begin date	End date	Bolts count	Stope		Roofbolter		
03.01.2019 00:00	04.01.2019 00:00	360.0	Red-8	3	Roofbolter 1		
🚡 Cross-docking tas	ks						
Begin date	End date	Source cross-de	ock point	Truck	Destin	ation	
-		CDP-18	-	Sandvik 10-3	OreDay	- 12	
01.01.2019 00:00	02.01.2019 00:00	CDP-18		Sandvik IU-3	Orepas	OrePass-12 OrePass-4	



🕼 Skip hoisting task	s				
+ – E					
Begin date	End date	Skip hoist			
01.01.2019 00:00	02.01.2019 00:00	Skip hoist (west)			

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

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

2.9.2. Production plans

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

2.9.2.1 Stopes plan

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

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

Each stopes plan record is characterized by the following parameters:

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



- Ore type
- Advancement type
- Mine area.

2.9.2.2 *Target plan*

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

Plans			
+- 🗈 🛧	+		
Begin date	End date	Quality, %	Planned mass, t
01.04.2023	01.05.2023	5,00	450 000,00
01.04.2023	01.05.2023	8,00	200 000,00

Each target plan record is characterized by the following parameters:

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



3. Scheduling and simulation

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

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

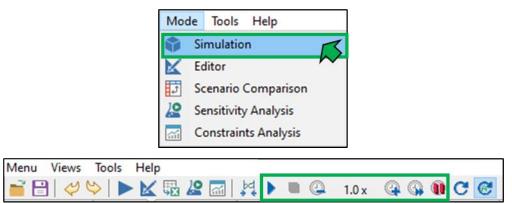
The simulation model checks the feasibility of the scheduler's plan, taking into account:

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

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

3.1. Simulation management

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



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

To pause the model, use the button 🔳 .



1440

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

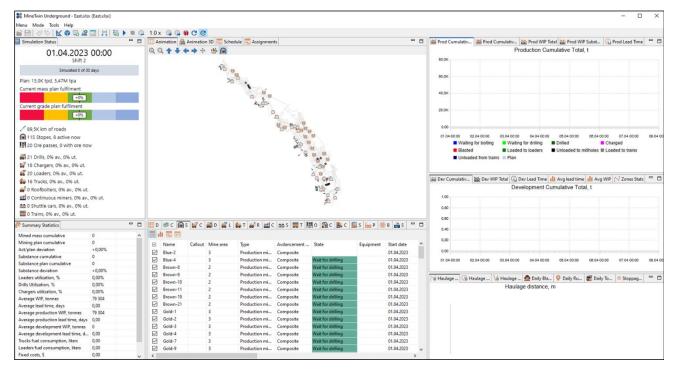
. To close the window for entering simulation time, use the "Esc" key.

To accelerate / slow down the simulation, use the buttons \bigcirc 1.0 x \bigcirc

For maximum acceleration, use the button 🍱.

3.2. Visualization of simulation results

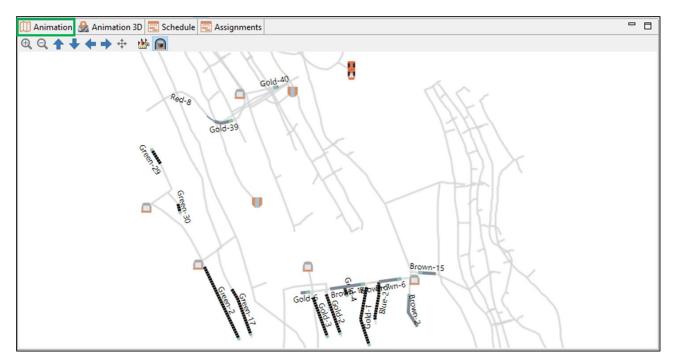
The layout of the scheduler window is shown in the figure below.



3.2.1. Animation

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





The top panel of the animation window contains the buttons that make it easier to work with the map. The buttons allow to zoom in/ out the map, the buttons allow to move the map. The button centers the map so that the entire mine is visible at the same time. The button turns on the display of the lengths of the mine field segments, the button allow with information about the status of the equipment unit opens a window with information about the status of the equipment unit, its availability and equipment utilization.

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





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

The button 🧖 in the information window closes the window.

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

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

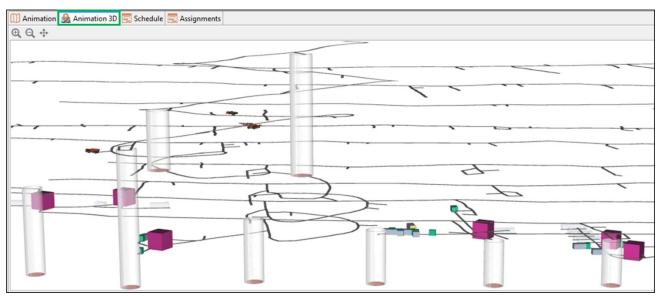


Marine Nice 🗛 Asime Nice 20 📼 Schedule 📼	Arrigenter to Miles Course 2.2. X				
Animation Animation 3D Schedule	HaulageFeature 000 NONE 0000 000 0000 0000 000 0000 0000 000 AT_PRE_LOADING_POSITION 0000 000 AT_PRE_LOADING_POSITION 0000 000 LOADING_POSITION 0000 000 LOADING_POSITION 0000 000 LOADING_POSITION 0000 000 LOADING_POSITION 0000	HaulageLoadingFeature	HaulageSimpleDumpFeature	IdlingFeature	0.00%
	0.00 LEAVING_LOADING_POSITION 0.00 MOVING_TO_PRE_UNLOADING_POSITION 0.00 AT_PRE_UNLOADING_POSITION 0.00 MOVING_TO_LINLOADING_POSITION 0.00 UNLOADING 0.00 UNLOADING_OSITION				

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

3.2.2. Map 3D

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



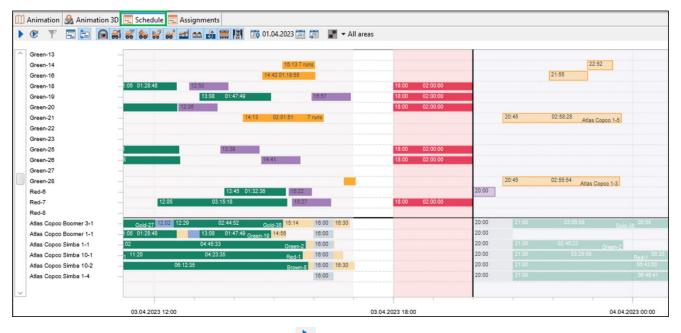
Clicking on the equipment unit opens a window with the name of the equipment unit.



The buttons $\textcircled{\ } \textcircled{\ } \textcircled{\ } \textcircled{\ } \textcircled{\ } allow to zoom in/ out the map, the buttons <math>\textcircled{\ } \textcircled{\ } \textcircled{\ } allow to zoom in/ out the map, the buttons (\textcircled{\ } \textcircled{\ } buttons (\textcircled{\ } buttons ($

3.2.3. Schedule

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



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

The simulation can be restarted to the required simulation time. To do this, set the vertical line representing the moment in time on the required date and press the button \mathfrak{V}_{-} .

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

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



A group of buttons a specific allows you to display the schedule for a specific date. The button 🖾 turns on the display mode of one day, the button 🛅 allows to set the date, the button 🕮 turns on the display of the schedule for the selected date.

3.2.4. Assignments

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

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

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

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

Statistical information 3.3.

3.3.1. Simulation status

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

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



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

Simulation Status	0	
03.04.2023 20:00 Shift 1		
Simulated 2 of 30 days		
Plan: 15,0K tpd, 5,47M tpa		
Current mass plan fulfilment		
-7%		
Current grade plan fulfilment		
-7%		
 * 89,5K km of roads 115 Stopes, 51 active now 20 Ore passes, 8 with ore now 21 Drills, 77% av., 83% ut. 		
💕 18 Chargers, 100% av., 9% ut.		
20 Loaders, 77% av., 52% ut.		
16 Trucks, 77% av., 20% ut.		
0 Roofbolters, 0% av., 0% ut.		
0 Continuous miners, 0% av., 0% ut. 0 Shuttle cars, 0% av., 0% ut.		
1 0 Trains, 0% av., 0% ut.		

3.3.2. Summary statistics

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

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



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

Summary Statistics		- 6
Mined mass cumulative	39 332	
Mining plan cumulative	42 500	
Act/plan deviation	-7,45%	
Substance cumulative	1 967	
Substance plan cumulative	2 125	
Substance deviation	-7,46%	
Loaders utilization, %	52,24%	
Drills Utilization, %	83,16%	
Chargers utilization, %	8,72%	
Average WIP, tonnes	62 403	
Average lead time, days	1,42	
Average production WIP, tonnes	62 403	
Average production lead time, days	1,42	
Average development WIP, tonnes	0	
Average development lead time, d	1,42	
Trucks fuel consumption, liters	0,00	
Loaders fuel consumption, liters	0,00	
Fixed costs, \$	0,00	
Variable costs, \$	0,00	
Total costs, S	0,00	

3.3.3. Daily volume stats

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

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





• ore mass unloaded from trains to the ore passes

The following also displayed:

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

Daily Volumes P	art 🏐 C ឰ	7 Ch 🔒	Dri 😽	Lo 🍪 Tr	😸 Ro	. 🚾 Co	👥 Sh	🎆 Tra	📳 Or	🔝 Cr	🛃 Cr	🖳 St	Ген Pr	🛞 Ble	👌 Ski
Date	Reached	Drilled	Blasted	Loaded to loa	ders U	Jnloaded to	millholes	Loaded	to trai	Unloaded	from trains	Plan	Quali	ty Rur	ns count
✓ 01.04.2023	1 350	159 779	159 779	123 502	1	23 474		0		0		450 00	0 5,00%	5 10 4	141
01.04.2023	1 350	12 739	4 578	3 443	3	359		0		0		15 000	5,00%	241	
02.04.2023	0	43 979	34 927	19 617	1	9 631		0		0		15 000	5,00%	1 69	91
03.04.2023	0	33 201	26 516	25 842	2	5 744		0		0		15 000	5,00%	2 11	8
04.04.2023	0	20 739	20 302	23 334	2	3 292		0		0		15 000	5,00%	5 191	10
05.04.2023	0	29 714	24 623	19 268	1	9 279		0		0		15 000	5,00%	1 68	33
06.04.2023	0	24 738	22 661	20 352	2	0 394		0		0		15 000	5,00%	176	54
07.04.2023	0	21 318	17 634	16 651	1	6 693		0		0		15 000	5,00%	5 1 43	39
08.04.2023	0	6 580	8 539	4 939	4	953		0		0		15 000	5,00%	440	

3.3.4. Costs

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



🗄 Dail 🗊 Costs 🝙 Sto 🐖	Ch <table-of-contents> Dril 😽 Lo.</table-of-contents>	🍪 Tru	😹 Ro 📷	Co 🏡 Sh 🎆 Trai 🕅	Ore 🔝 Cro 🛃	Cru 🖳 Sto 摌 Pro	🛞 Ble 👪 Ski
Category	Basis	Basis value	Total cost, \$	Average cost per basis unit, \$	Average daily cost	Average monthly cost	Average annual cost
✓ Total			35,3K		7,06K	212K	2,58M
✓ Fixed			19,7K		3,93K	118K	1,44M
Mine	Months	0,17	0,00	0,00	0,00	0,00	0,00
Trucks	Unit-months	2,67	5,33K	2,00K	1,07K	32,0K	389K
Loaders	Unit-months	3,33	3,33K	1,00K	667	20,0K	243K
Drillers	Unit-months	3,50	2,00K	571	400	12,0K	146K
Chargers	Unit-months	3,00	9,00K	3,00K	1,80K	54,0K	657K
Roofbolters	Unit-months	0,00	0,00	0,00	0,00	0,00	0,00
✓ Variable			15,6K		3,12K	93,7K	1,14M
✓ Trucks			1,88K		376	11,3K	137K
Shift-based costs	Active shifts	45,0	450	10,0	90,0	2,70K	32,9K
Hours-based costs	Working hours	273	546	2,00	109	3,28K	39,9K
Distance-based costs	Distance traveled, km	1,77K	883	0,50	177	5,30K	64,4K
Fuel	Fuel consumed, I	0,00	0,00	0,00	0,00	0,00	0,00
Maintenance	Maintenance events	0,00	0,00	0,00	0,00	0,00	0,00
Failure management	Failure events	11,0	0,00	0,00	0,00	0,00	0,00
> Loaders			10,2K		2,05K	61,4K	746K
> Drillers			2,01K		401	12,0K	146K
> Chargers			1,50K		300	9,01K	110K
> Roofbolters			0,00		0,00	0,00	0,00

The table displays:

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

3.3.5. Stopes stats

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

Da	ily Vo 🏐 Costs	s 😰 Stopes	💕 Charger	Drills St	😽 Loaders 👶	Trucks S	Roofbol	🚾 Continu.	🟫 Shuttle	Trains S	📳 Ore pas	🚮 Cross D	Crushers	Storage	s 🛃 Process	i 🛞 Blend
2	Name	Mine area	Туре	Avdanceme	State		Equipment		Start date	Completion of	da Act/p	Quality, %	Works status			
	Brown-8	2	Production	Composite	Drilling		Atlas Copco	Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	0 wells comple	eted, 15 wells	remaining	
	Brown-9	2	Production	Composite	Drilling		Atlas Copco	Simba 10-2	01.04.2023	12.04.2023	+0%	5,00%	12 wells comp	leted, 3 wells	remaining	
	Brown-10	2	Production	Composite	Haulage	1			01.04.2023	12.04.2023	+0%	5,00%	1 220 tonnes h	auled, 579 to	nnes remaini	ng, 87 runs
\square	Brown-11	2	Production	Composite	Haulage				01.04.2023	12.04.2023	+0%	5,00%	182 tonnes ha	uled, 1 617 to	nnes remainin	ng, 13 runs
	Brown-19	2	Production	Composite	Wait for drilling	1	Atlas Copco	Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	11 wells comp	leted, 4 wells	remaining	
	Brown-21	2	Production	Composite	Wait for drilling				01.04.2023	12.04.2023	+0%	5,00%	0 wells comple	eted, 15 wells	remaining	
	Gold-1	3	Production	Composite	Drilling		Atlas Copco	Simba 3-2	01.04.2023	12.04.2023	+0%	5,00%	0 wells comple	eted, 15 wells	remaining	
	Gold-2	3	Production	Composite	Haulage	1			01.04.2023	12.04.2023	+0%	5,00%	168 tonnes ha	uled, 1 631 to	nnes remaini	ng, 12 runs
	Gold-3	3	Production	Composite	Haulage				01.04.2023	12.04.2023	+0%	5,00%	70 tonnes hau	led, 1 729 to	nnes remainin	g, 5 runs
	Gold-4	3	Production	Composite					01.04.2023	12.04.2023	+0%	0,00%				
	Gold-7	3	Production	Composite	Wait for blast				01.04.2023	12.04.2023	+0%	5,00%				
	Gold-9	3	Production	Composite	Haulage				01.04.2023	12.04.2023	+0%	5,00%	2 072 tonnes h	auled, 633 to	nnes remaini	ng, 148 runs
	Gold-13	3	Production	Composite	Haulage				01.04.2023	12.04.2023	+0%	5,00%	98 tonnes hau	led, 2 607 to	nnes remainin	q, 7 runs

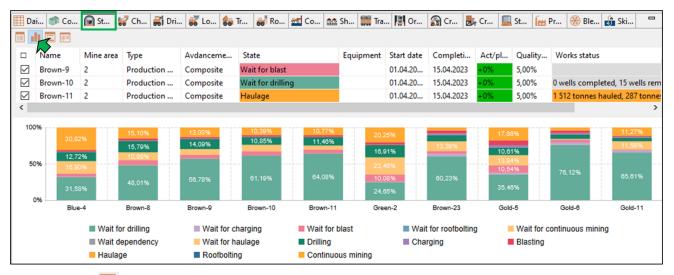
The following is shown for each stope:

• Mine area to which the stope belongs



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

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



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



🛛 Da	ii 🇊 Co	🝙 St	🦿 Ch 😽 Dri.	💞 Lo 🍪	Tr 💕 Ro 🗺 Co	🏫 Sh 🏢 Tra	関 Or	🔝 Cr 📕	Cr 🔲	St 🔟	Pr 🛞 Ble 👔	Ski
	Name	Mine area	Туре	Avdanceme	State	Equipment	Start date	Completi	Act/pl	Quality	Works status	
\checkmark	Brown-19	2	Production	Composite	Wait for haulage		01.04.20	15.04.2023	+0%	5,00%	1 400 tonnes haule	d, 399 tonn
\checkmark	Brown-21	2	Production	Composite	Wait for drilling	Atlas Co	01.04.20	15.04.2023	+0%	5,00%	4 wells completed,	11 wells rer
\checkmark	Gold-1	3	Production	Composite	Wait for blast		01.04.20	15.04.2023	+0%	5,00%		
<												>
в	rown-8	7	15:52	1 d. 20:58:29								
в	Brown-9	-	5 d. 00:49:12									
в	rown-10	_	6 d. 0	9:38:50			23:22	00	:10			
В	Frown-11	-	6 d. 1	12:35:07								
	Brown-11 Brown-19			12:35:07 7 d. 01:53:21		16:05	04:05 16:05	5 04:04 18:04	04:05 16:05	04:04	04:05 18:05 04:04	20:20
в					1	16:05 4 d. 00:34:40	04:05 16:05	5 04:04 16:04	04:05 18:08	04:04	04:05 18:05 04:04	
в	Brown-19				1		04:05 16:03	5 04:04 16:04	04:05 16:03	04:04	04:05	
в	Brown-19 Brown-21			7 d. 01:53:21			04:05 18:05	5 04:04 18:04 18:04 18:04	04:05 16:05	04:04		
в	Brown-19 Brown-21	03.0		7 d. 01:53:21 15:58							04:05 18:05 04:04	20:20 03:0 15.04.2023

3.3.6. Equipment stats

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

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

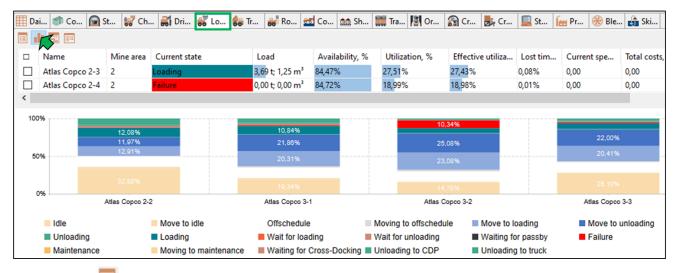
The data table on the operation of the equipment on the example of loaders is shown in the figure.

🔠 Da	i 🇊 Co 🝙 S	t 🔛 Ch.	🚮 Dri 😽 Lo 💏 T	r 😹 Ro 🗺	Co 🟫 Sh	🏬 Tra 🚺 Or	😭 Cr 🛃 Cr	🛄 St 👔	🙀 Pr 🛞 Ble.	👌 Ski
	Name	Mine area	Current state	Load	Availability, %	Utilization, %	Effective utiliza	Lost tim	Current spe	Total costs
	Atlas Copco 2-1	2	Move to loading	0,00 t; 0,00 m ³	84,22%	55,36%	55,09%	0,27%	9,70	0,00
	Atlas Copco 2-2	2	Move to loading	0,00 t; 0,00 m ³	85,05%	43,83%	43,75%	0,08%	9,70	0,00
	Atlas Copco 2-3	2	Loading	3,69 t; 1,25 m ³	84,47%	27,51%	27,43%	0,08%	0,00	0,00
\checkmark	Atlas Copco 2-4	2	Failure	0,00 t; 0,00 m ³	84,72%	18,99%	18,98%	0,01%	0,00	0,00
$\mathbf{\nabla}$	Atlas Copco 2-5	2	ldle	0,00 t; 0,00 m ³	72,90%	12,86%	12,85%	0,01%	0,00	0,00

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



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



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

🔠 Da	i 🗊 Co 🝙 S	t 💕 Ch.	觽 Dri 😽 Lo	👸 Tr 😽 Ro	📷 Co 🏫 Sh	🎆 Tra 🕅 O	r 🔝 Cr 😹	Cr 📃 St 👔	🙀 Pr 🛞 Ble	💼 Ski
	Name	Mine area	Current state	Load	Availability, %	Utilization, %	Effective uti	liza Lost tim	Current spe	Total costs
\checkmark	Atlas Copco 3-1	3	Move to loading	0,00 t; 0,00 m	³ 83,57%	64,06%	64,01%	0,05%	9,70	0,00
\square	Atlas Copco 3-2	3	Loading	4,51 t; 1,53 m	3 73,82%	74,97%	74,91%	0,05%	0,00	0,00
<										
A	tlas Copco 2-2 -	23:30	23:32 23:33				:40 23:41	23:42 23:43		:46 23:46
		CDP-16	14 Mass, t	14 Mass, t	14 Mass, t	CDP-16 14	Mass, t	14 Mass, t	14 Mass, t	CDP-16
A	tlas Copco 3-1 -	23:30 23 14 Mass. t	:31 23:32 23:32	00:05:12		3:38 23:39 Mass.t	23:40 23:41	23:43 23:44 14 Mass. t	4 23:45 14 Mass.t	23:46 23:47 CDP-1
A	tlas Copco 3-2 -	9 00:02:41		23:33 00:03:20	23:37 00:0	22000 C			23:44 00:02:41	23:47
		m, 10 kph	Gold-20 14 Mass, t	434 m, 8 kph OreP	ass-14 434 m, 10 kph	Gold-20 14 Ma	ss, t 434 m, 8 kph	OrePass-14	434 m, 10 kph	Gold-20 14 Ma
4	tlas Copco 3-3		23:32	00:04:42	23:37 23:38	3	00:05:51	23:4	14 00:1	04:42
	aas copee oo	OrePa	ss-5 761 m, 10 kph	(Bold-3 14 Mass, t 761 r	n, 8 kph		OrePass-5 781	m, 10 kph	
			с. с.	1 1 1	1 1	1	1	1	1	
				09.04.2023 23:35		09.04.2023 23:	40	09.04	4.2023 23:45	

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.

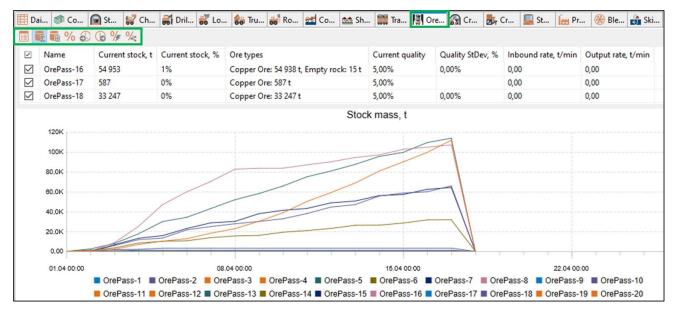


🔛 Da	i 🗊 Co	🝙 St 🙀 Ch.	🚮 Dri 💕 Lo 🕼	Tr 😹 Ro 🗺	Co 🏡 Sh	🏢 Tra 関 Or	🔝 Cr 🛃 Cr	🔜 St 🕍 Pr	🛞 Ble 👪 Ski	- 0
	Name	Mine area	Current state	Load	Availability, %	Utilization, %	Effective utiliza	Lost tim Curre	nt spe Total costs,	s ^
	Atlas Copco	1-1 1	Move to unloading	14,0 t; 4,73 m³	75,00%	61,34%	61,17%	0,17% 7,80	0,00	
	Atlas Copco	2-1 2	Move to loading	0,00 t; 0,00 m ³	84,22%	55,36%	55,09%	0,27% 9,70	0,00	
\checkmark	Atlas Copco	2-2 2	Move to loading	0,00 t; 0,00 m ³	85,05%	43,83%	43,75%	0,08% 9,70	0,00	
	Atlas Copco	2-3 2	Loading	3,69 t; 1,25 m ³	84,47%	27,51%	27,43%	0,08% 0,00	0,00	~
<										>
Loa	der	Туре	Begin time	End time	Duration	Current speed,	Distance traveled, m	Stoppage descript	ion Transportation s	ource ^
Atla	s Copco 1-1	Offschedule	01.04.2023 08:00:00	01.04.2023 08:45:0	0 00:45:00			ETO		
Atla	s Copco 1-1	Move to loading	01.04.2023 08:45:00	01.04.2023 08:55:0	4 00:10:04	10	1 628		Green-12	
Atla	s Copco 1-1	Loading	01.04.2023 08:55:04	01.04.2023 08:56:10	0 00:01:05				Green-12	
Atla	s Copco 1-1	Move to unloadi	ng 01.04.2023 08:56:10	01.04.2023 09:36:3	1 00:40:21	7	5 001		Green-12	
Atla	s Copco 1-1	Unloading	01.04.2023 09:36:31	01.04.2023 09:36:4	3 00:00:12				Green-12	

3.3.7. Ore storage places

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

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



The following information is displayed for each ore pass:

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



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

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

3.4. Graphs and charts

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

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

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



Animation	Animation 3D 📃 Schedule 🗄	Assignments	- 0	🕍 Prod Cu 🕍 Prod Cu 🕍 Prod WIP 🕍 Prod WIP 🖓 Prod Lea 🖓
• @ ¥	= = 🖬 🕷 🍀 😽 🕷	🖬 🐽 👸 🧱 🕅	01.04.2023 🛗 🗯 📲 🕶	Production Cumulative Total, t
Blue-2 Blue-4	12:16	8 18:00 20:45 800 runs	08:45 07:24:1618 run:	0000
Brown-8 Brown-9	-	800:50 800:50	09-39Rock, t: 1,44K	50,0K
Brown-10	-	03.04		8
Brown-11 Brown-19	-			0.00
Brown-21 Gold-1	lock, t: 1,44K	21:44	08:00 08:45 07:15:34	02.04 12:00 02.04 18:00 03.04 00:00 03.04 06:00 03.04 12:00
Gold-2 Gold-3	lock, t: 1,44K	21:45	06:00 08:45 06:24:24	🚈 Dev Cu 🅍 Dev WI 🥼 Dev Le 💼 Avg Ie 💼 Avg WIP 🔊 Zones 🖻
Gold-4 Gold-7		00:40	09:44Rock, t: 1,44K 09:40Rock, t: 1,44K	15.0K
Gold-9 Gold-13	:45:00 17 runs	20:45 07:45:00 19 runs	08:45 07:38:17 19 run 08:45 07:18:04	
Gold-18 Gold-17				5,00K
~				0.00
	02.04.2023 12:00	03.04.2023 00:00	03.04.2023 12:00	02.04 12:00 02.04 18:00 03.04 00:00 03.04 06:00 03.04 12:00
	<.			(



4. Scenario comparison

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

In the opened scenario comparison mode window, you can select several scenarios with the button \blacksquare in the upper toolbar, and exclude unnecessary scenarios with the button

The button lears the list of scenarios.

In the scenario comparison mode, simulation of each scenario can be run several times with different values of random variables. The button 100 is used to set the number of launches (replications).

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

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

Menu N	Aode Tools Help															
i 🗄	🖉 😂 🔣 📦 🐯	2 🔜														
🛛 Scenari	io Comparison															- E
+ 6	\lambda 🕼 🛧 🕂 🖳	-														
Index	Scenario		Replications	Errors 1	Mined m	Mining p	Act/plan	Substanc	Substanc	Substanc	Overall a	Trucks av	Drills ava	Roof bolt	Chargers	Cont.
		🐮 Откры	ытие										×			
		$\leftarrow \ \rightarrow$	∽ ↑ – Ковый том	ı (D:) → Amalg	gama 2.0 ⇒	minetwin >	scenarios >	Undergroun	d v	ū	Поиск в: Unde	rground	٩			
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¥ Prod	. 🕍 Prod 🖓 Prod	*	Имя		^			Дa	та изменения	Тип		Размер	^ ce	🛞 Blend	🗊 Costs	- 6
		~	🖂 🛃 Demo example.xl	5X				03.	07.2023 15:50	Лист Мі	icrosoft Excel	137 K	Б			
1.00 -			Demo-scenario-re					03.	07.2023 15:50	Лист Мі	icrosoft Excel	121 K	Б			
			Demo-scenario-re						07.2023 15:50		icrosoft Excel	161 K				
0,95		~	Excavation depen	dency.xlsx				03.	07.2023 15:50	Лист Мі	icrosoft Excel	57 K	·6 v			
0,90			<u>И</u> мя файла:	'Demo-scenari	o-real.xlsx"	"Demo exam	ple.xlsx"			~	*.xlsx		~			
0,85											<u>О</u> ткрыт	Отме	на			
0,80																
0,75																
0,70																

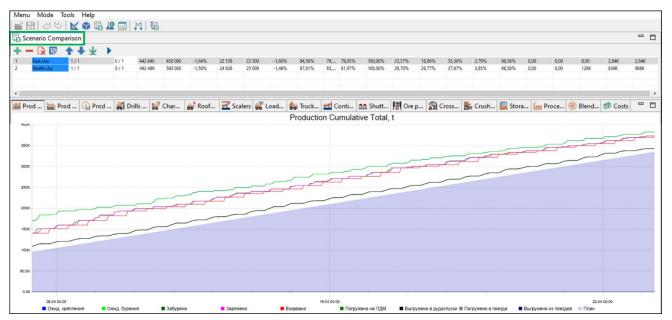
Scenario comparison is launched using the button 🕨.

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

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



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





5. Sensitivity analysis

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

In the opened window of the sensitivity analysis mode, you need to set the ranges for

changing the equipment quantity of each type using the button \overline{i} .

Menu	Mode Tools Help													
i E	🖉 😂 📐 🌍 🌄 🖉 🔜 🍹	\$ 疑												
🖉 Sen	itivity Analysis													
5														
K	Stenario	Replicat	ions	Errors	Trucks co	Drills cou	Chargers	Loaders	Roof b	olt	Continu	Shuttle c	Scalers c	Mined m
		ſ									_			
										×				
			Equipmen	t units qu	antity varia	ation								
			Select vari	ation paran	neters and co	nfirm selectio	n							
		_												
			Trucks coun	t: 2 4			<u> </u>			X				
			Drills count:	6 9			<u></u>	<u>.</u>		X				
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	l Cum 🕍 Prod WIP 🖓 Prod Le		Loaders cou	nt: 5 6			<u></u>	<u> </u>		X	Continue	🟫 Shutt		
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0,8	0													
0,3														

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

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



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Sensitivity Analysis										
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Seenario	Replications	Errors Trucks	o Drills cou	Chargers	Loaders	Roof bo	lt Continu	Shuttle c	Scalers c	Mined m
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		nt units quantity v iation parameters an		on						
	Trucks cour			<u> </u>			x			
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1,10	Scalers cou Replication	s	5				X Jlative	Total, t		
0.90	Total numb	er of scenarios <mark>1</mark> 0				ОК				
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0,70										

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

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

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

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



6. Constraints analysis

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

The following constraints are consistently removed during constraints analysis:

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

The constraint analysis is started using the button **b**. The button **c**lears the list before a new launch.

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

	Mode Tools Help				
_	traints Analysis	·····) + + +23			
Index	Scenario	Mined mass difference, %	Mined mass cumulative	Mining plan cumulative	Act/plan deviation
1	Demo5	132 216	400 000	-66,95%	6 610
2	Ore quantity	185 258	400 000	-53,69%	9 261
3	Chargers	132 216	400 000	-66,95%	6 610
4	Drills	248 381	400 000	-37,90%	12 418
5	Loaders	270 770	400 000	-32,31%	13 538
6	Trucks	130 682	400 000	-67,33%	6 533
7	Ore quality	136 805	400 000	-65,80%	68 402
8	Blasts frequency	132 216	400 000	-66,95%	6 610

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