INDIRES User Documentation
Evacuation Simulation Software

30th November 2020

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TABLE OF CONTENTS

1 INTENDED AUDIENCE

An output of the INDIRES project is user documentation for each of the products produced during the project. However, the status of the various products differs and, for this reason, the intended audience for the *User Documentation* will be different for each product. It is necessary, therefore, to indicate the type of user who will benefit from this particular *User Document*.

The software for simulating the evacuation of a mine is fully complete. As such, the information provided in this *User Document* could be utilised by end users who have a need for this functionality. Such users can consider the instructions on how to use the software as definitive.

End users who want to know more are referred to *Section 5.*

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2 OVERVIEW

The document is divides into two different sections.

The first part provides a detailed description of the evacuation software and presents all the steps needed to correctly build a model, with particular emphasis on the individual steps.

This way, it is possible for the software user to easily follow each step and build a model of a mine where an evacuation will be necessary.

The second part presents a case study of a coal mine where miners are attempting to escape from a fire and reach a safe zone. Unlike the first part, this is more focussed on a real-world situation.

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3 SOFTWARE DESCRIPTION

This section describes the steps to create a model.

3.1 Introduction

Pathfinder is an agent-based egress and human movement simulator. It provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis.

3.1.1 Graphical User Interface

Pathfinder includes a graphical user interface that is used primarily to create and run simulation models, as shown *Figure 1*, which illustrates the Velenje Mine.

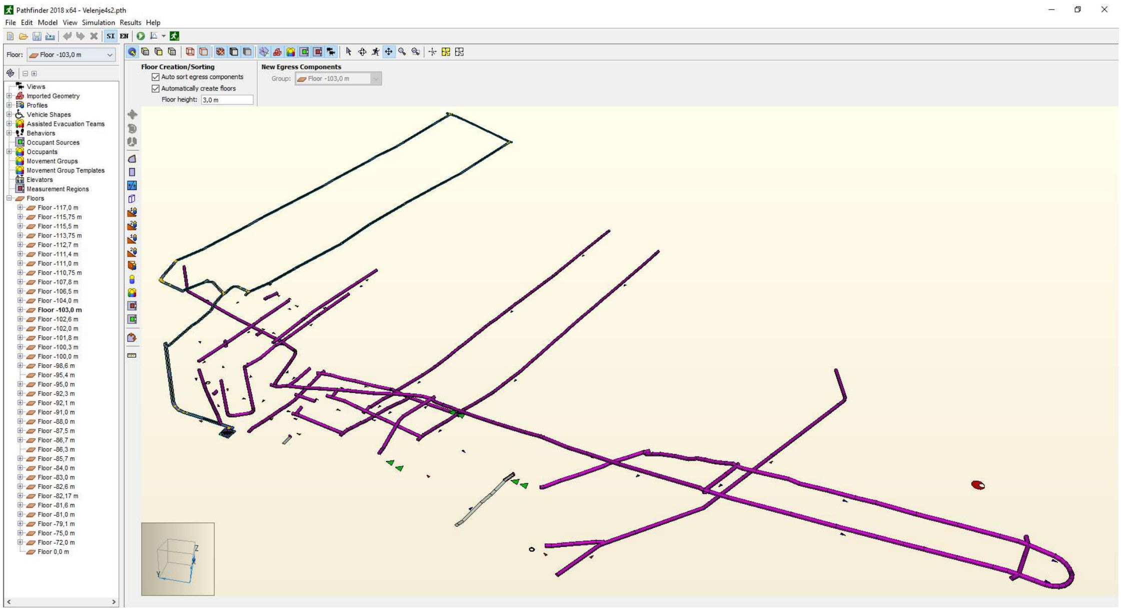

Figure 1 – 3D View of a Coal mine Modelled in Pathfinder

Pathfinder also includes a second program designed specifically for high-performance visualization of 3D time history.

In addition to 3D visualization, Pathfinder also provides output in the form of 2D time history plots of CSV (comma separated values) out files and a text summary of room clearing times and doorway flow rates.

3.1.2 Model Representation

The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model. This movement mesh can be entered manually or automatically based on imported data (e.g. FDS geometry).

Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator but are represented implicitly because occupants cannot move in places where no navigation mesh has been created.

Doors are represented as special navigation mesh edges. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow.

3.1.3 Simulation Modes

Pathfinder supports two movement simulation modes. In "Steering" mode, occupants use a steering system to move and interact with others. This mode tries to emulate human behavior and movement as much as possible. SFPE mode uses a set of assumptions and hand-calculations as defined in the Engineering Guide to Human Behavior in Fire (SFPE, 2003). In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density.

3.1.4 System Requirements

The minimum requirements to run Pathfinder include:

- 32 or 64-bit Windows 7 or higher,
- A processor of the performance of an Intel i5,
- 4GB of RAM,
- Graphics support for OpenGL 1.2.

3.1.5 Where to Download the Software

The software can be downloaded in the link
https://support.thunderheadeng.com/pathfinder/

There is a free trial version for 30 days, but if one wants to have access to it for a longer period, it must be purchased.

3.2 Software Basics

Pathfinder provides three main views for working on evacuation models: the 2D View, 3D View, and Navigation View. These views represent the current model. If an object is added, removed, or selected in one view, the other views will simultaneously reflect the change.

- Navigation View: This view lists all objects in the model in a hierarchical format. It can be used to quickly locate and modify objects by name.
- 3D View: This view shows a 3D representation of the current model. The model can be explored and modified using various tools.
- 2D View: This view is very similar to the 3D View, but it provides an additional snapping grid and an orthographic view of the model, as shown in *Figure 2*.

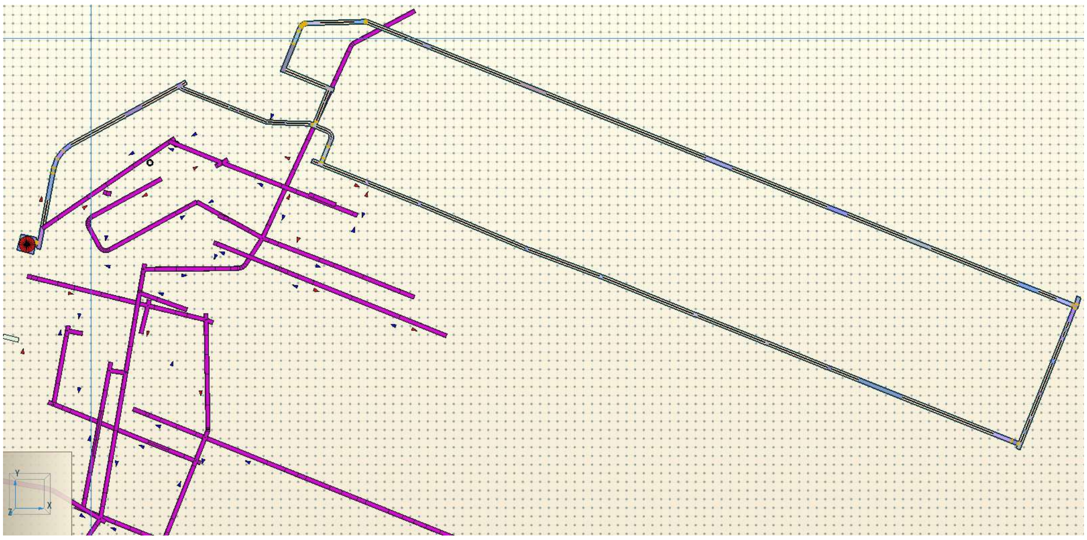

Figure 2 – 2D View of a Coal Mine Modelled in Pathfinder

3.2.1 Navigating the 3D View

Several tools are provided for navigating through the model in the 3D view, including orbit, roam, pan, and zoom tools, as shown in *Figure 3*.

Figure 3 – 3D navigation Options

The main navigation tool for the 3D view is the Orbit tool (second in the figure). By left clicking and dragging, the model is rotated about its centre point.

Another navigation tool in the 3D view is the Roam tool (third in the figure). This tool allows the camera to move in and out of the model at will. It has a higher learning curve but is the most flexible viewing tool because it allows the camera to be placed anywhere in the model.

The other navigation tools include a pan/drag tool, which moves the camera left and right and up and down, a zoom tool, which zooms in and out of the model while click-dragging, and a zoom box tool, which allows a box to be drawn that specifies the zoom extents.

Pathfinder can also be navigated while using the Selection/manipulation tool (first in the figure). To Orbit the camera while in perspective view, use a right-click and drag combination. Similarly, use a middle-click and drag to Pan in perspective view.

3.2.2 Navigating the 2D View

Navigation in the 2D view is simpler than in the 3D view. The selection tool not only allows objects to be selected if single-clicked, but it allows the view to be panned by middle or right-clicking and dragging, and the view to be zoomed by using the scroll wheel. The drag and zoom tools are also separated into separate tools for convenience.

3.2.3 Model Organisation with Groups

The main method of organization in Pathfinder is to use groups. In every model there are already some implicit groups that cannot be modified, including Views, Imported Geometry, Profiles, Vehicle Shapes, Assisted Evacuation Teams, Behaviours, Occupant Sources, Occupants, Movement Groups, Movement Group Templates, Elevators, Measurement Regions, and Floors as shown in *Figure 4*. Sub-groups can be created to further organize the model as discussed in the following sections.

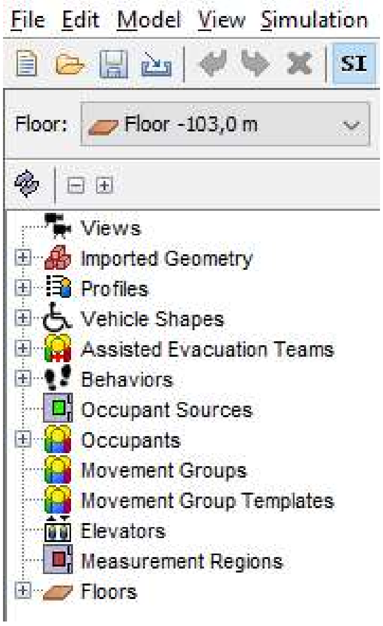

Figure 4 – Predefined Groups in Pathfinder

3.3 Creating Movement Space

Pathfinder is built on the idea of creating floor space on which occupants can walk. Every navigation component drawn in Pathfinder is some piece of flooring that can be travelled on, which can range from floors, to doorways, to stairs.

The main egress components include rooms, which are empty floor spaces bounded by walls, doors, which connect rooms on the same level, stairs/ramps, which connect rooms on different levels, and elevators, which connect multiple levels. Rooms can have any polygonal shape and can never overlap on the same level. Doors can be either thick if they are occupying a doorway (the area between two rooms) or thin if they are simply connecting two touching rooms. Stairs/ramps are always rectangular and implicitly contain a thin door on each end to connect the adjacent rooms. Elevators can be any shape and can travel in any direction.

3.3.1 Floors

Floors are the primary method of organization in Pathfinder. At their most basic level, they are simply groups in which rooms, doors, stairs, ramps, and exits can be placed, but they also control the drawing plane for most tools and filtering of imported geometry.

In every Pathfinder model, at least one floor must exist, and at any given time, there is one active floor. Whenever any navigation object is drawn, it will either be placed in the active floor or a subgroup of the active floor.

In the case of a mine, it is likely that there will be quite a few floors, as shown in *Figure 5*.

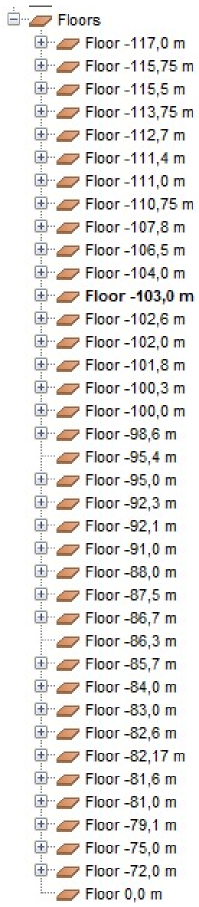

Figure 5 – Floors Defined for a Coal Mine Modelled in Pathfinder

Floors can also be created manually at any time. To do so, click on the floor drop-down box above the Navigation View, and select <Add New…> as shown in *Figure 6*.

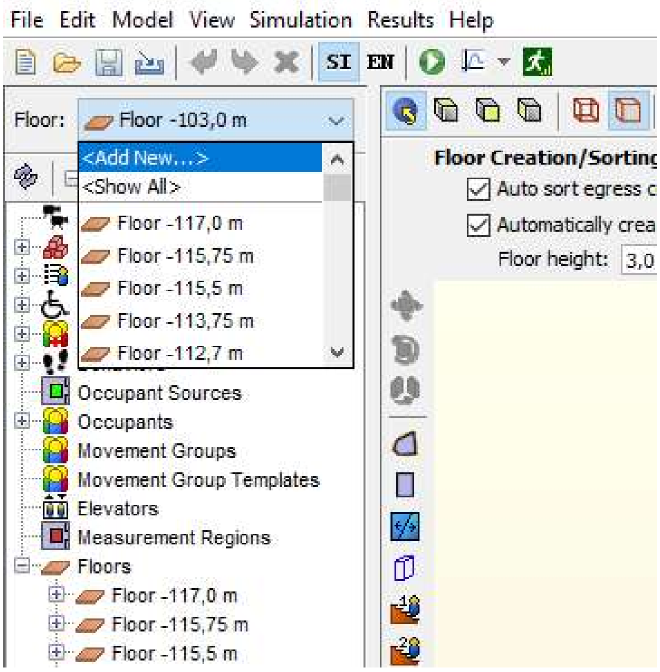

Figure 6 – Creation of Floors of a Coal Mine Modelled in Pathfinder

Floor Properties

To edit a floor's properties, first select the desired floor. The property panel, as shown in *Figure 7*, will appear, showing the floor name, its working Z location, and the Z clipping planes for imported 3D geometry.

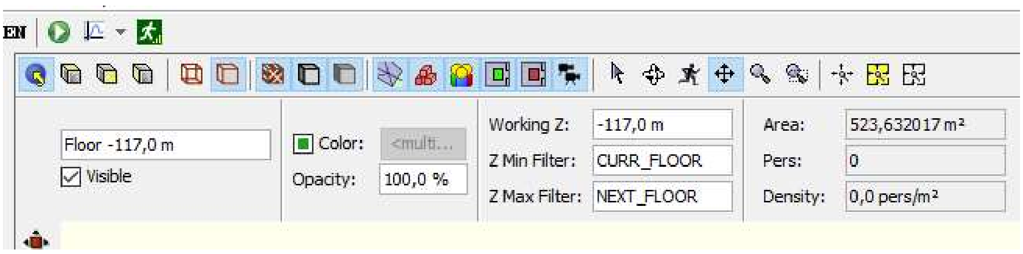

Figure 7 – Example of Floor Features in a Coal Mine Modelled in Pathfinder

3.3.2 Rooms

Rooms are open spaces in which occupants can freely travel. Each room is bounded on all sides by walls. Rooms can be drawn so that they touch each other, but an occupant can only travel between them if they are connected by a door. Only one room can occupy a given space at any time, so if one room is drawn overlapping another, the overlapping area will be subtracted from the old room and given to the new. Rooms can also be merged into one, separated into constituent parts, and have internal, thin boundaries drawn in them.

Adding New Rooms

Pathfinder provides two tools for adding new room geometry:

- Polygonal Room Tool: this tool allows for the creation of complex shapes with any number of vertices. Left click anywhere in the model to set the first point and continue left clicking to add more points to the polygon. When at least three points are defined, right-clicking will close the polygon and complete the shape. Alternatively, x-y coordinates can be entered from the keyboard with the Add Point and Close Polygon buttons from the property panel.

- Rectangular Room Tool: this tool creates simple rectangular geometry by left clicking two points in the model. The rectangular area can also be created by entering coordinates for two points in the property panel and clicking the Create button.

Merging Rooms

The Merge command is used to join two or more rooms that share boundaries into one room. To use it, select the neighbouring rooms and select Merge from either the Model menu or the right-click menu

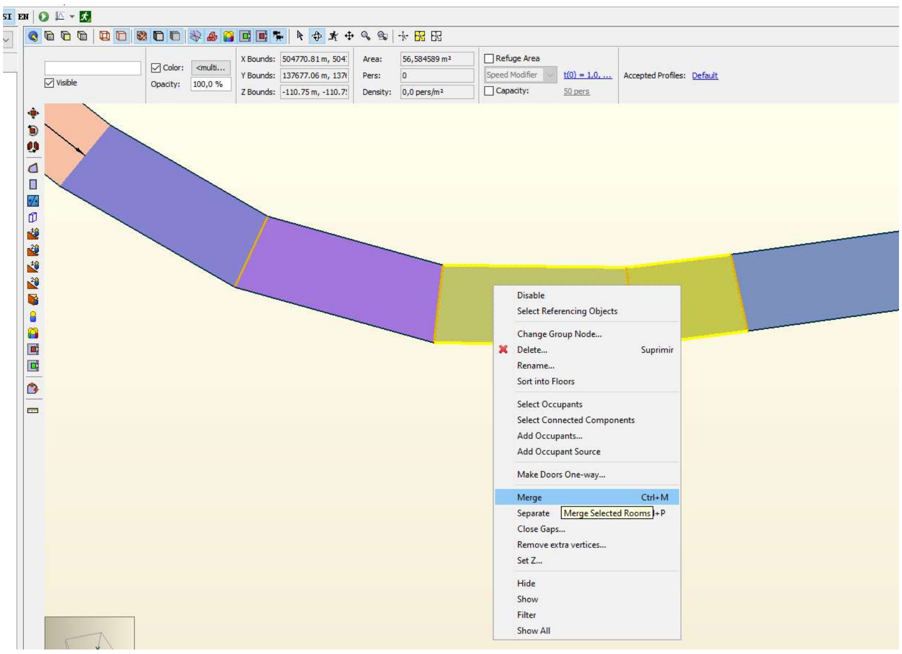

Figure 8 – Example of Room Merging in a Coal Mine Modelled in Pathfinder

Preventing Room Crossing

In some cases, such as modelling seating rows or shops in a mall, it may be desirable to only allow occupants to exit the room and not cross through it. This can be accomplished by making all the doors connected to the room one-way (see *Section 3.3.3*) and ensuring that their directions point out of the room. Pathfinder provides a tool to make this easy. Instead of individually setting the one-way status of all the connecting doors, perform the following:

- Select the room(s) that should not be crossable.
- Right-click one of the rooms, and from the menu select Make Doors One-way
- A dialog will appear as in *Figure 9*. From this dialog, choose whether occupants can only Enter or Exit the room. If any of the room's doors were already marked as one-way, another option will be provided to overwrite the one-way status of those doors. Press OK in this dialog to make the doors one-way.

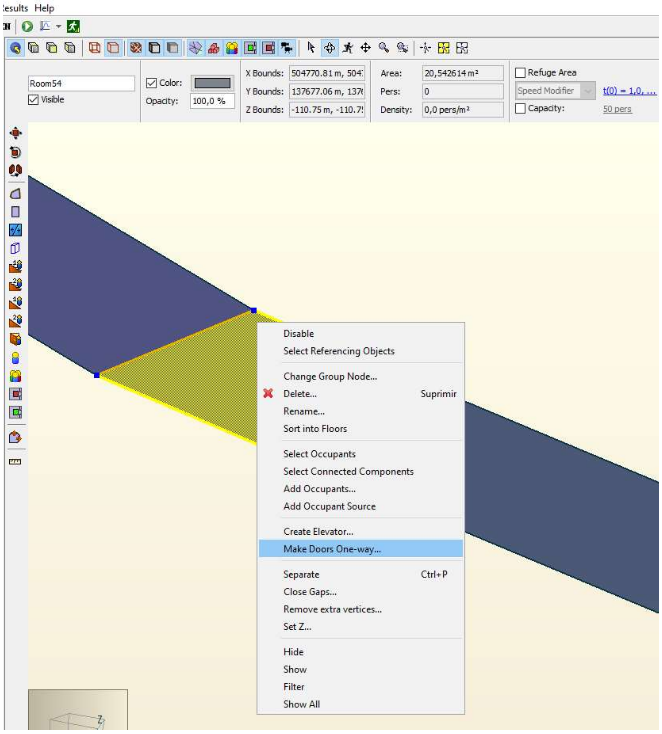

Figure 9 – Example of Preventing Room Crossing in a Coal Mine Modelled in Pathfinder

3.3.3 Doors

In Pathfinder, occupants cannot pass between two rooms unless they are joined by a door. Also, the simulator requires that each occupant must have a path to at least one exit door. Doors provide useful flow measurements in simulation results. Also, in the SFPE mode doors act as the primary flow control mechanism. You can add doors using the Add a New Door tool.

To edit a door's properties, select the door. Its properties will appear in the property panel as shown in *Figure 10*.

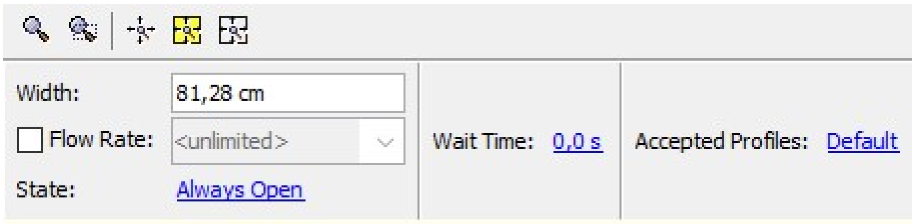

Figure 10 – Example of Door Features in a Coal Mine Modelled in Pathfinder

The main features are as follows:

- Width: The width of the door. Changing this value will change the width of the door, but the value cannot exceed the length of its room edge.

- Flow Rate: Checking this box overrides the default door flow rate setting in the Simulation Parameters Dialog. Setting this value controls the maximum occupant flow rate for the door in units of pers/t. This could be used, for instance, to specify a gated mechanism, such as a turnstile. A value of 0.9 pers/s, for instance, would mean that one occupant can go through the door every 1.1 seconds (1/0.9).

- State: Indicates the timed opening, closing, and changing the one-way direction of the door. A one-way door is one through which occupants can only travel in one direction. By default, all doors are always open throughout the simulation. To change this, click the link. The Edit Door State dialog will appear as shown in *Figure 11*. This dialog allows the initial state of the door to be specified as well as additional timed states.

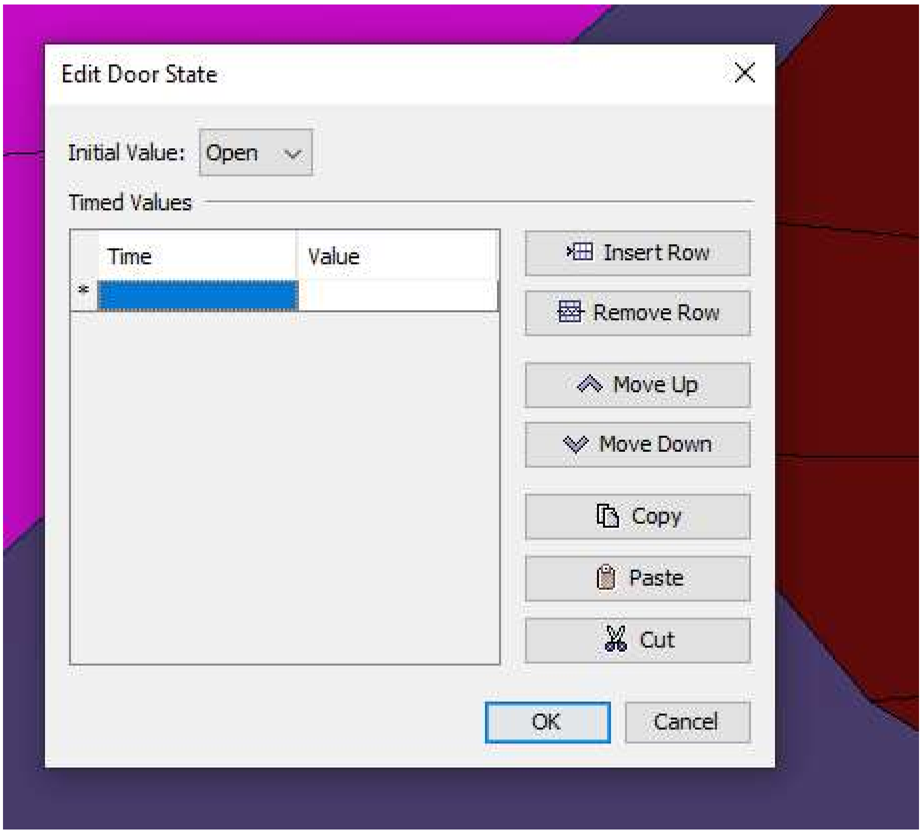

Figure 11 – Scripted Events Dialog in Pathfinder

- Wait Time: an amount of time for which each occupant must wait at the door before walking through it. This can be used to simulate turnstiles or doors with access keys. The specific wait time for each occupant will be drawn at random from a predefined continuous or discrete distribution.

- Accepted Profiles: A list of occupant profiles for which the occupants can enter this door. By default, all occupant profiles are accepted.

3.3.4 Elevators

Pathfinder supports elevators in egress-mode operation, which is based on current thinking described in Using Elevators In Fires. The basic operation of elevators in evacuations can be summarized as follows.

- Each elevator has one discharge floor. This is where the elevator starts at the beginning of the simulation and where it will take occupants it has picked up.
- Each elevator has at least one pickup floor. These are floors where the elevator will pick up occupants that it will take to the discharge floor.
- An elevator is called on a pickup floor by an occupant when they come within 0.5m of the elevator door.
- The elevator uses a priority system to serve called floors. By default, floors are served from top to bottom; however, other floors can be given higher priority to simulate fire floors.
- When travelling to a pickup floor, the elevator can change to another pickup floor mid-flight if a higher-priority floor is called that is above the elevator's current location
- Once an elevator has picked up occupants, it will only travel to the discharge floor before letting the occupants off. It will not travel to any other floor to pick up more occupants

Creating Elevators

Elevators can be made after creating the rest of the model. Perform the following steps to create the elevator:

- Draw a room that defines the shape of the elevator, preferably on the discharge floor.
- Draw all doors on the boundary of the base room. Occupants will use these doors on every floor to enter and exit the elevator.
- Right-click the base room, and from the right-click menu, select Create Elevator…. This will show the New Elevator dialog.
- In the New Elevator dialog, enter all parameters for the elevator:
    - Name – the name of the elevator,
    - Nominal Load – the number of people in a full load (estimated),
    - Elevator Geometry – the base room that defines the elevator shape,
    - Travel Direction – a vector defining the direction the elevator can travel,

    - Elevator Bounds – this defines the bottom-most and top-most floors the elevator can connect to,
    - Elevator Timing – this defines a basic timing model used to calculate the travel times for the elevator to travel from the discharge floor to each pickup floor,
    - Acceleration (Elevator Timing) – [optional] the acceleration of the elevator,
    - Max Velocity (Elevator Timing) – the maximum velocity that the elevator can accelerate to,
    - Open+Close Time (Elevator Timing) – the sum of the door opening and closing times. Each value will be taken as half of this,
    - Call Distance – the distance away from the elevator door at which an occupant can call the elevator,
    - Double-Deck – whether the elevator should use two connected decks to transport occupants.

- Press OK to create the elevator.

3.3.5 Exits

In Pathfinder, exits are merely thin doors that exist on the boundary of the model. An exit can only have a room on one of its sides.

Exits are created in almost the same way as thin doors. The only difference is that the door must lie on an edge of a room, and the edge must not be shared between two rooms.

Exit doors are displayed the same as thin doors except that they are green as shown in *Figure 12*.

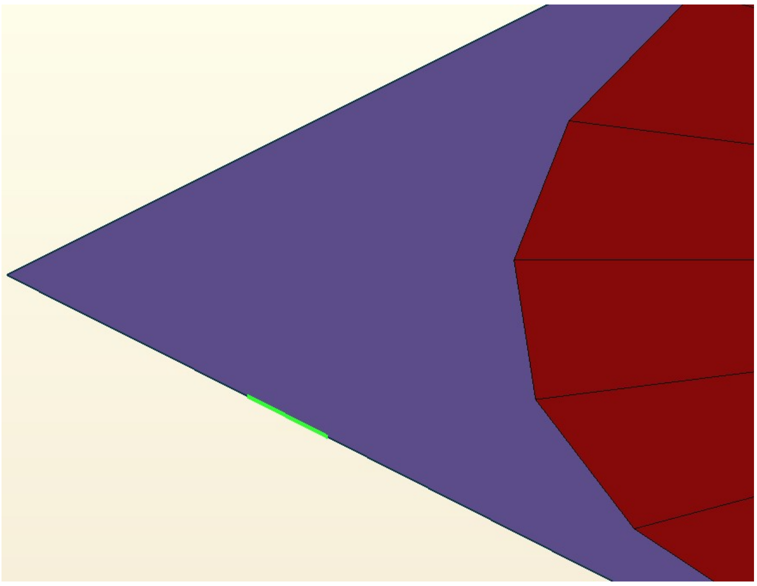

Figure 12 – Example of Exit Door (Green) in a Coal Mine Modelled in Pathfinder

3.4 Importing Files

Pathfinder can import a large number of image and CAD formats. Imported files can be used as an aid to more quickly generate the navigation mesh and give more context and visual appeal to a simulation.

3.4.1 Importing CAD Files

Pathfinder can import geometry from several CAD formats, including AutoCAD's DXF (Drawing Exchange Format), DWG, FBX, DAE, and OBJ files.

- DXF – a basic CAD format provided by Autodesk. This format supports robust geometry types, including 3D faces, lines, and text, but it does not support material information, such as textures, lighting parameters, etc. In Pathfinder, the main purpose of the imported geometry is for display and floor extraction. Because of this, Pathfinder does not need to perform any special post-processing of the imported geometry.

- DWG – similar to DXF, but it also has basic support for materials, including textures. It has only basic support for mapping textures onto objects, however, and few CAD applications can export DWG files. Some, such as Revit, exclude material and texture information

- FBX – provides support for 3D faces only, but it has very good support for material information and materials mapping. In addition, many 3D modelling applications have built-in support for exporting FBX files. This is an excellent format for importing 3D building models into Pathfinder

To import one of these files, under the File menu, select Import... and select the desired file. After selecting a file, a step-by-step dialog will open as shown in *Figure 13*.

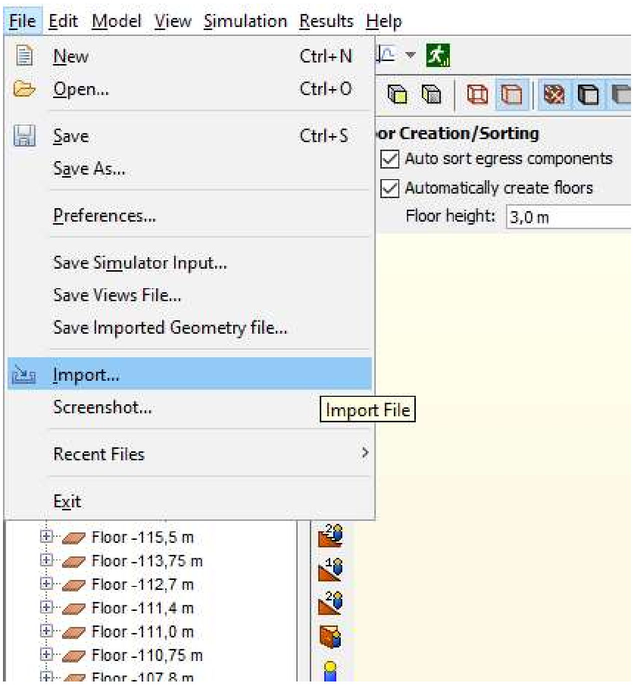

Figure 13 – Import Option in Pathfinder

3.4.2 Import REVIT Files

While Pathfinder cannot directly import Autodesk Revit files (RVT), there are several ways to export the data from Revit into a file format that Pathfinder can read. Each method has advantages and disadvantages as discussed below.

- Revit to DWG (direct): The first method is to export a DWG directly from Revit, which can then be imported into Pathfinder. While simple to perform and only requires Revit, this method loses all information about materials, including textures, due to Revit's limited DWG support. To perform the export in Revit Architecture 2014, perform the following:
    - Open the desired RVT file within Revit Architecture.
    - Click the Revit icon at the top left.
    - Select Export->CAD Formats->DWG.
    - In the DWG Export dialog, for Export, select <In session view/sheet set>.
    - For Show in list, select Views in the Model.
    - Click the Check None button, and then in the view table, select the check box for 3D View.
    - Click the Next… button and choose a file name for the DWG file.
    - Click OK to create the DWG.
    - Import the DWG into Pathfinder.
- Revit to FBX (direct): This method exports an FBX file directly from Revit, which can then be imported into Pathfinder. As with exporting a DWG, this method is simple to perform and only requires Revit. Unfortunately, this method also loses all information about materials and textures because Revit encrypts the material data, making it unreadable by Pathfinder. To export using Revit Architecture 2014, perform the following:
    - Open the desired RVT file within Revit Architecture.
    - Click the Revit icon at the top left.
    - Select Export->FBX.
    - Choose a file name for the FBX file.
    - Click OK to create the FBX.
    - Import the FBX into Pathfinder.
- Revit to FBX using third-party plugin: This method requires the use of a third party plugin, but it generally produces good results with materials, textures, and texture coordinates well-supported. In many cases, this is the most reliable method of reproducing the graphical representation of the original Revit file within Pathfinder. SimLab Soft is one company that provides commercial FBX export plugins for several CAD packages, including Revit and Sketchup, among

others, and provides robust texture support. To export using a third-party plugin, perform the following:

- Download and install the appropriate plugin.
- Follow the plugin instructions to export an FBX file from Revit. If the plugin supports embedded media, select this option before exporting. This option allows textures to be embedded into the FBX file, making it much easier to transfer the FBX to another computer, as only one file has to be transferred.
- If the FBX file is to be imported into Pathfinder on the same computer as the one that exported the file or the embedded media option was selected, continue to the next main bullet, otherwise, some additional steps may be necessary to ensure the textures can be found when importing into Pathfinder.
    - Determine the directory into which the FBX exporter saved the textures. Some exporters may place the textures in a sub-directory of the FBX file and give it the same name as the FBX file. Others may save the textures to a common program-specific location.
    - Cut this folder and paste it in the same location as the FBX file. The pasted folder may be left as is or renamed to be the same as the FBX file, without the .fbx extension.
    - Transfer the FBX file and the texture folder to the computer that will be importing the FBX file into Pathfinder.
- Import the FBX file into Pathfinder.

- Revit to FBX to AutoCAD to DWG: This method requires both Revit and AutoCAD and does not perform a perfect conversion, but it retains some information about materials and texture coordinates. The steps described here use Revit Architecture 2014 and AutoCAD 2014:
    - Open the desired RVT file within Revit Architecture.
    - Click the Revit icon at the top left.
    - Select Export->FBX.
    - Specify the desired filename and click Save.
    - Open AutoCAD.
    - On the Insert tab in the ribbon, select Import.
    - Select the FBX file created by Revit.
    - The FBX Import Options dialog will appear. The following are recommended settings for the FBX import:
        - Import section: Make sure Objects and Materials are checked. Lights and Cameras are unused in Pathfinder.
        - Assign Objects to Layers: any option may be selected, but By Material is a useful option for Pathfinder.

    - Unit Conversion: This section is somewhat misleading. While the Current Drawing Unit is correct, the FBX file unit tends to be incorrect. No matter what unit is displayed in the greyed-out text for FBX file units, the actual unit in the FBX file is always FOOT. The appropriate values need to be specified to make the proper unit conversion.
    - Block: Uncheck Insert file as block.
- Click OK to finish the import. You may receive a warning about the clip plane of the camera.
- Save the file as a DWG.
- Import the DWG into Pathfinder.

3.4.3 Importing Pyrosim and FDS Files

Both PyroSim and FDS files can be imported into Pathfinder. To import one of these file types, select Import… under the File menu. Then select the appropriate FDS or PSM file. The imported geometry will be added to the Imported Geometry group.

3.4.4 Importing FDS Output Data

Pathfinder can use the PLOT3D data output from FDS to create time history data for each occupant as they move throughout the simulation. In cases where FDS PLOT3D output data is available for CO Volume Fraction, CO2 Volume Fraction, and O2 Volume Fraction, Pathfinder will also output FED for each occupant specified.

FDS data integration is a measurement only and does not alter the movements or decision making within the Pathfinder simulation. However, enabling this feature causes simulations to require additional runtime because of the additional processing load relating to reading the FDS output files and mapping PLOT3D data to occupants.

To enable FDS Integration:

- On the Simulation menu, click Simulation Parameters.
- On the FDS Data tab, select Enable FDS Integration.
- Click Edit… and select the SMV file from the FDS simulation of interest.

The dialog will display information about the attached SMV file and indicate which quantities were found.

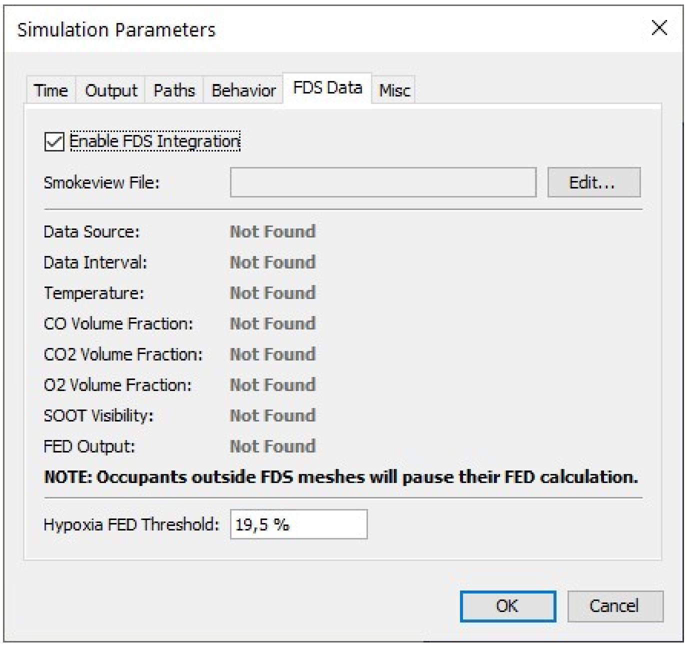

Figure 14 – Import Option in Pathfinder

The parameter Hypoxia FED Threshold defines the oxygen concentration at which hypoxia contributes to the FED calculation. When oxygen concentration is above the threshold, low O2 hypoxia will not contribute to accumulated FED. The default value of 19.5% prevents misleading FED accumulation for occupants that are in safe conditions.

To enable FED and PLOT3D quantity output for one or more occupants:

- Select one or more occupants.
- In the selection editor, click More.
- In the Additional Occupant Properties dialog, on the Output tab, enable Print CSV Data.
- In the Print CSV Data dropdown, select Yes.

Once the simulation has completed, CSV data is available for each specified occupant in the output folder.

3.5 Creating Occupants

In Pathfinder, occupants are defined in two parts: *profiles* and *behaviors*. The *profile* defines fixed characteristics of the occupants, such as maximum speed, radius, avatar, and colour. The *behavior* defines a sequence of actions the occupant will take throughout the simulation, such as moving to a room, waiting, and then exiting.

3.5.1 Profiles

Pathfinder uses an *occupant profile* system to manage distributions of parameters across groups of occupants. This system helps you control the occupant speed, size, and visual distributions.

To open the Edit Profiles dialog: on the Model menu, click Edit Profiles.

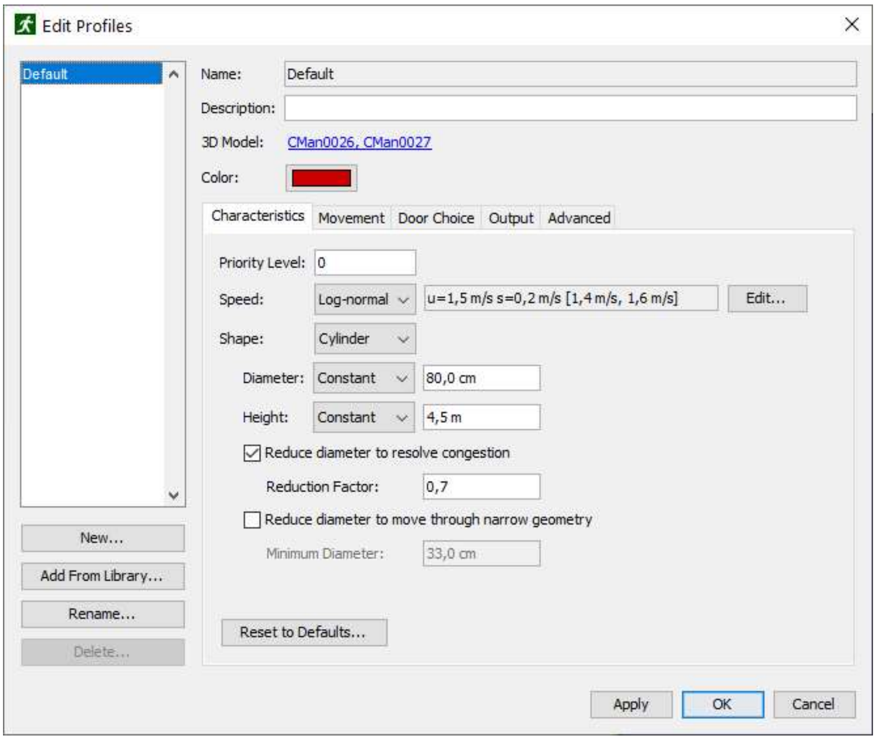

Figure 15 – Import Option in Pathfinder

Characteristics Tab

- Priority Level of the occupants are completely relative and higher values indicate a higher priority. For instance, if three occupants meet with assigned priorities of 4, 6, and 12, they will behave the same as if their priorities were 0, 1, and 2, respectively. This allows occupants of lower priority to move out of the way of those of higher priority. This would be useful when simulating first responders that must be able to move easily through a crowd of occupants.

- The Shape of the occupant can be either a cylinder or a polygonal shape. In the case of a Cylinder, Diameter, Height, Reduction Factor and Minimum Diameter can be specified.

- Diameter of the cylinder representing the occupant. This is used for collision testing and path planning during the simulation. This value will also affect how many occupants can be added to a room without overlapping. The default value of 45.58cm is based on the average of measurements of male and female persons from nine countries. As shown in the Pathfinder Validation and Verification Manual, this size (and Comfort Distance) results in movement that matches the SFPE and experimentally measured fundamental diagrams. Caution should be used in changing the default Diameter value.

- Height specifies the height of the cylinder used for inter-occupant collisions. This is useful for limiting collisions that might occur between occupants on different floors when the floors have been modelled close together.

- Reduction Factor is an optional Steering Mode Parameter that specifies how well an occupant may squeeze past other occupants in tight situations. This factor should be specified as greater than 0 and less than or equal to 1. This factor is directly multiplied by the shoulder width during calculations, so a Reduction Factor of 0.5 would lead to the occupant being able to squeeze to one-half his shoulder width.

- Minimum Diameter for movement through narrow geometry (optional) specifies a diameter to which the occupants can squeeze their bodies to pass through a narrow area, such as narrow doors or corridors. Occupants will reduce their diameter to this value only if the geometry would otherwise prevent them from further following their path. The default value of 33.00cm is based on the maximum depth of a human body for 95th percentile of measured individuals.

Movement Tab

- Initial Orientation: The degree counter-clockwise from the positive x-axis which the occupants will use as their orientation in the beginning of the simulation.

- Requires Assistance to Move: Whether the occupant requires assistance from another occupant in order to move.

- Ignore One-way Door Restrictions: Whether the occupant will ignore the direction specified for one-way doors.

- Walk on Escalators: Whether the occupant will walk on escalators and moving walkways.

- Restricted Components: Specifies which doors, rooms, stairs, ramps, and elevators the occupant will accept or reject during path planning.

Door Choice Tab

The Door Choice tab provides parameters related to how occupants choose doors to exit from in each room.

- Current Room Travel Time: The cost of travelling to a door in the occupant's current room, ignoring all other occupants.
- Current Room Queue Time: The cost of waiting in a queue at a door in the occupant's current room.
- Global Travel Time: The cost of travelling from a door to an exit or the occupant's next goal, ignoring all other occupants.
- Elevator Wait Time: The time during which the occupant will prefer to use an elevator, even if using a stair would be faster.
- Current Door Preference: Makes occupants stick to their currently chosen doors.
- Current Room Distance Penalty: Exponentially increases the cost associated with travelling based on how far the occupant has travelled in the current room.

Advanced Tab

The Advanced tab provides the following parameters:

- Acceleration Time: The amount of time it takes for the occupant to reach maximum speed.
- Persist Time: The amount of time an occupant will maintain an elevated priority when trying to resolve movement conflicts.
- Collision Response Time: Controls the distance at which an occupant will start recording a cost for colliding with other occupants when steering.
- Slow Factor: The fraction of the occupant's speed in which they are considered to be slow.
- Wall Boundary Layer: Specifies the distance that occupants try to maintain with walls and other static obstructions.
- Comfort Distance: The desired distance one occupant will try to maintain with others in a queue.

Output Tab

The Output tab provides the Print CSV Data option. When checked, additional CSV output data is generated for each occupant using this profile. The file contains data for each time step, such as occupant speed, location, etc.

3.5.2 Behaviours

Behaviours in Pathfinder represent a sequence of actions the occupant will take throughout the simulation. Once the occupant has completed all actions, they are removed from the simulation. Actions may be added that can make the occupant wait or travel to a destination, such as a room, point, or exit. The last destination for the occupant can be thought of as the occupant's sink. By default, there is one behaviour in the model called "Goto Any Exit." This behaviour simply makes the occupant move from their starting position to any exit present in the model by the fastest route.

As with profiles, any number of occupants can refer to a single behaviour. Any changes to the behaviour will be reflected in referring occupants.

Creating a New Behaviour

To create a new behaviour, right click the Behaviours node from the Navigation View, and from the right-click menu, click Add a Behaviour…, which will open the New Behaviour dialog shown in the next figure. In the New Behaviour dialog, enter a behaviour name, and optionally specify an existing behaviour to base the new behaviour on. Using this option will copy all the actions from the existing behaviour.

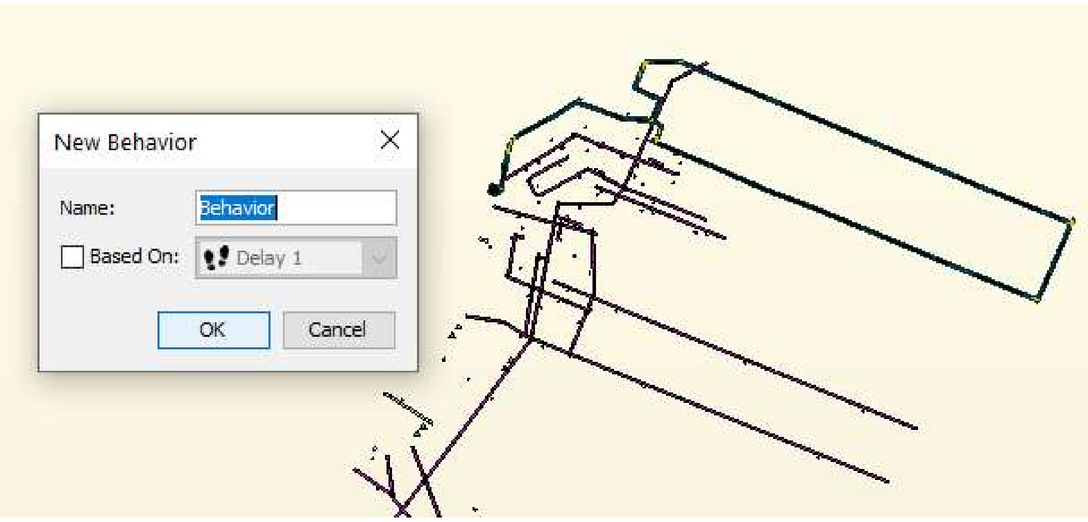

Figure 16 – New Behaviour Dialog in Pathfinder

With the new behaviour selected, the behaviour property panel will appear as shown in *Figure 17*.

Figure 17 – Behaviour Property Panel in Pathfinder

Initial Delay specifies an initial delay that makes the occupant wait at their starting position before moving to the next action. If this link is clicked, it will show a dialog where different distribution curves can be entered for the delay, similar to those discussed in Profiles.

Adding Actions

Additional actions can be added to any behaviour, such as going to a room, a waypoint, an elevator, or simply waiting in place. To add an action, select a behaviour or existing behaviour action. The property panel (*Figure 18*) will show a drop-down button with the description of an action that can be added. To add the currently shown action, simply click the button. To add a different action, click the down-arrow shown to the right of the button and select the desired action from the behaviour actions list.

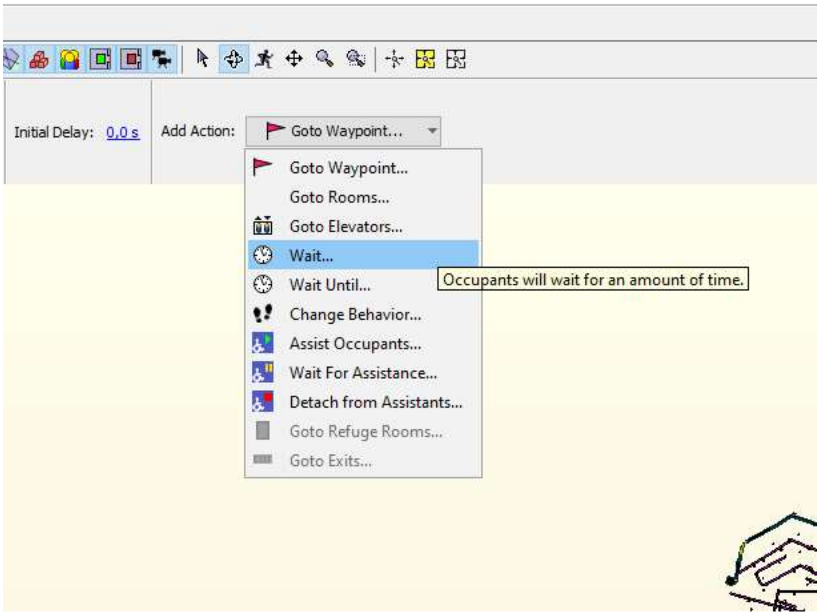

Figure 18 – Behaviour Actions List in Pathfinder

Once the desired action is clicked, a creation panel will be shown above the 3D/2D View depending on the action. Enter the desired parameters in the creation panel as discussed in the following sections, and then click Create to create the action and append it to the behaviour. If the behaviour itself was selected when adding the action, then the new action will be appended to the end of the list. If, instead, an action was selected when the new action was created, then the new action is inserted directly after that selected action.

Actions always occur in the order shown in the Navigation View.

Behaviour Action Types

In *Table 1*there is a brief description about the behaviour action types

Action	Description
Goto Waypoint	Specifies that an occupant should go toward a specific point on the navigation mesh.
Goto Rooms	Specifies that an occupant must select a room out of a set and go to it.
Goto Elevators	Tells an occupant to use evacuation elevators
Wait	Tells an occupant to wait in their current location for a specified amount of time.
Wait until	Instructs an occupant to delay their movement until a specified simulation time passes.
Assist occupants	Instructs the occupant to join an assisted evacuation team and begin assisting occupants who request assistance from that team.
Wait for assistance	Indicates that the occupant should wait for assistance from other occupants.
Detach for assistants	Detaches a client from their assistants, allowing the assistants to continue helping other clients.
Goto refugee rooms	Instructs the occupant to go to one of a set of rooms marked as refuge areas.
Goto exits	Instructs an occupant to take the fastest route to a set of exits.
Change behaviour	Instructs an occupant to change a behavior to a new behavior picked randomly from a behavior distribution.

Table 1 – Brief description of behavior action types

The Goto Waypoint Action

A *Goto Waypoint* action specifies that an occupant should go toward a specific point on the navigation mesh. Once they arrive within a certain radius of the point, they will move on to the next action in their behaviour.

The Goto Rooms Action

A *Goto Rooms* action specifies that an occupant must select a room out of a set and go to it. Once they cross a door into the room, they are considered to be in the room and can move on to the next action in their behaviour. If multiple rooms are specified for the action, the occupant will go to the one that is fastest to reach.

The Goto Elevators Action

A *Goto Elevators* action tells an occupant to use evacuation elevators. When using this action, an occupant will go to a specified elevator, call it, wait for it to arrive, enter it, and then wait for it to reach the discharge floor. Once they reach the discharge floor, they can begin their next action. The *Goto Elevators* action can only be used for occupants who are not on the discharge floor of the desired elevator. If multiple elevators are specified for the action, the occupant will use the one that allows them to reach the discharge floor fastest.

The Wait Action

A *Wait action* tells an occupant to wait in their current location for a certain amount of time. Once that time has elapsed they will begin their next action.

The way they wait will vary depending on their most recent destination. For instance, if their previous destination was a waypoint, they will try to stay close to the centre of the waypoint. If the previous destination was a room, they will try to move toward the furthest point in the room away from all active doors. This allows other occupants to enter the room. If their previous destination is an elevator, they will first move toward the walls as in waiting in a room, and then stand still when the elevator travels. In all cases, a waiting occupant will move out of the way of occupants headed toward a destination unless the destination overlaps with the waiting occupant's most recent destination.

The Wait Until action

A *Wait Until* action instructs an occupant to delay their movement until a specified simulation time passes. This action is useful for synchronizing movement of many occupants at a time. Occupants fill space during a *Wait Until* action per the same rules described for the Wait action. Wait Until actions can be specified using three different approaches: occupants can wait until a specific time, the next in a list of times, or the next time in a periodic function.

The Assist Occupants action

This action instructs the occupant to join an assisted evacuation team and begin assisting occupants who request assistance from that team. When an occupant joins a team, they become an assistant. Once all occupants requesting assistance have completed their actions for which they wanted assistance, the assistant will begin their next action.

The Wait for Assistance action

This action indicates that the occupant should wait for assistance from other occupants. This action requires that the occupants using it have a vehicle shape with at least one attached occupant location. When an occupant begins this action, they are a client, and assistants will approach the client. The client cannot move once they begin waiting for assistants until enough assistants attach to the client to fill all the attached occupant positions. Once all positions are filled, the client begins their next action. The assistant will stay attached to the client until either the client has completed all subsequent actions, or the client begins a Detach from Assistants action as described below.

The Goto Refugee Rooms Action

This action instructs the occupant to go to one of a set of rooms marked as refuge areas. Like the *Goto Exits* action, this action must be the last action in the behaviour. When an occupant reaches the refuge area, they will remain in the simulation and wait for the simulation to complete. Their behaviour while waiting is described in the Wait action above.

The Goto Exits Action

This action causes an agent to take the fastest route to a set of exits. Like the *Goto Refuge Rooms* action, this action must be last in the behaviour. Once an agent goes through an exit, they are removed from the simulation and reported as having exited the model in the Occupants Summary and Occupant History output files.

The Change Behaviour Action

This action causes an occupant to switch its behaviour. After this action, the occupant will start performing actions from a different behaviour. This new behaviour is randomly selected from a given behaviour distribution. Besides other behaviours, the same behaviour and No Change can also be selected. If the occupant changes behaviour to its current behaviour, the behaviour will be restarted. If the occupant selects to make No Change, the *Change Behaviour* action will have no effect. It is possible to create loops in the behaviour references. That way the occupant might keep performing the actions forever (until the end of the simulation). Note that depending on the specific setup, it is possible that actions that come after a *Change Behaviour* action will not be performed by the occupant.

3.5.3 Generating Occupants

Occupants can be added to the simulation in several ways. The simulation can either be pre-seeded with any number of occupants or it can have occupants continuously generated by occupant sources. When pre-seeding the model, occupants can be placed individually in the 3D or 2D view, distributed in a rectangular region of a particular room, or distributed throughout the entire area of a room.

Individual Placement

Individual occupants can be added to the model with the Add Occupant tool. Occupants can only be placed in pre-existing rooms, stairs, and ramps and cannot overlap other occupants or room boundaries. Left-click a desired position with the mouse or enter an x-y-z coordinate and press the Create button from the property panel to place an occupant.

Group Placement

Groups of occupants can be added to the model with the Add Occupant Group tool. The occupants are distributed throughout this region using parameters in the property panel.

Room Placement

In addition to distributing occupants in placement regions, occupants can be distributed throughout entire rooms. To do this, select the desired rooms and choose Add Occupants… from the Model menu or the right-click menu. This will bring up the Add Occupants dialog. For an explanation of the dialog's options, please see the section, Group Placement. Click the OK button after selecting the desired options to place occupants and exit the dialog.

3.6 Simulating

This is the last step to launch a simulation.

3.6.1 Parameters

The Simulation Parameters dialog provides a way to control certain features of the simulation, as well as provide some default values.

The Time tab provides the following options:

- Time Limit: can be used to automatically stop the simulation after a set simulation time.
- Time Step Size: controls the resolution of simulation time steps. Increase the time step size to speed up simulations, reduce the time step size to ensure simulation accuracy.

The Output tab provides the following options:

- 3D Output Freq: controls the time between 3D output file updates. Increasing this value causes data to be written less often, leading to less disk usage and run faster simulations (no file write delay), but can produce a misleading 3D results visualization. In the 3D results visualization, occupants will move in a straight line between two data points – if the two points are far apart in time, an occupant might appear to pass through an obstruction when it actually navigated properly.
- CSV Output Freq: controls the time between CSV output file updates. Increasing the value causes fewer rows to appear in the resulting CSV files (i.e. lower data resolution). This option has a negligible effect on simulation performance or disk usage but can affect performance in the 2D results.
- Runtime Output Freq: controls the time between simulation status updates in the Run Simulation dialog. This option has a negligible effect on simulation performance or disk usage.

- Jam Velocity: controls the speed threshold at which occupants are recorded as being jammed in the Occupants output file.

- Occupant CSV Data: controls how the CSV data is generated for occupants with Print CSV Data enabled.

3.6.2 Starting a Simulation

To run a simulation: on the Model menu, click Run Simulation. The simulation will begin and the Run Simulation dialog.

A simulation can also be paused, resumed, and cancelled at any time.

4 PRACTICAL CASE TO BUILD A MINE MODEL FOR EVACUATION SIMULATIONS

Before modelling a mine evacuation process with the Pathfinder software, it is important to be clear on how to choose the evacuation model's features.

4.1 Introduction

The study focused on a practical case in Velenje Mine, where several simulations were carried out in order to assess the mine's safety.

Two kinds of simulations were launched:

- Simulations type 1: fire simulations covering the whole escape route of the mine.
- Simulations type 2: sensitivity analysis assessing the effect of varying the mine's cross-sectional area.

The smoke and harsh conditions that take place in the smoke path make the evacuation more difficult, mainly because of the lack of visibility, that provokes a dramatic reduction in the evacuation velocity. This applies to the simulations type 1, because its interest is calculating the evacuation time and assessing whether the miners can get to a safe zone.

To carry out the simulations type 2, the worst scenario from the simulations type 1 is chosen. Then, geometrical changes are studied, which allows to know the range of values where the fire effects are worse for miners. The results are examined through the variables of the fire (visibility, temperature, CO concentration) and also through the radiation, which is rather related to the fire service's intervention to extinguish the fire.

In the present document, a user's guide is presented to elaborate and launch an evacuation simulation.

The steps to take in order to make an evacuation study are as follows:

- Launch several CFD fire simulations, varying some aspects of the scenario (fire location, fire power, ventilation regime, burning material).
- Assess the evolution of the main variables (temperature, visibility, CO concentration) in the escape route.
- Select the worst scenario to make a sensitivity analysis.
- Launch several evacuation scenarios considering the fire simulations already carried out.
- Assess if the smoke effect on miners during the evacuation allows them to get to a safe zone.

4.2 Preliminary CFD Simulations

The first step to take to make a complete evacuation study is to launch several CFD simulations. Two sorts of simulations have to be considered: one to analyse the smoke conditions in the evacuation route and another one to assess how the geometrical changes affect the fire evolution.

4.2.1 Simulations in the Whole Escape Route

This kind of simulations covers the whole escape route of the miners. Several aspects have to be specified: the fire location, the miners' location and the escape route the miners take, making the assumption that the fire blocks the miners' route.

For example, for a coal mine, if a fire takes place in the vicinity of the coal face, it can be assumed that there is a permanent airflow (whose value can be changed to study its impact), as shown in *Figure 19*.

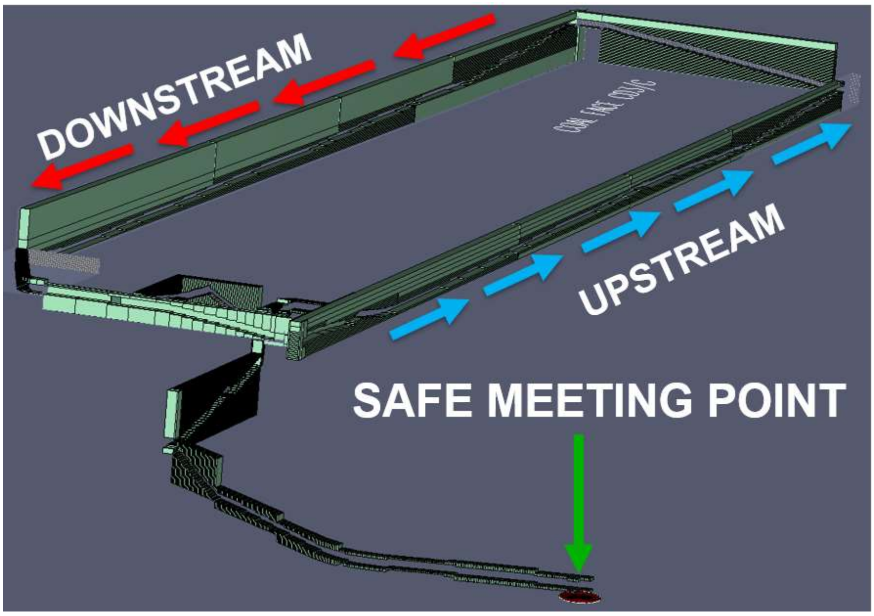

Figure 19 – Fire and Evacuation Scenario

This model can be studied modifying some parameters, such as the fire location, the ventilation regime, etc. This way, four scenarios can be analysed: SC-1, SC-2, SC-3 and SC-4, as it is outlined in *Table 2*.

Scenario	Fire Location	Material	Ventilation Rate (m^3/min)
SC-1	Connection (Coal Face – Downstream Gallery)	Conveyor Belt	Nominal ventilation rate Upstream Gallery: 1710 m^3/min Downstream Gallery: additional 520 m^3/min
SC-2	Connection (Upstream Gallery – Coal Face)	Conveyor Belt	Nominal ventilation rate Upstream Gallery: 1710 m^3/min Downstream Gallery: additional 520 m^3/min
SC-3	Connection (Coal Face – Downstream Gallery)	Conveyor Belt	50% Nominal ventilation rate Upstream Gallery: 855 m^3/min Downstream Gallery: additional 260 m^3/min
SC-4	Connection (Upstream Gallery – Coal Face)	Conveyor Belt	50% Nominal ventilation rate Upstream Gallery: 855 m^3/min Downstream Gallery: additional 260 m^3/min

Table 2 – Fire Scenarios to be Studied

4.2.2 Results in the Fire Vicinity

These scenarios are illustrated in *Figure 20 – Figure 23*.

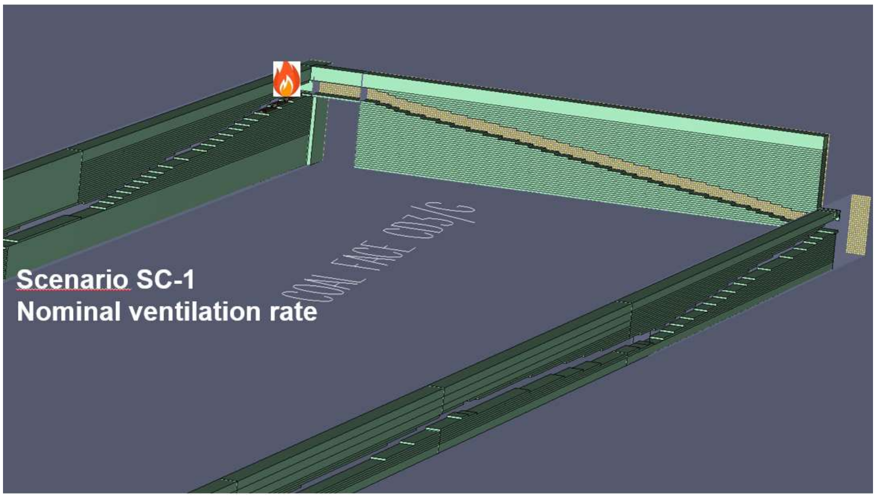

Figure 20 – Scenario 1 in the Whole Mine

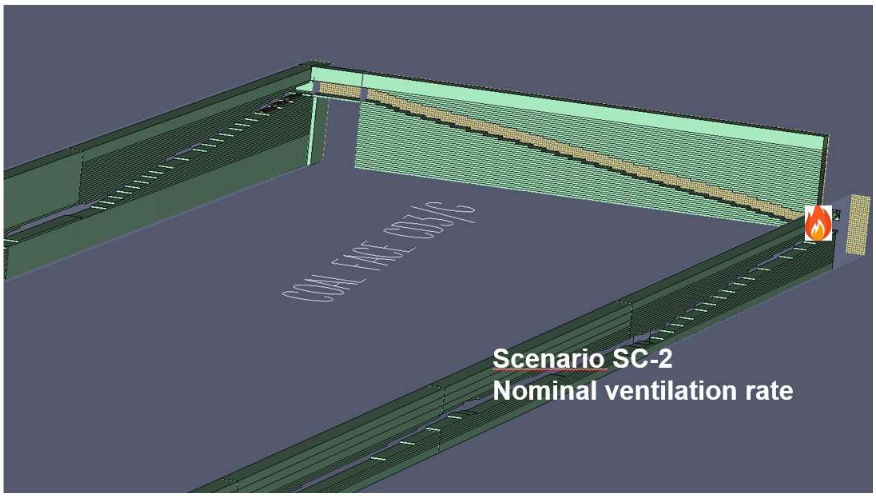

Figure 21 – Scenario 2 in the Whole Mine

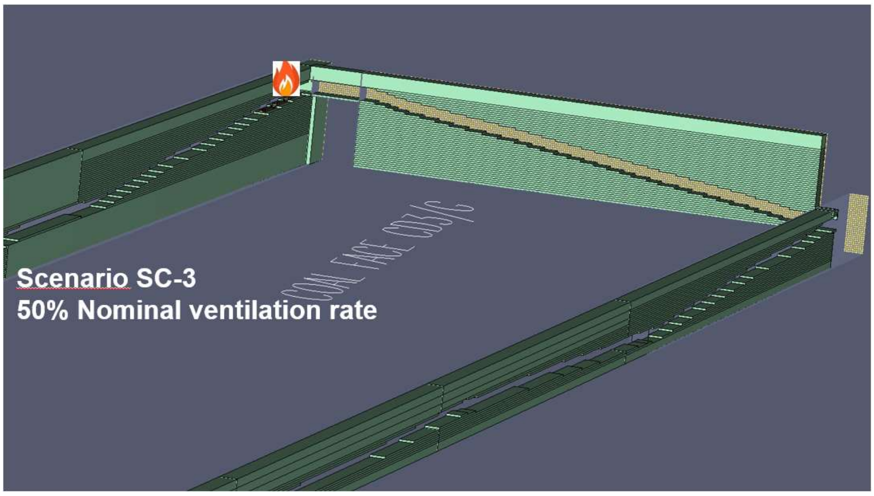

Figure 22 – Scenario 3 in the Whole Mine

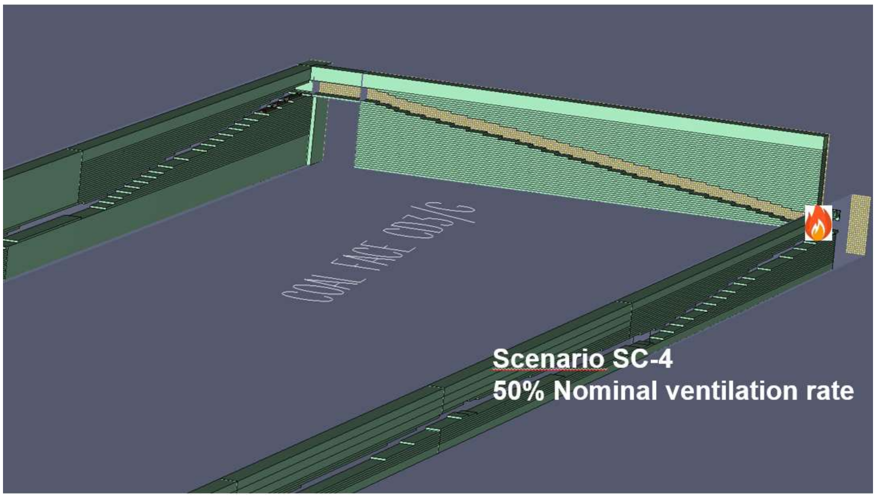

Figure 23 – Scenario 4 in the Whole Mine

Once all the simulations have finished, it is possible to determine which scenario presents the worst results in terms of safety.

The results of the main variables (temperature, CO concentration, visibility) in the nearby downstream region (not far from the fire) allow to determine the worst scenario, as shown in *Figure 24* and *Figure 25*.

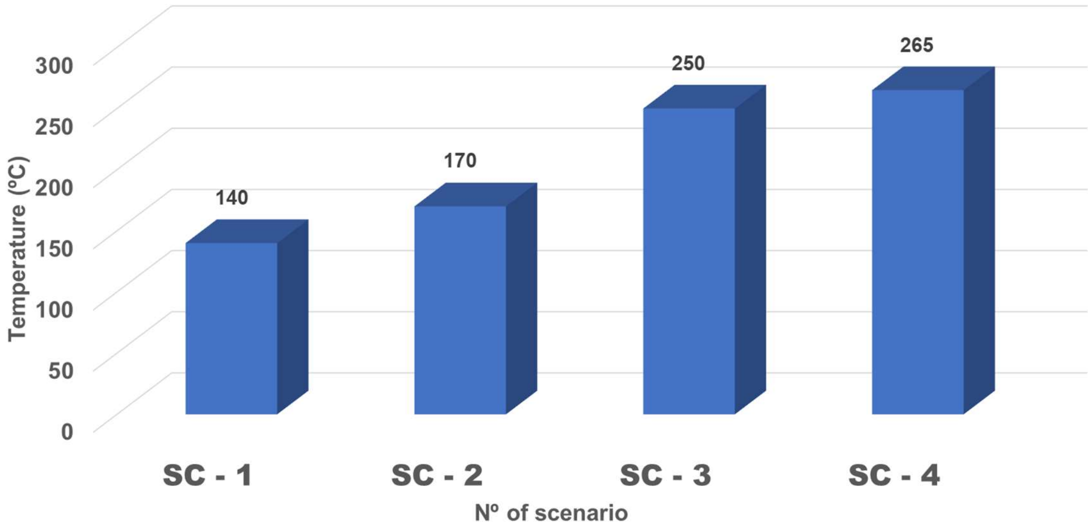

Figure 24 – Temperature Variation in the Downstream Region

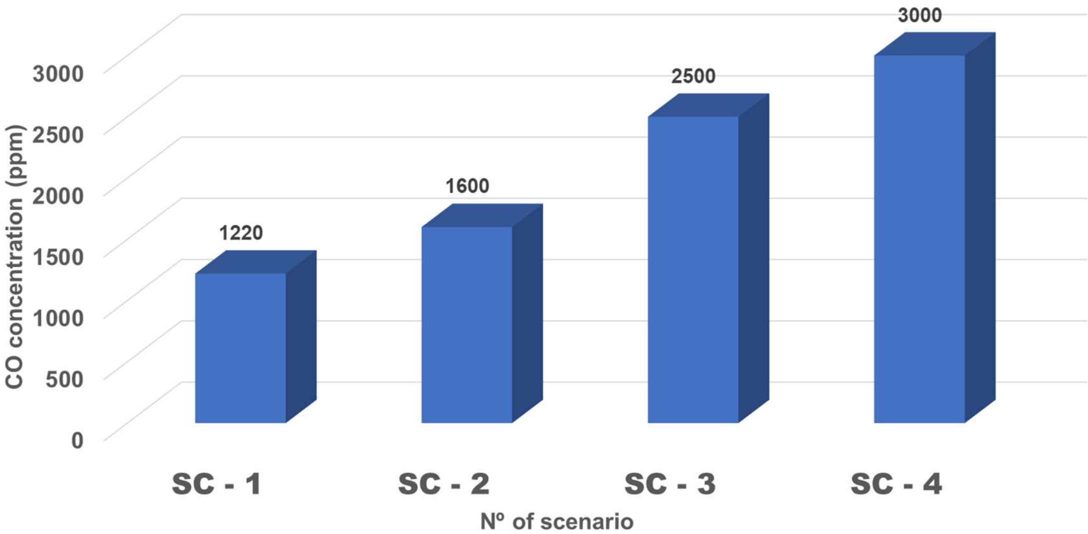

Figure 25 – CO Concentration Variation in the Downstream Region

4.2.3 Results in the Downstream Region

It has been verified que the scenario 4 constitutes the worst scenario among the four scenarios that have been studied.

The results of the main variables (temperature, CO concentration) in the downstream region, which is the main evacuation route, are the ones shown in *Figure 26* and *Figure 27*.

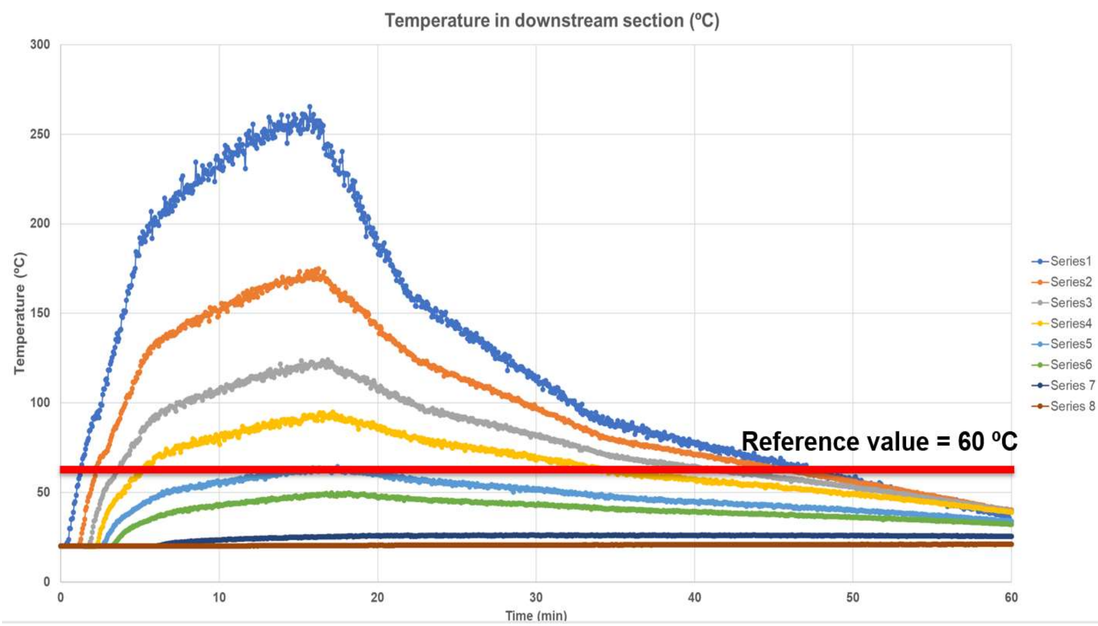

Figure 26 – Temperature Evolution in Downstream Region

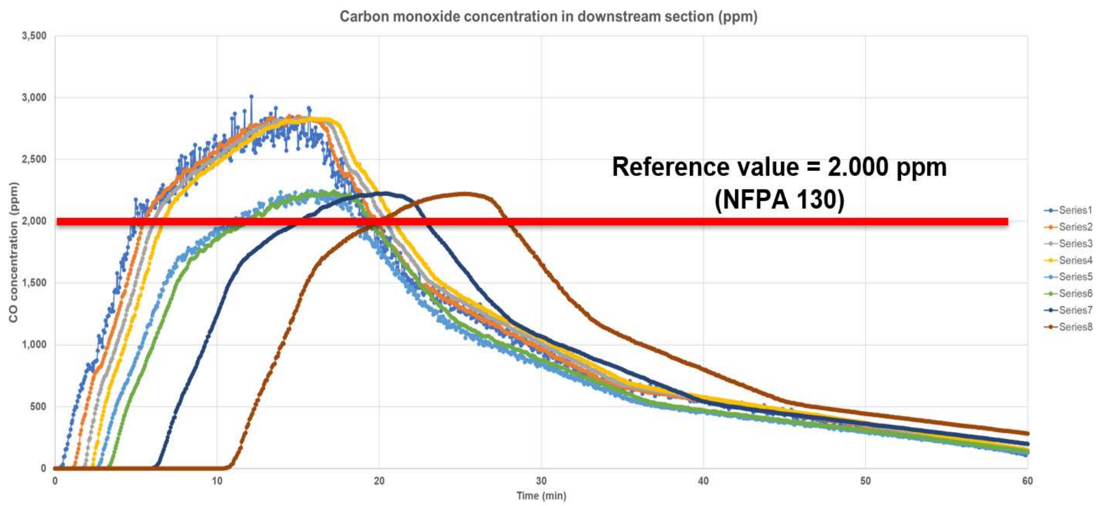

Figure 27 – CO Concentration Evolution in Downstream Region

These results allow to have an idea of how harsh the conditions are in the downstream region during the miners' evacuation.

4.2.4 Simulations in the Fire Vicinity

Thanks to the previous simulations, it is possible to know that the scenario 4 is the one that presents the worst results in terms of safety. Therefore, this is the one that should be selected to conduct the simulations.

The next step consists of setting up geometrical changes in the model. These changes are progressive reductions in the mine's cross-sectional area.

The comparison among all the areas studied allow to determine the most unfavourable case, as shown in *Figure 28* – *Figure 30*.

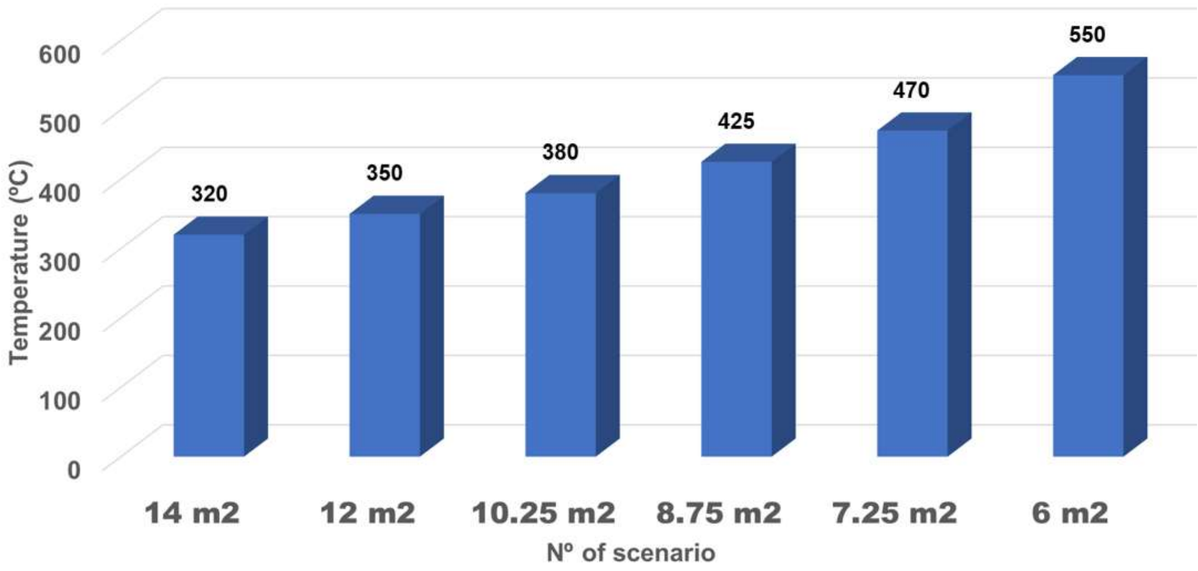

Figure 28 – Temperature Maximum in the Fire Source

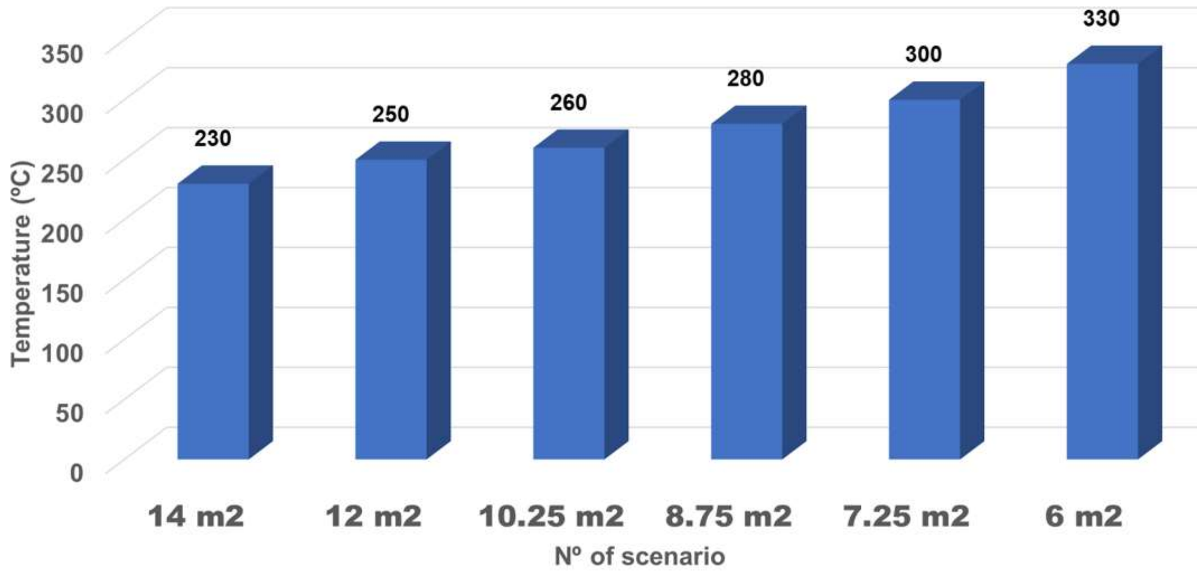

Figure 29 – Temperature Maximum in the Downstream Region

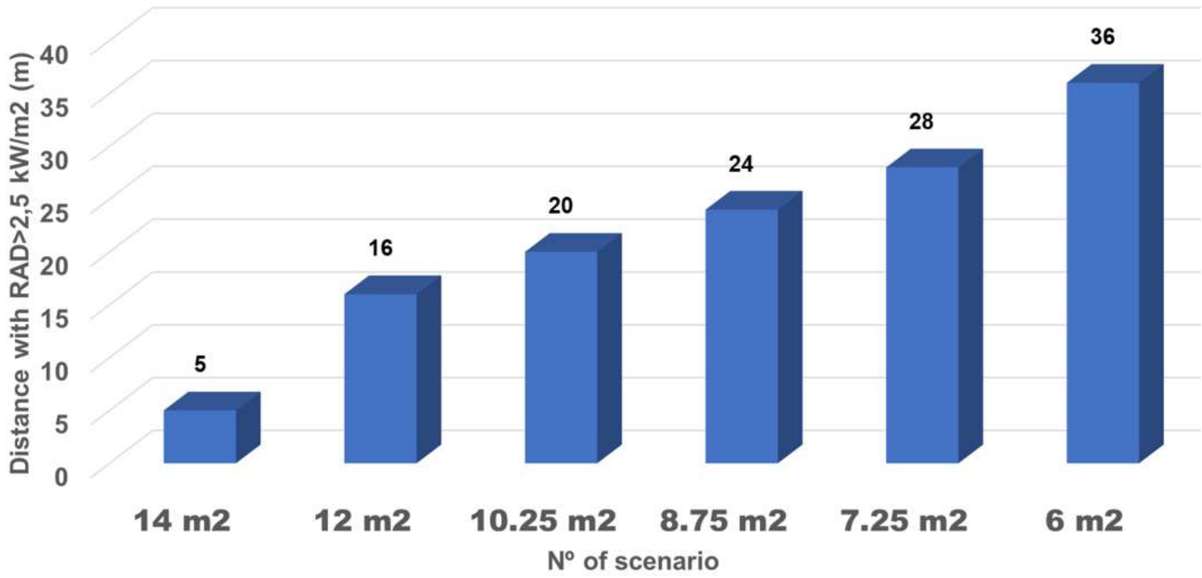

Figure 30 – Length of Regions with Radiation > 2.5 kW/m²

This analysis has allowed it to be determine which scenario is the most unfavourable and the cases where a fire service's intervention would be more complex because of the more spread radiation.

4.3 Evacuation Simulations

The first step of launching a wide variety of CFD fire simulations is already covered; this allows the most unfavourable case of fire in the mine to be selected.

The next step consists of launching several evacuation simulations, integrating the CFD simulations. This way, it is possible to take into account the smoke evolution and to assess in which measure the toxicity and visibility affect the miners during their process of evacuation.

4.3.1 Choice of the Scenarios to Analyze

For example, if we continue the study with the scenarios SC-2 and SC-4, we can have an evacuation analysis with two cases, as outlined in *Table 3*.

Scenario	Fire Location	Cross-sectional area	Ventilation Rate (m^3/min)
SC-2	Connection (Upstream Gallery – Coal Face)	14 m^2	Nominal ventilation rate Upstream Gallery: 1710 m^3/min Downstream Gallery: additional 520 m^3/min
SC-4	Connection (Upstream Gallery – Coal Face)	14 m^2	50% Nominal ventilation rate Upstream Gallery: 855 m^3/min Downstream Gallery: additional 260 m^3/min

Table 3 – Fire Scenarios to Continue with Evacuation Simulations

4.3.2 Creation of the Geometry

The geometry of each scenario exists in cad format but also it is available in FDS format, since it has already been launched in this program.

Therefore, the best is to get the same file that has been used in the FDS simulation and import it in the evacuation program Pathfinder, as shown in *Figure 31*.

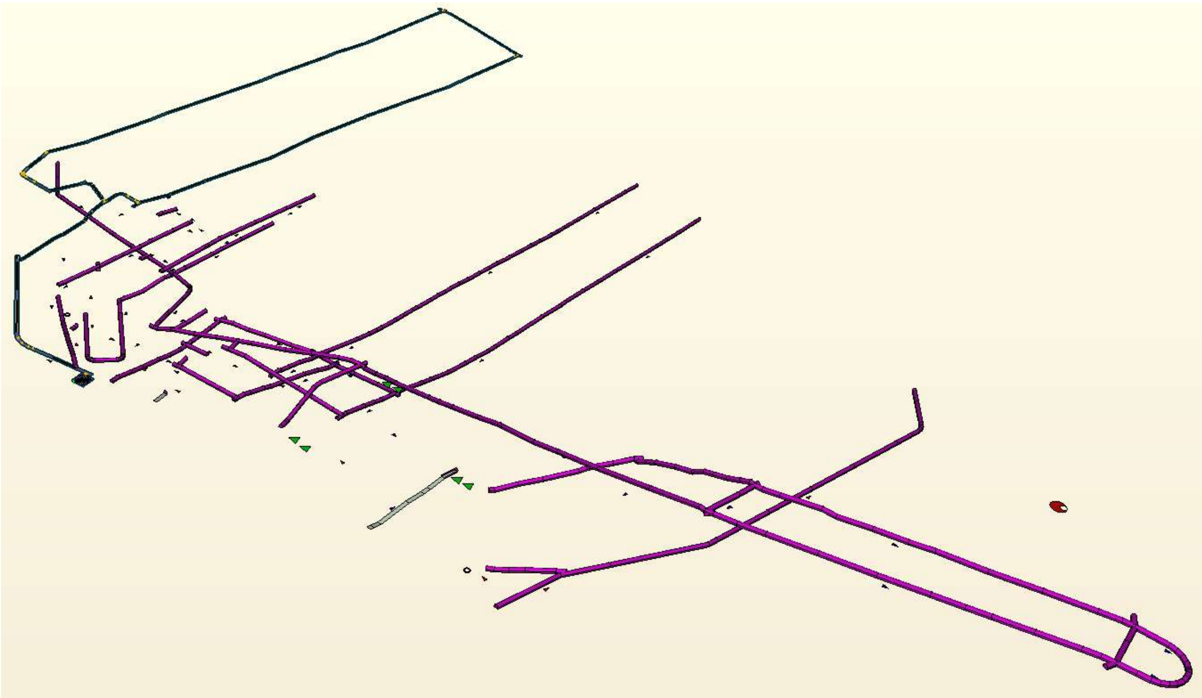

Figure 31 – Mine Geometry Integrated in Evacuation Software

4.3.3 Setup Escape Routes

When the geometry is integrated in the evacuation model, it is possible to define all which is related to the evacuation: the escape routes, the exit, the obstacles to avoid, etc.

It is necessary to define the routes that miners will take when a fire is declared, as shown in *Figure 32*.

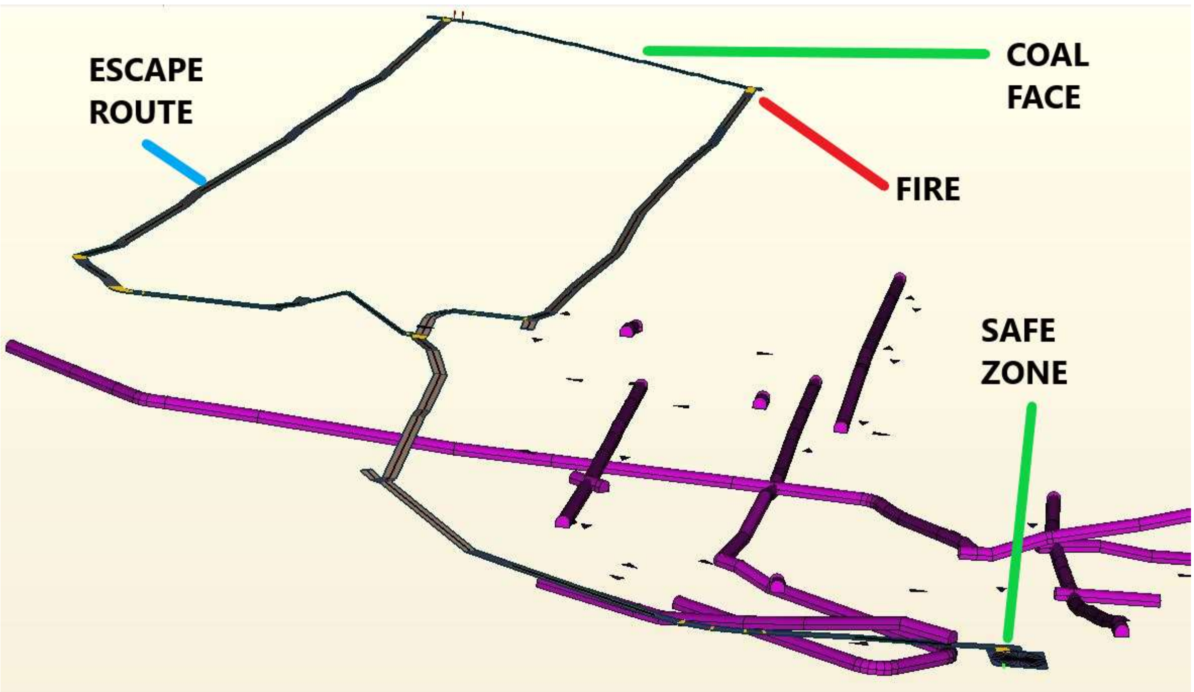

Figure 32 – Setup of Mine Geometry

Besides, in order to correctly model the miners' velocity, it is important to know where the obstacles are placed, something that can be done thanks to the photos of the inside of the mine, as shown in *Figure 33*.

Figure 33 – Obstacles in the Escape Route

This way, it is possible to represent some objects in the galleries, such as the conveyor belts or other devices. It is necessary to define both the escape routes and the intervention routes for the fire service, as explained in *Figure 34* and *Figure 35*.

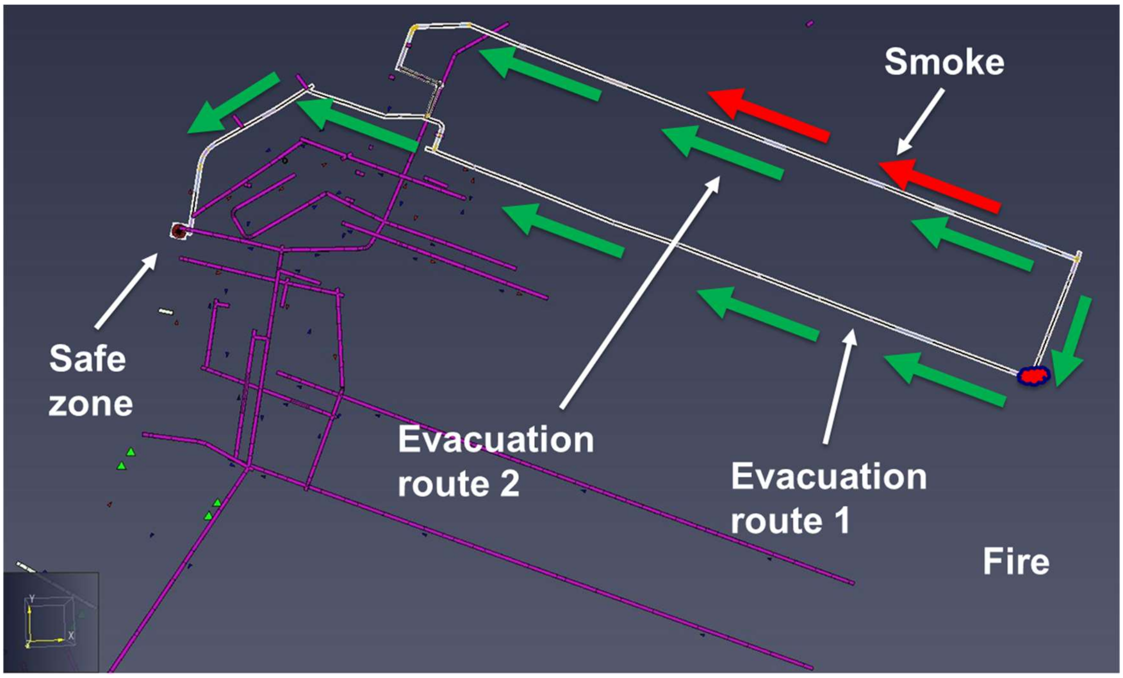

Figure 34 – Escape Routes in a Mine after the Fire is Declared

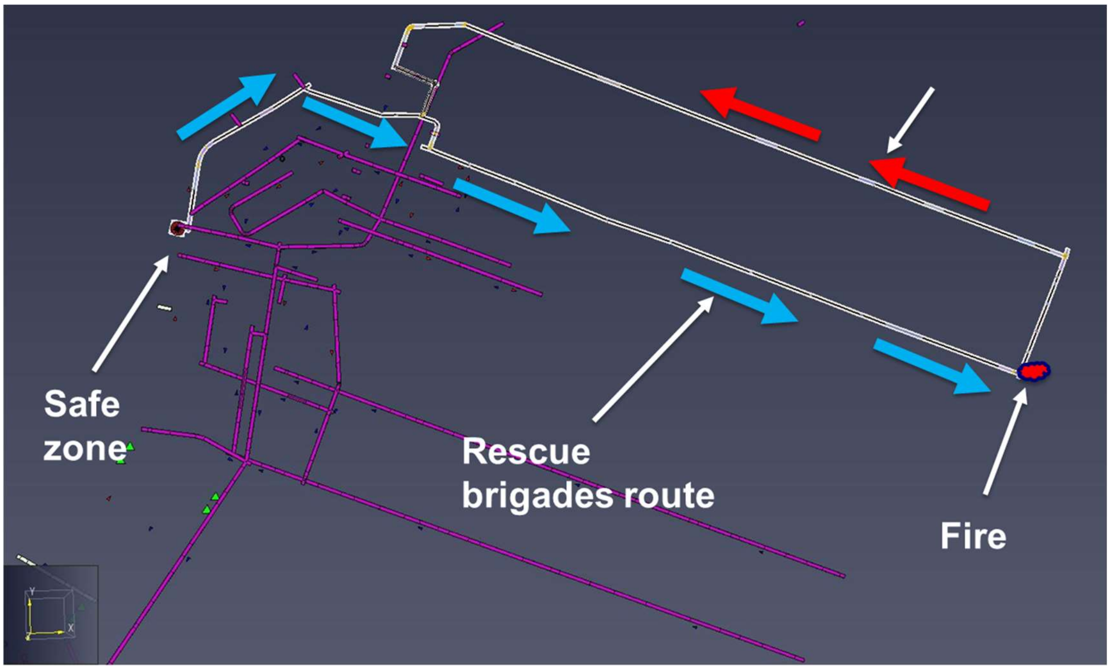

Figure 35 – Intervention Routes in a Mine after the Fire is Declared

Since there are miners at both sides of the fire (upstream and downstream), there are two escape routes, which can be appreciated in the previous figure. When the emergency services get to the mine, they try to get closer to the fire through the upstream gallery.

4.3.4 Definition of the Users

It is necessary to define all the features of the miners, as defined here:

- Physical features,
- Evacuation velocity,
- Pre-movement time,
- Interaction with other miners.

Besides, there is an aspect that is necessary for the evacuation simulations, which is the regions where the velocity is reduced because of the lack of visibility.

This can be obtained thanks to the CFD simulation, since it shows where the visibility attains levels lower that 10m, considered critical, according to NFPA 130.

Besides, it is necessary to define the moment upon which the first miner is aware of the occurrence of a fire. In the CFD simulation, it is possible to estimate when this happens, since some emergency devices are placed throughout the mine:

- Smoke detector,
- Temperature detector,
- Carbon monoxide detector.

Once this time is known, it can be specified in the evacuation model.

4.3.5 Integration of CFD Results

It is possible to import these results in the evacuation model, so that the evacuation process will calculate the effect of the smoke.

In the case of a coal mine, the miners carry SCSR units, which allow them to have fresh air to breathe during its autonomy, which is usually 30 minutes.

Therefore, the time upon which it is necessary to assess the impact of the smoke on miners is after the SCSR autonomy is finished. So, the first aspect to verify is whether the miners are able to get to a safe zone before the autonomy is over.

On the other hand, the effect of the temperature on miners is something that does not depend on the fact of whether the miners carry SCSR units or not and should be evaluated.

The integration of the CFD results allow to see at the same time the evolution of the fire (all the variables related to it) and the evacuation process, as it can be appreciated in *Figure 36 – Figure 41*.

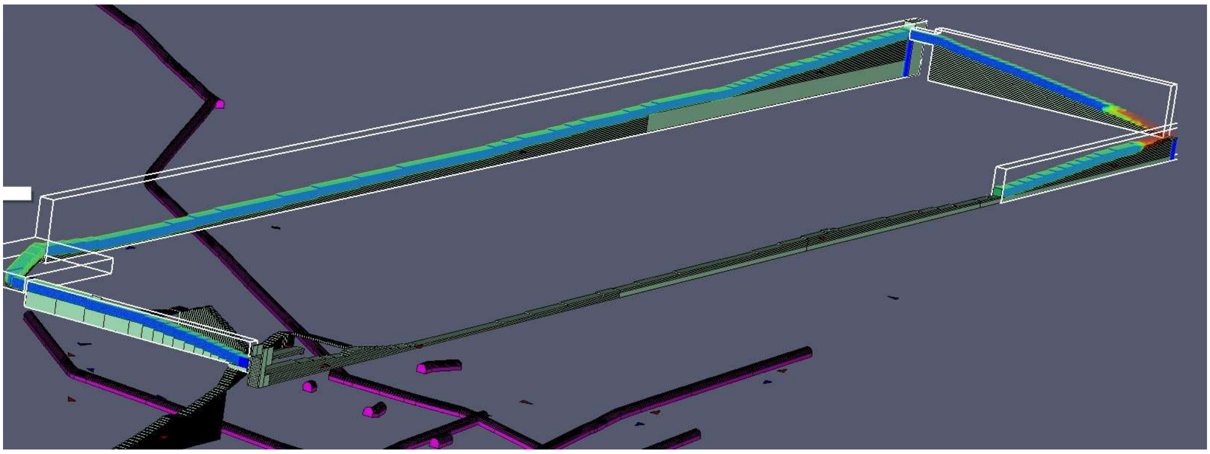

Figure 36 – Visibility Evolution in the Mine (t=60s)

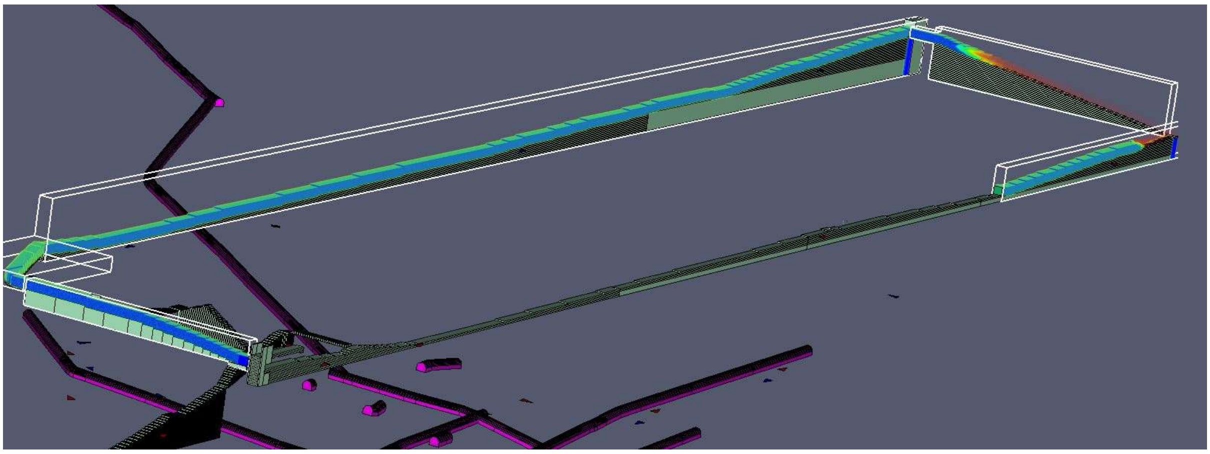

Figure 37 – Visibility Evolution in the Mine (t=120s)

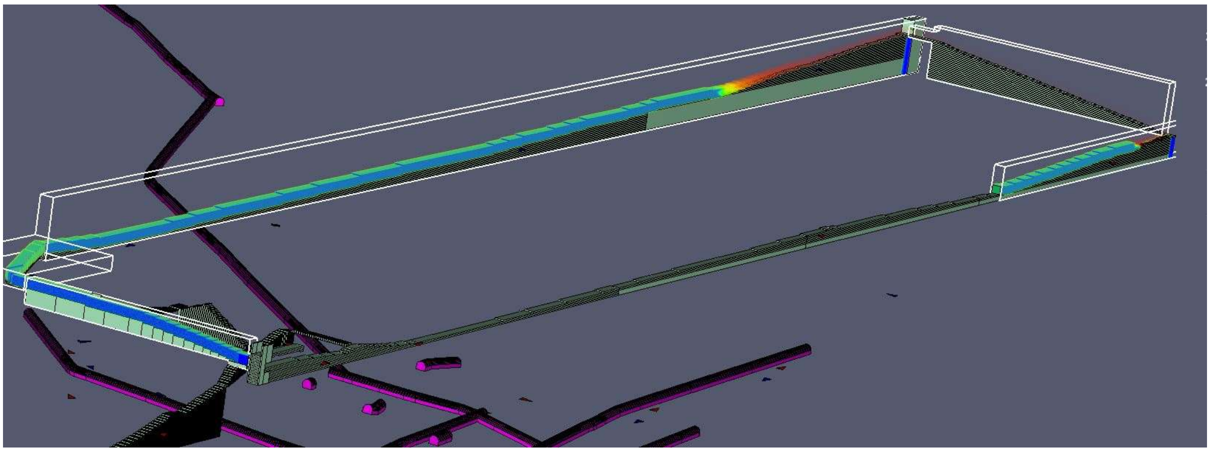

Figure 38 – Visibility Evolution in the Mine (t=240s)

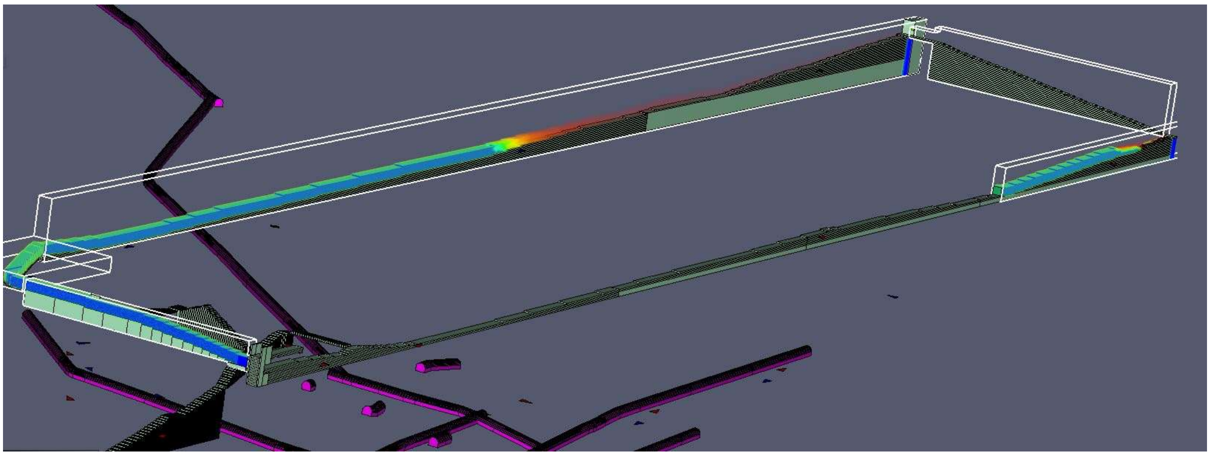

Figure 39 – Visibility Evolution in the Mine (t=360s)

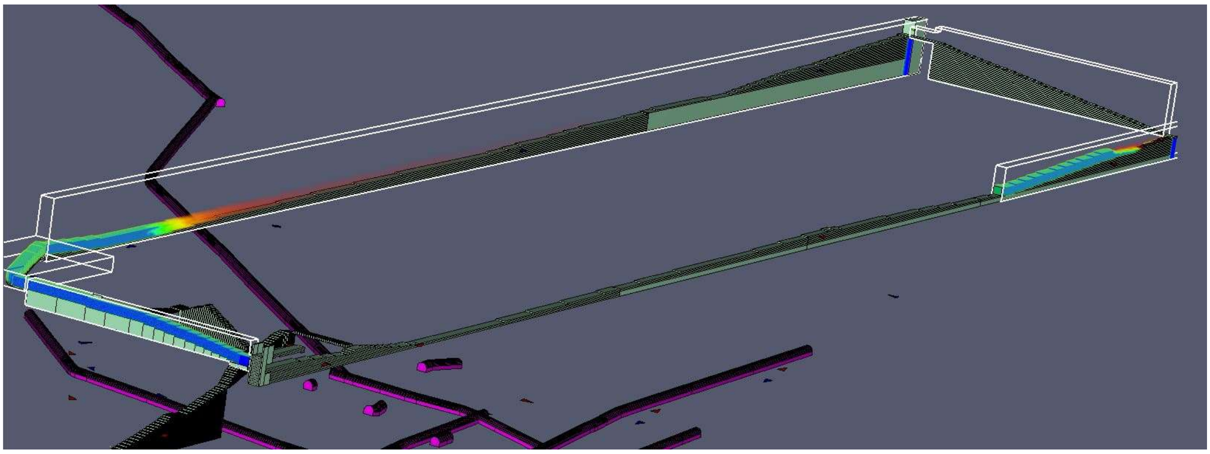

Figure 40 – Visibility Evolution in the Mine (t=540s)

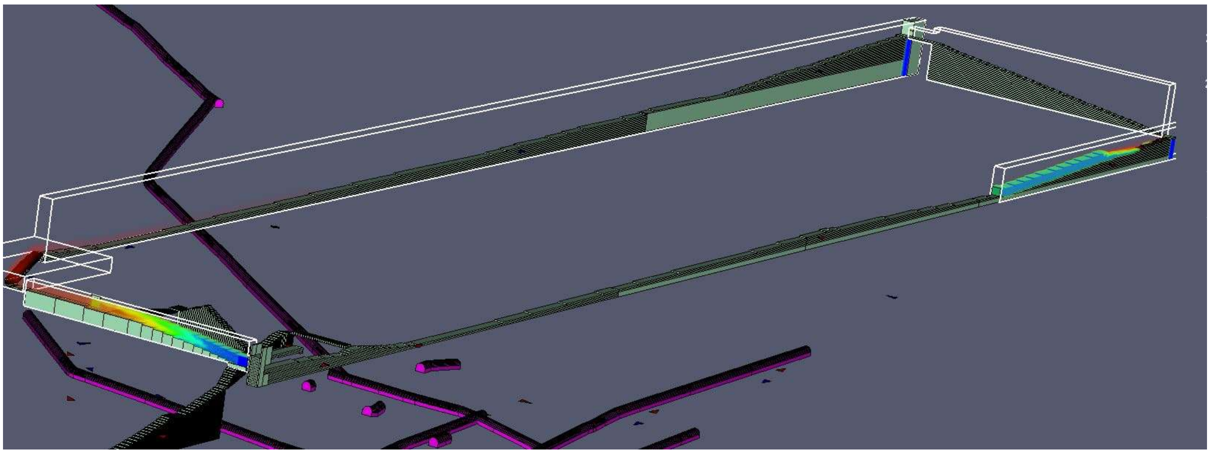

Figure 41 – Visibility Evolution in the Mine (t=690s)

4.3.6 Assessment on the Evacuation Results

As explained before, the assessment of the fire's effect on miners has to be done through two variables:

- CO concentration,
- Temperature.

The miners are not affected by the fire's toxicity while the SCSR is working, since it provides fresh air during its autonomy and they do not have to breathe smoke.

However, the temperature affects miners and should be evaluated, despite the fact that they carry SCSR units.

Besides the evacuation, it has to be analyzed the time required for the fire service to get to the place where the fire is located and verify if they can approach it with a registered level of radiation below 2,5 kW/m^2.

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5 FURTHER INFORMATION

Geocontrol has experience in the domain of evacuation simulations in coal mines and is always looking forward to collaborating in projects related to coal mines. Further information about evacuation simulations and studies carried out by Geocontrol can be solicited.

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