WP 7.1 Project Deliverable

Accurate definition of cases

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Authors	Eddy Verbesselt (LTF), René-Michel Faure (CETU), Klaus Schäfer (FDDo), Rainer Koch (FDDo), Gunther Lenz (SiTu) Editor: R.M. Faure
Contact Details	Institute for Structural Analysis / SiTu Research Univ. Prof. Dipl.-Ing. Dr. techn. Gernot Beer Lessingstrasse 25/II 8010 Graz / Austria Tel.: +43 316 8736180 Fax: +43 316 8736185 Email: gernot.beer@ifb.tu-graz.ac.at

Abstract	Description of cases for using the simulator
Keywords	Specification, Software, Simulation, Visualization

Contents

1 Introduction

The aim of this delivery is the presentation of the level of accuracy of cases that will run in the VIRTUALFIRES simulator.
Early when the project started, it appeared compulsory to the team that a good definition of cases for getting a common knowledge about tunnels has to be done. The world of tunnels, as an example of closed volume, is defined with its own vocabulary that all users must know, for a better communication. For more sophisticated projects, an ontology has to be used, but here for sharing a good knowledge about tunnel and for having friendly exchanges of ideas, an accurate definition of cases that will be simulated by the VIRTUALFIRES simulator, is sufficient.

About tunnels three steps of knowledge can be defined for running a simulator:

- The geometry of the tube, with all features added in it,
- The smoke control system,
- The management of the smoke control system and human intervention.

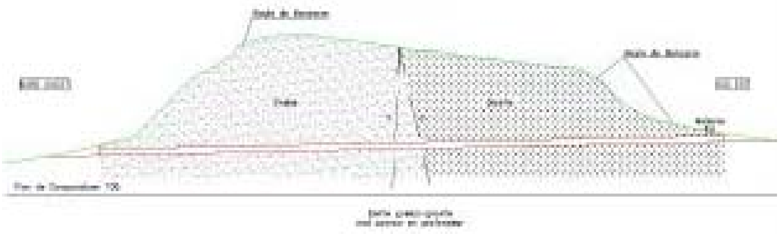
The geometry of existent tunnels was leaded by civil engineering aspects (geology, geotechnics, concrete,), but now for new tunnels safety aspects are more and more used for construction design.
The smoke control system and its management is clearly described in a PIARC document (in French and English language: Fire and smoke control in road tunnels) and this document was presented and discussed in the meeting of 8th and 9th January 2002, in Lyon. During this meeting, lot of explanations about tunnel was given and new French rules were presented.
The human intervention is generally defined through scenarios.

This delivery is beyond the proposed date, at a time when cases examples written in the first part of delivery WP 2.4, about the specifications of planned system capabilities, are near to be simulated.

2 Geometry

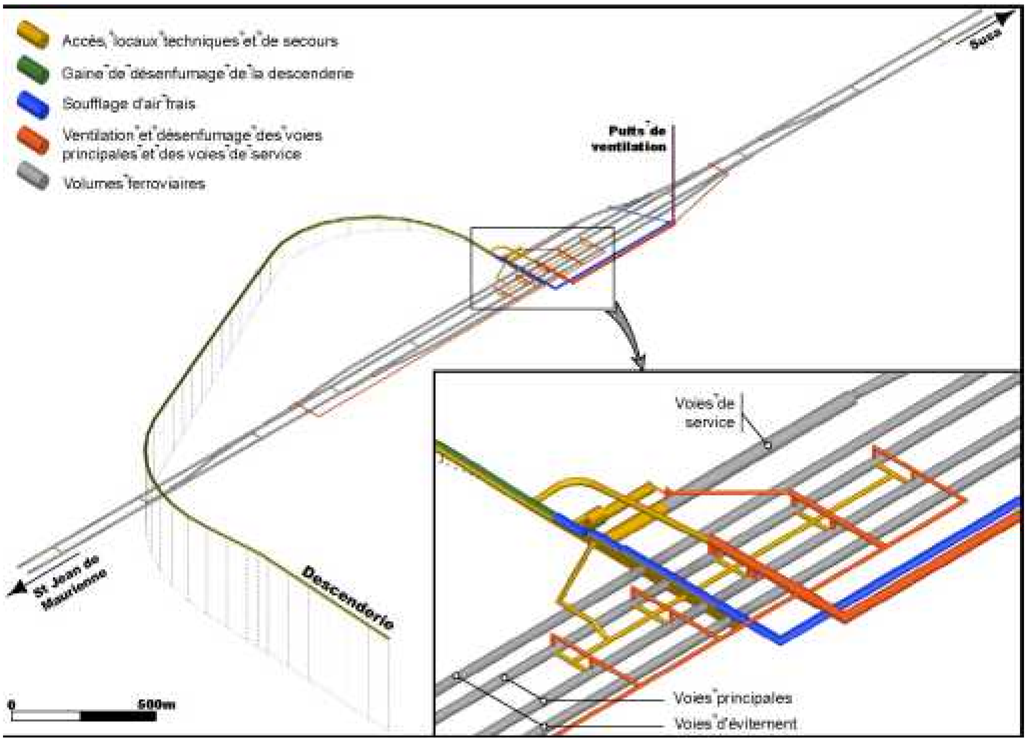
Usually sections and profiles define the geometry of a tunnel.

Profiles are generally simple for usual and old tunnels.



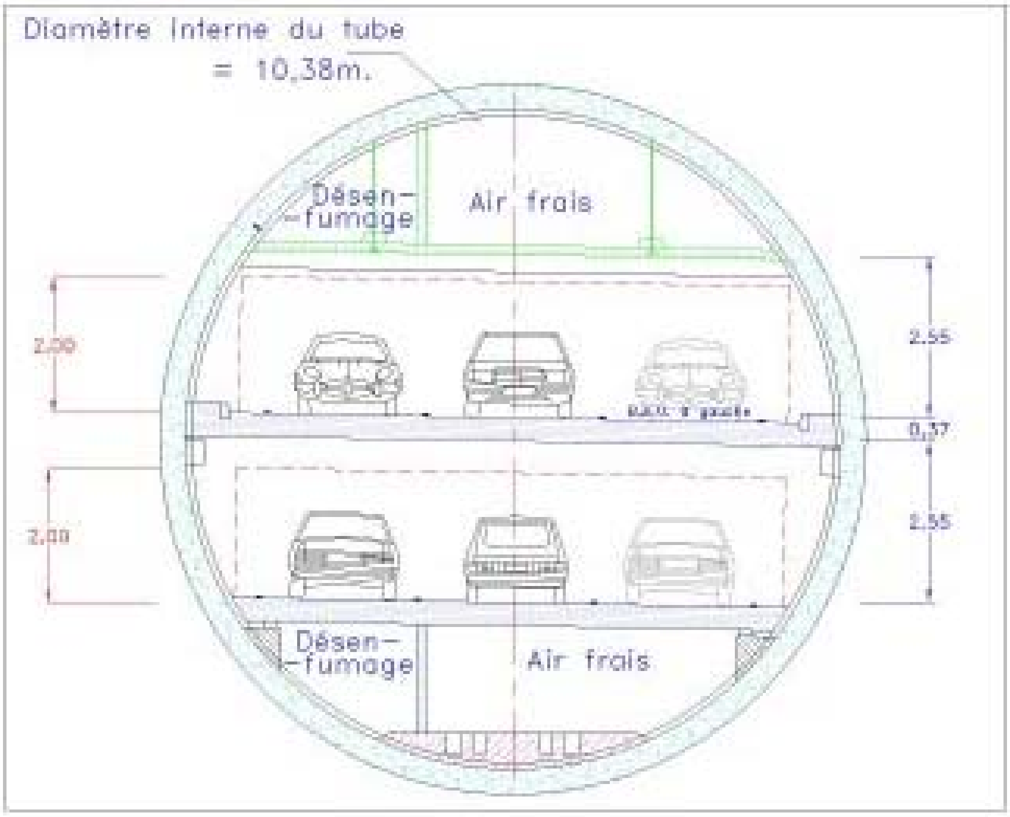
Usual profile of a tunnel

Profiles can also be very complex for metro networks and for example for the railway station, 300 meters beneath the town of Modane.

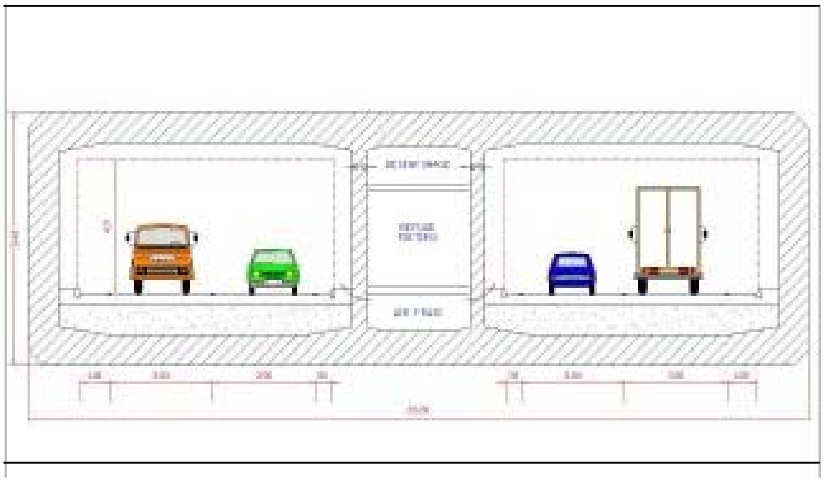


3D view of a more complex tunnel : the Modane station.

Sections of tunnel may be also quite complex as the air ducts, for fresh or exhaust air, are situated either in the upper part, either under the pavement level. The shape of these ducts is important and also the features that allow remote control of their aperture.

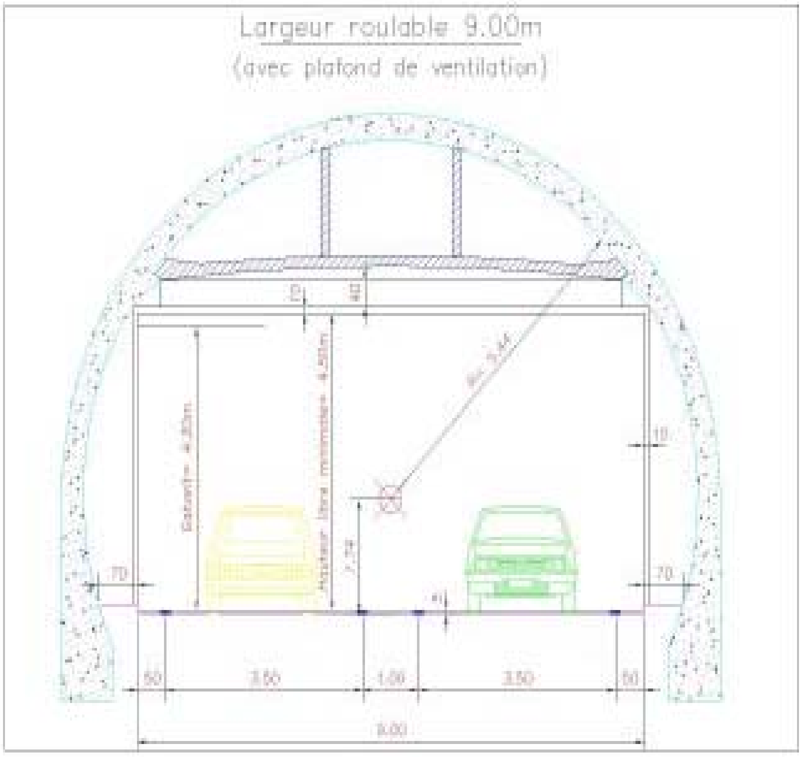


Section of a bored tunnel with two decks for cars

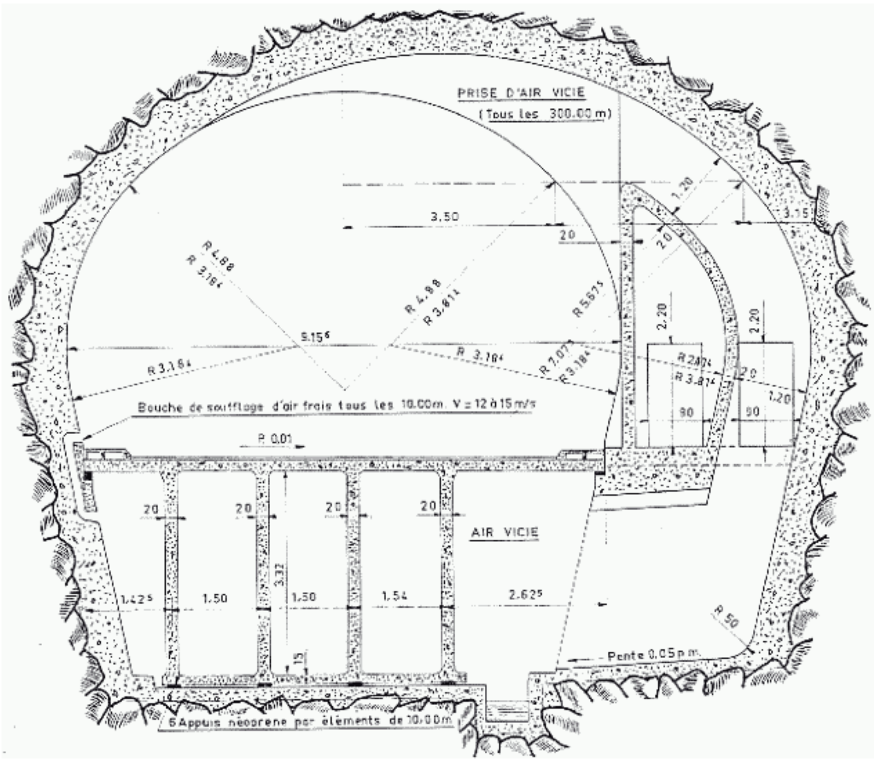


Section of an immersed tunnel

(See also a railway tunnel section in chapter 4)



Typical section for road tunnel



The Mont Blanc tunnel section with air ducts under the pavement

3 Smoke control system and ventilation.

In this chapter we deal with the ventilation systems that are used for pollution and in case of fire. Generally the installed power is designed for fire conditions that are more stronger, but it is difficult to determine accurately this power. The control of the design of ventilation system is one of the major aims of VIRTUALFIRES.

The ventilation system installed in a tunnel must provide acceptable air quality under normal operation. In the event of a fire, it must ensure safety for the public, as well as facilitate fire-fighting and emergency operations. Furthermore, the ventilation system must prevent the formation of an explosive mixture during a fire. Although an explosive mixture cannot occur in the seat of the fire, it can be produced farther away through incomplete combustion in the hot flue gases.

The possible ventilation systems are natural ventilation, longitudinal mechanical ventilation and transverse ventilation.

3.1 Natural ventilation

Natural ventilation can be obtained by two ways:

- Induced by the air temperature and meteorological conditions,

A tunnel may be sufficiently ventilated by wind, by a difference in air pressure between portals, and possibly by some convective or chimney effect. Natural ventilation of tunnels with portals at different elevations is basically a "chimney" effect and although it is generally not possible to arrange tunnel portals at different heights, there may be some situations in mountainous areas where the effect would be worth considering. When the difference of pression is high, in old tunnel where the installed power is low, it is impossible to reverse the airflow, and safety conditions become very poor.

- Induced by traffic

Underground railways are ventilated mainly by the "piston" action of the trains entraining the air along the tunnel. The "piston effect" can ventilate one-way road tunnels although the induced air velocity is less with road vehicles that do not fit the tunnel cross-section as closely as trains. However, as the tunnel diameter increases, the gain of air volume is marginally greater than the reduction of the induced air speed; consequently the dilution of pollutants slightly increases with tunnel size.
Even when the traffic-induced ventilation is adequate for the dilution of pollutants in normal traffic conditions, fans are often provided to cater for idling and slowly moving traffic and for adverse wind conditions.
Large portions of road tunnels in the world rely on wind and traffic for ventilation. Generally, they are not more than several hundreds meters long except for very low traffics. Traffic-ventilated tunnels longer than 500 m carry, generally, one-way traffic.
Ventilation of this type is common in mountainous areas. If this situation may be fit for the dilution criterion, it is often not safe enough to fit the smoke control criterion (especially for the longest tunnels).

3.2 Longitudinal mechanical ventilation system.

Longitudinal ventilation is an easy and cheap way to ventilate road tunnels. and in several countries it is the only actual way. Longitudinal ventilation means that the ventilation system creates a uniform longitudinal flow of air all along the tunnel.

In such a system, the air enters the tunnel from the portal, practically clean, and gets gradually polluted with substances emitted by vehicles, thus reaching the tunnel exit with a higher percentage of pollution. This system is relatively cheap and easy to install and is particularly suitable for tunnels carrying one-way traffic, where the "piston effect" assists the airflow.

From the point of view of the dilution criterion, the ventilation is considered satisfactory when the system is able to keep the concentration of pollutants in the tunnel air below certain thresholds, which are obviously under the noxious levels for people who travel throughout the tunnel or who are forced to be stationary within for a while.

A ventilation system designed only according to the above-exposed dilution criterion, could be satisfactory also from the smoke control point of view, but is often not; thus the project has to be verified to take into account the smoke control criteria.

In tunnels with longitudinal ventilation, the concentration of noxious substances increases in the direction of the airflow and decreases with the fresh air rate. The maximum concentration increases according to the tunnel length. In any cases, the production of pollutants varies with the traffic volume, its velocity, the roadway gradient and the tunnel altitude. Therefore, If we compute the required airflow for the ventilation of two tunnels with the same (flowing) traffic, we would find the greater flow rate for the longer one and for the tunnel with the greater upward slope.

The longitudinal airflow velocity has a practical upper limit; consequently, for a given traffic and slope of the roadway, the tunnel length for which longitudinal ventilation is possible has a maximum limit too. As a first estimate, this upper limit could be evaluated knowing the cross-sectional area of the tunnel and the maximum air velocity {today considered to be about 8 to 10 m/s) which is cost effective and does not disturb vehicles and the staff operating within the tunnel. Moreover, the mechanical power of the ventilation system increases, in fact, with the third power of the tunnel length in tunnels used bi-directionally. For tunnels that require an overall airflow over the aforementioned threshold, the longitudinal ventilation is still possible, but has to be supplemented with shafts for massive exchange of exhaust with fresh air.

Longitudinal ventilation is generally performed by axial-flow fans called "jet fans" or "boosters" distributed along the tunnel and outside the traffic gauge. The size and distribution of the jet fans along the tunnel have practically no effect on the overall tunnel air velocity provided that a few technical rules are observed. Sometimes also the longitudinal ventilation by injection is used, where the Saccardo effect is the way of transmission of the thrust.

The cheapest criterion for the installation is the concentration of fans near the portals. In this way the length of cables is the shortest possible. From the aerodynamics point of view, if the fans are too close to the exit their efficiency is reduced. Consequently the first and last sets of fans are usually installed at least 80-100 m within the tunnel.

3.3 Definitions concerning other mechanical ventilation systems.

In mechanical ventilation systems other than longitudinal, the ventilation air is supplied and/or extracted through purpose built ducts. Such systems are hereinafter classified through the percentage of fresh air that is supplied and the percentage of exhaust air that is evacuated through additional ducts (being the remaining part supplied/evacuated through the tunnel portals).

- Fully transverse system

In fully transverse ventilation systems there is one or more fresh air ducts that lay parallel to the traffic tube. The fresh air is supplied through louvers distributed all along the tunnel; the exhaust air is removed in the same way from the opposite side of the tunnel by using one or more exhaust ducts. In this system, the amount of exhausted air per meter of tunnel length equals the amount of supplied air. In-some cases of cut-and-covers, there are no ducts: the fresh air is injected directly from outside through small fans, and the exhaust air is discharged in the same way directly to the outside. The two air streams (injected fresh air and extracted exhaust air) create a flow in the main tube, the direction of which is transverse to the longitudinal axis of the tunnel.

Such flow is perturbed by other factors (differences in wind pressure on tunnel openings, atmospheric pressure differences, traffic, fire in the tunnel, etc.) that create a longitudinal airflow. This means that, in practice, a flow that is purely transverse to the longitudinal axis of the tunnel will hardly ever occur. A second aspect which attracts the attention is that the longitudinal airflow is difficult to control even if the transverse ventilation system has a large capacity because there are no compensating forces present in the longitudinal direction The most usual way to get some control on this longitudinal airflow is to create successive independent ventilation sections in which fresh air injection and/or exhaust air extraction can be operated separately.
The concentration of pollution in the air is constant all over the tunnel (if there is no longitudinal airflow). This system is therefore suitable for application in long tunnels. In principle there is no limit to the tunnel length as far as the pollution removal is concerned; but of course technical and economic restrictions apply.

The ventilating air is generally supplied and extracted through purpose built air ducts. The total volume of ventilating air required is considerable, especially in long tunnels. As a result the ducts are large and therefore expensive. The air velocity in the ducts determines the required capacity of the fans to a significant extent. In long tunnels the ducts system is therefore longitudinally divided into sections and the air is supplied at various places in order to restrict the air speed in the various sections. Speeds of 15 to 25 m/s in the air ducts under full load conditions are usual. As already mentioned, creating several independent ventilation sections also provide a means to have some control on the longitudinal airflow. The fans are usually installed near the tunnel portals in order to be easy to reach, or in underground plants.

In case of a fire, the exhaust air duct in the fire area is turned on to full exhaust and the neighboring ventilation sections are controlled in such a way that a longitudinal air velocity in the fire zone can move the smoke in a suitable way. However, experience shows that, in short tunnels and under the influence of the wind and chimney effect of the hot smoke, it is not easy to control the air direction and speed in the fire zone.

- Semi-transverse system (and reversible semi-transverse system.

In a semi-transverse ventilation system, outside air is added equally along the tunnel, generally out of an air supply duct, but there is no air extraction: the fresh air is supplied transversely to the direction of the longitudinal axis of the tunnel while the polluted air flows longitudinally to the two portals.
In reversible semi-transverse ventilation, it is possible to reverse the airflow direction in the ducts: the fresh air then flows into the tunnel from the portals (therefore with a direction parallel to the longitudinal axis) while the exhaust flow is extracted through louvers and the reversible air ducts. So this extraction induces a longitudinal airflow along the tunnel that comes from the two portals or neighboring ventilation sections still running on air supply. This operational mode is generally reserved to the event of fire within the tunnel. Another possibility to deal with fires is to have a separate smoke extraction duct, which is used only in case of fire.
Just as in transverse ventilation, in semi-transverse ventilation external factors can create a longitudinal airflow that is difficult to control.

- Partial (pseudo) transverse system

Partial transverse (also called pseudo-transverse) ventilation systems are intermediate between transverse and semi-transverse systems and have therefore intermediate characteristics that can be more similar to the first or the second one depending on what percentage of the ventilation flow is injected or extracted.
In any case the engineering works are similar to the transverse system, being necessary to deal with both fresh and exhaust air (though in partial transverse systems, fresh and exhaust ducts are usually not balanced). It is also possible to add jet fans to the tunnel in order to create and maintain the desired longitudinal airflow, especially for the case of fire.

The ventilation system of a tunnel may be very complex, and the new coming rules for safety in tunnel will ask for more performances. The use of the VIRTUALFIRES simulator will be obvious for tunnel designers and managers.

4 Scenarios

The main way for checking the safety level of a tunnel is the answer of the system to a given scenario. We present there some basic scenario.

4.1 Railway scenario

Three main scenarios are carefully studied when a train runs into a tunnel.

4.1.1 Controlled stop in an underground station with emergency facilities

In this scenario the driver is informed of a fire on board, and he suppose that he can reach an underground station with facilities for fighting again fires. This kind of station is for example the station of Modane, deep in the ground. This scenario is one of the safer as lot of emergency features are concentrated in the station. Firemen that are in the station, can fight directly the fire, and the simulator will be an effective help for a good knowledge of the fire fighting environement, and the best use of it.

4.1.2 Uncontrolled stop somewhere in the tunnel

In this scenario an emergency stop is done and the train stops in the tunnel. The main mean of fight is the use of the ventilation system, and the role of the driver is important giving information to the ventilation controller who decides the use of the system. Following this information, the simulator can help in the choice of a good use of ventilation.

4.1.3 Interaction of the end user with the simulator

In all scenarios the interaction of people on board, in the control room and firemen is very important and a good co-ordination is the key for mitigating the fire and its effects. We detail here each role showing the different possibilies of use of the simulator that will be able to simulate and show the result of all decision.

There are 3 kinds of end users: the on board staff, control centre staff and fire brigade.

On board staff:

These people will have to organise the evacuation of the passengers from the train into the other tunnel.

The interactions with other actors are:
-inform the “smoke controller” via radio about the location of the fire on the train

-start the evacuation of passengers to the safe side of the train (when situation is safe: smoke disappears,…) For this the on board staff must know the incidence of any decision that he can take, and the role of a simulator is obvious.

Control centre staff

The operator in charge of the "smoke management" will have instant feedback on his actions to be sure that he is working on the right way. Training with the help of the simulator will be a good preparation in case of incident.

The interactions with other actors are:
Following the fire detection, the location of the fire will be displayed immediately on the surveillance screen, so he can broadcast this information.

-radio connection with the train staff (train driver). He will inform the control centre about the location of the fire (on the front or rear end or in the middle)
-according this information, activation of the longitudinal ventilation in one or the other direction to enable the evacuation.
-as a direct result of his action he will see on the screen that the relevant cross passage door (emergency door which leads to the safe tunnel) becomes visible for the train crew.
-opening and closure of the relevant cross passage door.

Fire Brigade

The interactions with other actors are:
-radio connection to the control centre to reverse or to stop the ventilation,
and the job they have to do can be summarized by:
-walking (with oxygen masks) in a very smoky environment without any visibility
-extinguishing of the fire with the water hoses
-activation of water curtain

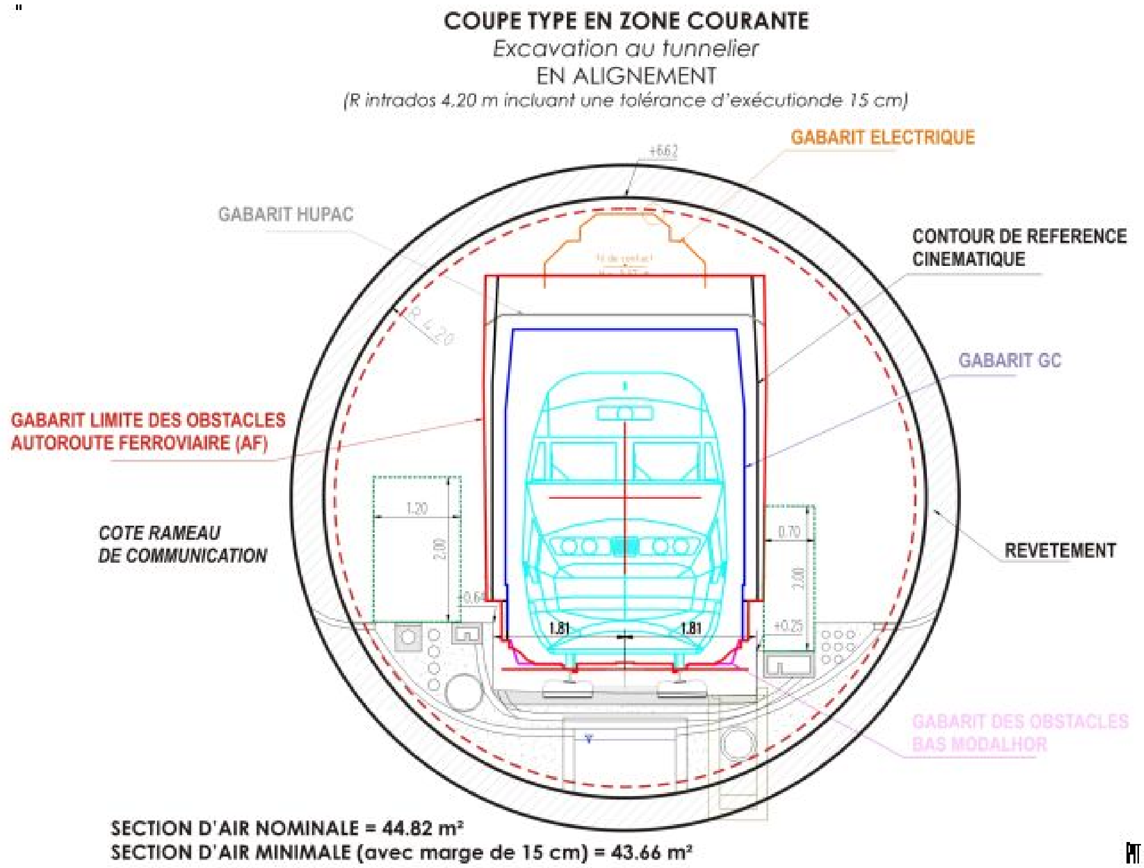
Following this description, it is clear that for train crew staff and fire fighters the CAVE version (also the HMD) of the simulator is the one with the most added values. Although that it not completely replaces the practical training it is to be considered as a good additional training method. The PC screen version is useful for theoretical training.
For the control centre staff the PC screen version is the best-adapted version for their training exercises (emergency procedure training).

4.1.4 A detailed railway scenario with data

For example, in the major tunnel of Lyon-Turin link the two following scenarios have been defined.
-firstly, a train that comes to a controlled stop in one of the safety- or intervention stations in the tunnel (Modane, St Martin, La Praz, Venaus). The concept of these stations is such that passengers (either from a high speed train or a freight train) are quickly evacuated in a safe area. From there, an evacuation train can evacuate them outside the tunnel.

Fumes will not be on the platform because extraction of fumes is done by very powerful equipment (400m3/s) and temperature will be controlled by a water curtain (brumisation). The simulator can check if the access to the fire for fire fighters is well designed to facilitate the tackling of the fire.
In spite of having a real fire, the situation will not reflect the same inconvenient for staff and emergency services, as it would have been the case for the same event somewhere else in the tunnel.

-Effectively, the other major category of major events is the case of a train that comes to an uncontrolled stop somewhere in the tunnel (=that there is no special emergency facilities as there is in the underground safety stations!).
It is of most importance that staff (on the ground but also in the control centre) is correctly trained on the evacuation procedures.
The "Virtual Fires Simulator" could play an essential role in order to reach this objective. Train crew and fireman could gain a lot from this 3D real time training facility.



In order to make the training as realistic as possible, the following assumptions should be used as input data for the VF simulator that would check the feasibility of the escape procedures:

Rolling stock:
-Train in conformity with the "High Speed" TSI's
-length:400m

-capacity: max 1000 passengers (double deck stock)
-fire dampers (=air conditioning fans closed when requested)
-fire dimension (max 15 MW : curve power - time)

Ventilation:

-longitudinal, reversible and the max velocity (6m/s) is activated, to the front of the train, 1'38"after that the train has stopped and is working at full regime 2'38"after the train had stopped

-4'00" is the time it takes to the ventilation system to have a tunnel environment acceptable to start the evacuation (the air is to be considered as acceptable from the moment that the ventilation has reached a velocity of 4 m/s)

-31'00" is the time to clear the rear of the train from all fumes (between the time that the fire alarm is given and the moment that this comes to a stop, fumes have filled the tunnel in the rear stream of the incident train)

There are cross passage (rameau de communication) doors every 400m that allow passengers to reach the other (safe) tunnel in case of danger (fire).

Evacuation:

It takes about 30 minutes to have all passengers evacuated in the safe tunnel.
Some details: - 1 passengers leaves the train every 2 seconds, the walking speed in the tunnel is between 0,5 and 1 m/s)

That is an example of scenario, and the use of the simulator gives the possibilities of lot of neighboor scenarios, when only one parameter changes.

4.2 A road scenario

For second example we can take a fire scenario following the French guide for specific study of danger in road tunnel.

This typical scenario is based on some assumptions that are:
-Traffic is dense (estimated at 4000 cars/h)
-The distance from the portal defines the position in the tunnel by “metric point” (pm)
-At the time t=0 an accident occurs at pm 362. 171 seconds later another accident occurs at pm 789: a lorry bumps into a queue of cars stopped by the first accident and the truck takes fire with important smoke emission.
-The burning power of this lorry is 100MW with a standard development and emission curves.
-No new vehicles are allowed in the tunnel 2 minutes after the beginning of the fire
-Passengers cans escape either via the two portals (pm0 and pm 1073) or the escape routes situated at pm (237,437, 701 and 891).
-Passengers will leave their car only 90 seconds after that the smoke has reached (surrounded) their vehicle; their walking speed is directly depended to the smoke density.
-Ventilation management: as passengers are blocked between the two accidents and in order to safeguard the “living conditions”, the strategy of ventilation management allows the back-layering.
-At t=0, the air velocity is evaluated at 3m/s due to the piston effect of the traffic.
-At t=240 s, downstream the visibility is reduced due to the presence of the smoke. Upstream there is almost no smoke present

-At t= 291s (2 minutes after the beginning of the fire) the ventilation is running at full capacity; a great part of the downstream tunnel is filled with smoke mostly situated at the ceiling of the tunnel (back-layering effect); after that more and more smoke is extracted out of the tunnel by the ventilation system and the presence of smoke is quite symmetric around the fire spot; the quantity of smoke produced by the fire of 100 MW is so important that all the smoke cannot be extracted; as time passes by, back-layering vanishes and at t=570 s, some smoke escapes by the north portal.

As to determine the danger caused by the smoke and toxic gas we have to know, at each time, the position of the passengers during their evacuation:
-During the first 171 s, we suppose that the tube, between pm 362 and pm 789, filled up with cars, and after the beginning of the fire, cars are stopping (one after the other) at pm 789 in rear of the fire. Downstream the first incident, cars carry on their journey out of the tunnel. A visual representation of passengers trapped between the initial accident and the spot of the fire caused by the second accident, and passengers stopped by the fire, can be produced. So for each of them, we can obtain the time when smoke reach them. It is supposed that they move, 90 s after this delay and they go, at a mean speed depending of toxicity and smoke density, to the nearest escape lane, the capacity of escape is limited, that give a new delay for escape. In this example, at pm 470, passengers are in a danger zone, level 3, between t=300 and t=870, time when the last passenger escape. For passengers upstream the fire spot, although the path escape is longer, they never stay in a danger zone as there is no smoke.

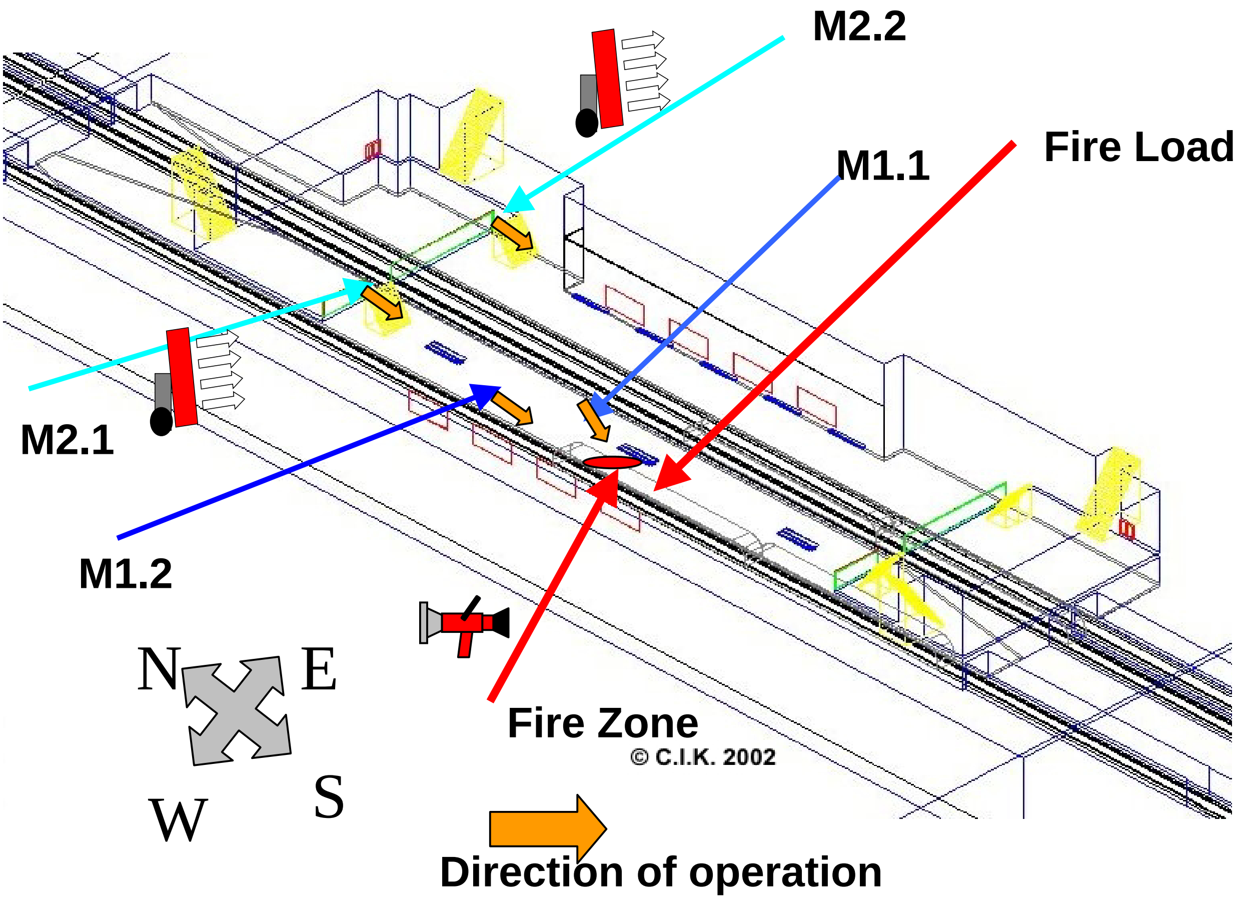
The evaluation of risk for passengers may be done in terms of casualties and injures. Statistic analyses give us the lifetime of a man in the different danger zone and we can set the following table:

	Number of passengers	Casualties	Injures
Users down stream of the spot fire	178	0 to 1	5 to 10
Users up stream of the spot fire	240	0	5 to 10

In this example some calculations are done for determining the progress of the smoke and toxic gas. The use of the projected Virtualfires system is obvious for a quicker answer and high possibilities of changes in assumptions and men actions. The Virtualfires system will have a friendly user interface as to act quickly on the scenario, giving the capacity of visualisation of the effects of the changes.

4.3 Subway station scenario

Subway stations are more complex than a subway network due to the numerous interactions with the ground surface and links for the users transfer.
The following figure supports a simple scenario in a subway station.



Definition of a subway station with firemen intervention features

This scenario is defined outside and inside, by the temperature, the wind velocity and the wind direction. The action of firemen is defined by the accurate location and direction of the fire fighting systems used (on the figure two nozzles and two turbo-ventilators), the exact time when they are used. Each system is given with its own performances that are stored in a database. The fire load is also well described.
In this case, as the scenario defines also the use of fire figthing system, the VIRTUALFIRE simulator will show the efficiency of the fire attack, that is the repartition of gaz temperature showing if the escape routes are safe or not. Other informations as lethal zone (toxic gaz) are also given.

For this specific scenario the following conditions and actions are suggested for evaluation purposes:

Environmental Conditions

On the surface (outside the station)	
Temperature	25° C
Wind velocity	2 m/s
Wind direction	west
Time	Daylight
Inside the station (at connection of tunnels)	
Temperature	15° C
Wind velocity	1 m/s
Wind direction	south
Light	artificial

Fire load: Subway Train GT8:

Length	2* 29 m
Height	3,3 m
Width	2,4 m
Location	as placed in geometry
Fire Load	15 MW
Colour of smoke	dark grey
Type of temperature/time-Function	s. Ref. /1/

Time line

Timestep	Time	Event/Action	Description	Remarks
t 0	0 min.	Ignition		
t 1	15 min.	M1.1	C-Nozzle 1 on platform activated	s. D1
t 2	20 min.	M1.2	C-Nozzle 2 on platform activated	s. D1
t 3	25 min.	M2.1	Turbo-ventilator 1 on mezzanine activated	s. D2
t 4	27 min.	M2.2	Turbo-ventilator 2 on mezzanine activated	s. D2

Description of Actions

Mission	Location	Operation direction	Operation parameters
M1.1	on platform 4 m beside the train	towards the train	Spray option: 220 l/min., 60 deg.
M1.2	on platform 8 m in front of the train	towards the train	Direct access: 150 l/min., 6 deg.
M2.1	on mezzanine at western stairs	towards the platform	600 m3/min., 75 deg.
M2.2	on mezzanine at eastern stairs	towards the platform	600 m3/min., 75 deg.

5 User interaction

This section describes the interaction of the user with the simulator. It is split into 2 parts, one describing the setup of a new simulation and the other one the interaction possibilities when running the simulator with the userinterface in the VR environment. If not mentioned explicitly the description applies to all types of the described scenarios, i.e. a railway-, road- or subwayscenario.

5.1 Setup

The process of setting up a new simulation is done outside the VR environment using an administration tool.

5.1.1 Creating a new simulation scenario

Setting up a new simulation requires initial data, that has to be provided by external partners:

- the VR models
  these models are used for the representation of the objects in the vr scene, e.g. the tunnel shell, signs, cars, trains, lights, fans.
  These models contain the geometry and textures and must be provided in a file format used by the VR environment.
- the initial cfd domain files
  these are the files, that are required to compute the cfd calculation for the given scene.

The user creates a new simulation scenario entry, e.g. "Subwaystation". He then uploads the data files for the VR models and the initial CFD files to the databse server and specifies the required parameters for the simulation. Alternatively if stored items can be reused, the user selects them and attaches them to the new scenario.

5.1.2 Changing a simulation scenario

The user is able to add and remove objects from a scenario. This step requires the upload of an updated cfd-domain and yields to a loss of all computed data for this scenario.

5.1.3 Delete an existing simulation scenario

The user selects a scenario for removal from the simulator database and confirms the deletion process. This yields to the deletion of all data associated with this scenario.

5.2 Driving the simulator in the VR environment

5.2.1 Selecting a scenario for the simulation

The user selects an item from the list of available scenarios. The simulator loads the scene into the VR environment and displays it.
If there are already missions defined for that scenario, the user can select an item from the list of available missions.

5.2.2 Mission handling

A mission is made up of a list of events that happen at specific points in time during a simulation. It is the basis for a simulation run.

5.2.2.1 Creating a mission

The user can create a new mission by defining its duration and timely resolution and giving it a name. The newly created mission contains no initial events nor any result data.

5.2.2.2 Selecting a mission

The user selects an item from the list of available missions and confirms the selection. If there exists already calculated CFD data, the data for time t=0 is loaded.

5.2.2.3 Deleting a mission

The user selects an item from the list of available missions and confirms the deletion. All data associated with this mission is deleted.

5.2.3 Event handling

Changing the state of a simulation object is done by defining events. They describe the new state of an object at a given point in time, e.g. "Fan 1:on at 430s".
Before the user is able to manipulate the events, he has to select a mission.

5.2.3.1 Adding events to a mission

The user adds a new event to a mission by selecting one of the available objects and then enters or selects new values for its state and defines the point in time where the event occurs. All results past the event are purged.

5.2.3.2 Editing an event

The user selects an event from the list of defined events and edits the parameters for the state. After confirmation of the changes all results past this event are purged.

5.2.3.3 Deleting an event

The user selects an event from the list of defined events and confirms the deletion. All results past this event are purged.

5.2.4 Navigation

5.2.4.1 Navigation in 3D space

The user is able to navigate through the whole scene at any time using the wand inside the CAVE or the spacemouse on the PC based installation.

5.2.4.2 Navigation in time

Using a VCR-like interface the user is able to change the position on the timeline of the displayed simulation data. The interface supports the follwing buttons:

- *Play*: start the playback of the data in realtime, i.e. 1s wallclocktime corresponds to 1s simulation time. The playback stops at the time of the last CFD result. If new results become available the playback continues automatically.
- *Pause*: the playback stops at the current time. Pressing "Play" continues playback from the this point in time.
- *Stop*: the playback is stopped and the current time position is set to 0s. Pressing "Play" will then playback from time t=0s.

- *Fast Forward*: The playback of the data is played back 2x faster than realtime, i.e. 1s wallclocktime corresponds to 2s simulation time.
- *Fast Rewind*: The playback direction of the data is reversed and 2x faster than relatime, i.e. 1s wallclocktime corresponds to -2s simulation time.

This interface also allows for navigating to a specific point in time by entering the value of the time directly. After confirming the corresponding dataset is displayed immediately.

5.2.5 Computational steering

The user is able to start or stop the calculation of CFD data according to a mission. He can also query the status of running computations.
As data is delivered from the CFD solver to the database it is immediately available for displaying, i.e. the user can also view the progress of a running computation in realtime.

5.2.5.1 Starting a computation

The user selects an item of the list of available missions for calculation and confirms his selection. The mission data is transferred to the CFD solver and the computation continues from the point in time of the last calculated result. If the endtime of the mission is reached, the calculation stops. The calculated CFD results are pushed to the database everytime a timestep is finished.

5.2.5.2 Stopping a computation

The user selects a running computation and confirms it. The CFD solver is stopped and the last timesteps calculated are written to the database.

5.2.6 Exploring the results

If there is CFD data for a selected mission available the user can investigate them. The user can select a suitable method of visualisation (further called a probe) for a given parameter of the calculated data, e.g. isosurfaces for the temperature. The selected visualisation method is invoked and can immediately be seen in the scene. Its parameters can be adjusted and the updates are shown immediately. For convenience the user can temporarily remove probes from the scene and later on reactivate them with the same parameterset.

5.2.6.1 Creating a probe

The user is shown a list of parameters available in the result dataset. He selects an item from this list and confirms his selection. Depending on the type of the parameter, i.e. scalar or vectorial data, he is presented a list of suitable visualisation methods for this type. He selects an item from the list and confirms his selection. He is now presented a set of parameters for this method. After changing and finally confirming these parameters the probe is immediately invoked in the scene and updates everytime a new timestep is loaded.
The available probes, depending on the type of data, are

- for scalar data:
  - Isosurfaces
  - Direct Volume Rendering ("Fire and smoke")
- for vectorial data:
  - Streamlines
  - Line integral convolution

5.2.6.2 Editing a probe

The user selects an item of the list of available probes and confirms his selection. He is presented a set of the actual values of the probe parameters and can change them. After confirmation of the changes the probe is updated wit its new parameters.

5.2.6.3 Deleting a probe

The user selects an item of the list of available probes and confirms the deletion. The probe is immediately removed from the scene.

5.2.6.4 Hiding a probe

The user selects an item of the list of available probes and confirms hiding. The probes is removed from the scene, but keeps its parameters and stays active.

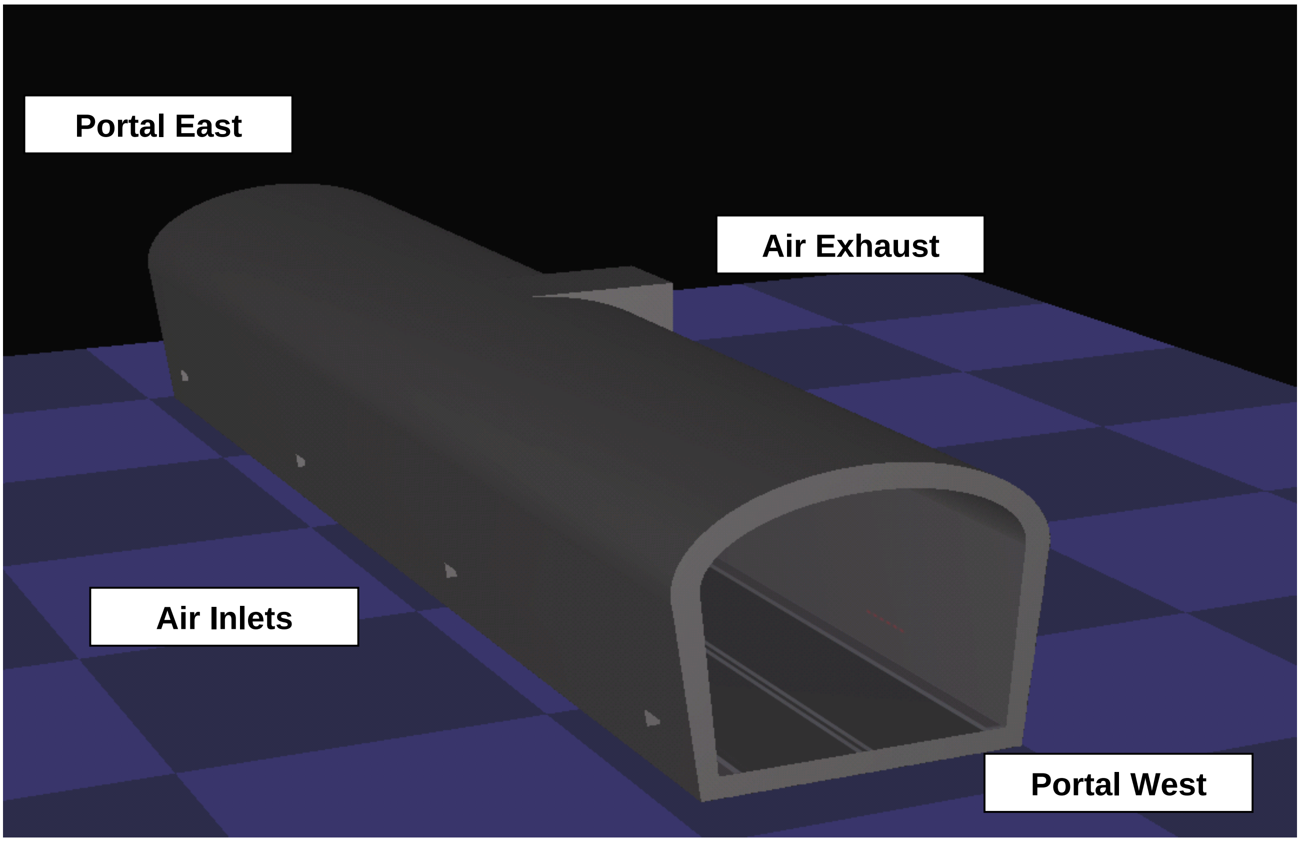
5.2.6.5 Showing a probe

The user selects an item of the list of hidden probes and confirms his selection. The probe is inserted into the scene again.

6 Specification of the selected testcases

3 Testcases have been selected and were setup in the simulator: 2 road tunnel accidents and a train on fire in a subwaystation.

6.1 Test Case MontBlanc



6.1.1 Description of scenario:

The use of this scenario is to show the impact of different fire loads to the user.

6.1.2 Size of the domain

The domain size is 100m x 10m x 5m and consists of 40000 cells.

6.1.3 Initial state of boundary conditions

6.1.3.1 Tunnel portal West

A fixed relative pressure of 1 [Pa] is specified at the west portal.

6.1.3.2 Tunnel portal East

A negative relative pressure of 2[Pa] is specified at the east portal. This results in a pressure difference of 3 [Pa] along the length of the considered tunnel section.

6.1.3.3 Exhaust air extraction

For the exhaust air extraction opening an underpressure of 500 [Pa] is specified.

6.1.3.4 Fresh air inlets

Fresh air is injected with a velocity of 5.5 [m/s].

6.1.3.5 Initial fire region

In the initial fire region a heat load of 50 [MW] is placed.

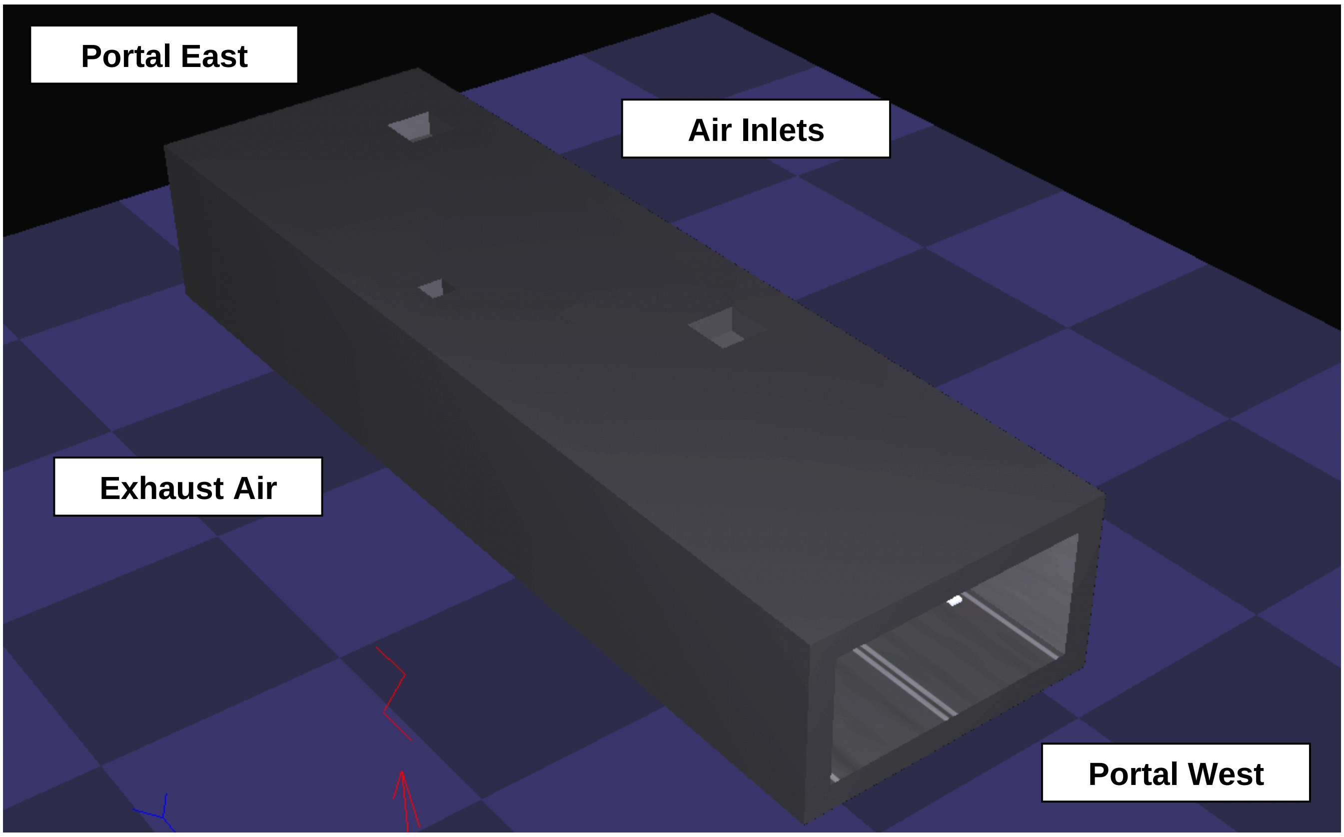
6.1.3.6 Potential fire region

In the potential fire region a heat load of 15 [MW] is specified. The ignition temperature is specified at 500 [K].

6.1.4 User Interactions

The user can change the initial fire loads and the weather boundary condistions at any point in time.

6.2 *Test Case Gleinalm Tunnel*



6.2.1 Description of scenario:

A HGV (Heat load about 50 [MW]) is on fire in the Gleinalm tunnel. There is an initial longitudinal velocity 5.5 [m/s]. The user can observe the spread of fire and smoke and intervent on the axial ventilation.

6.2.2 Size of the domain

The domain size is 100m x 9m x 7m and consists of 50400 cells.

6.2.3 Description of initial boundary condtitions

6.2.3.1 Tunnel portal West

Specification of a longitudinal velocity of 5.5 [m/s]

6.2.3.2 Tunnel portal East

A fixed relative pressure of 0 [Pa] is specified.

6.2.3.3 *Exhaust air extraction*

A negative relative pressure (under pressure) of 1000 [Pa] is specified.

6.2.3.4 *Fresh air inlets*

Fresh air is injected with a flow speed of 0.1 [m/s].

6.2.3.5 *Initial fire region*

The heat load of the intial fire region is 50 [MW].

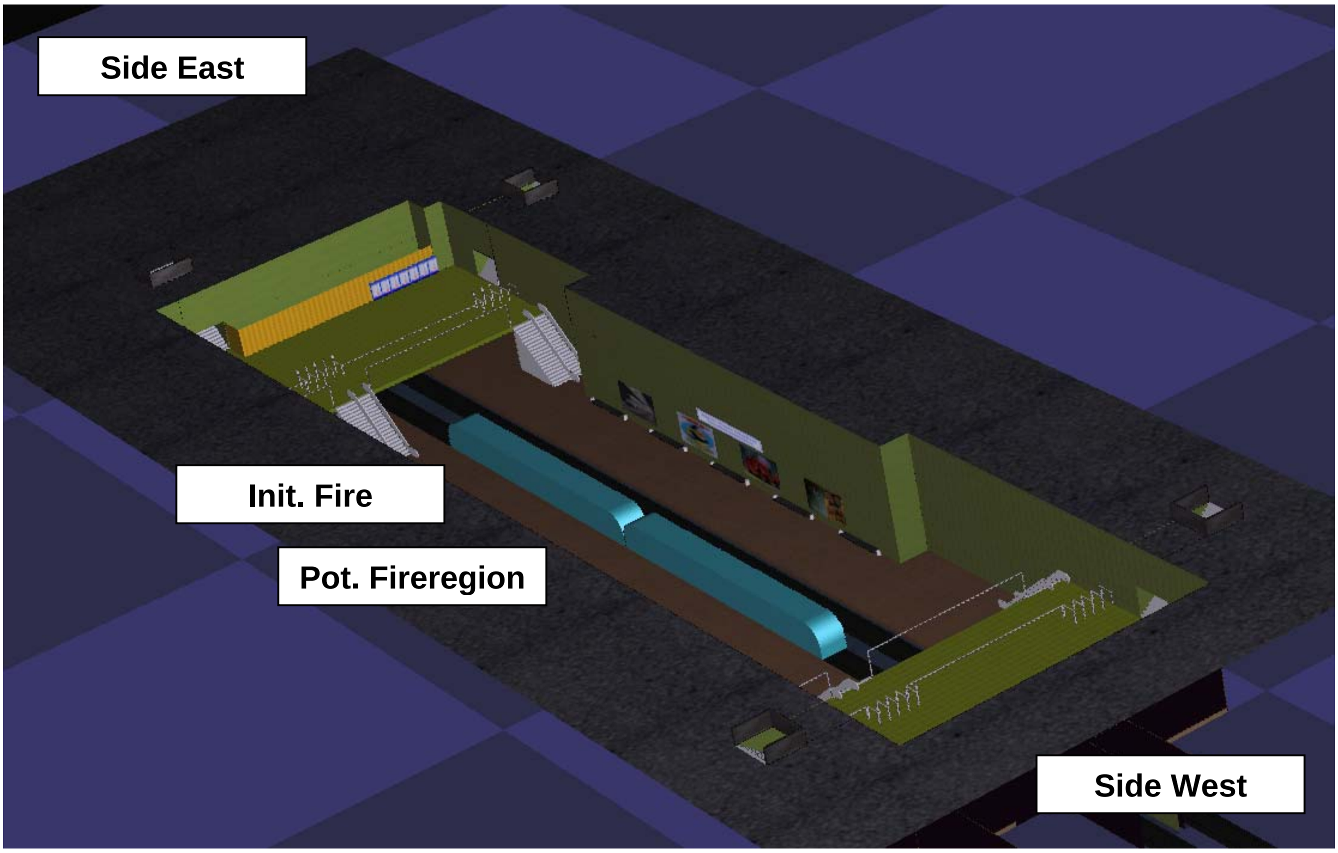
6.2.3.6 *Potential fire region*

The heat loads of the potential fire regions are specified with 15 [MW].

6.2.4 User Interactions:

The user can change the weather boundary conditions and the axial ventilation parameters (speed, on/off) at any point in time.

6.3 Test Case Dortmund Subway Station



6.3.1 Description of scenario

Within a station of the Dortmund subway a train is on fire. There have been two additional potential fire regions identified. There is no ventilation system within the subway system. Two nozzles are placed in the station and can be activated by the user. It is also possible to use fans instead of the fire nozzles.

6.3.2 Size of the domain

The domain size is 120m x 30m x 12m and consists of 345600 cells.

6.3.3 Description of initial boundary condtitions

6.3.3.1 Tunnel side West

Specification of a longitudinal velocity of 1.5 [m/s]

6.3.3.2 Tunnel side East

A fixed relative pressure of 0 [Pa] is specified.

6.3.3.3 Initial fire region

The heat load of the intial fire region is 50 [MW].

6.3.3.4 Potential fire region

The heat loads of the potential fire regions are specified with 15 [MW]. The iginition temperature is 700 [K].

6.3.3.5 Fire nozzles/fans

The flowrate of the fire nozzles/fans is set to zero initially.

6.3.4 User interactions

The user can change the weather boundary conditions and the parameters of the nozzles (flow rate, on/off) or fans (speed, on/off) at any point in time.

7 Conclusion

The complexity of the world of tunnels, with human responses and actions, is large and the challenge of the VIRTUALFIRES simulator is to give through Virtual Reality the possibility of a better knowledge and a good perception of it.

The range of users is large as we can find:

- Tunnel designers
- Tunnel operators
- Authorities
- Tunnels users
- Fire brigades.

European rules for safety in tunnel will contain scenarios that will be checked to define the safety level of a tunnel. Among all the other uses of the VIRTUALFIRE simulator (design, training…) the checking of given scenarios will be one of the strongest answer to the need of safety that European people ask to authorities.