EvacTunnel 3.0

Stochastic Simulation Model of Human Evacuation in Road Tunnels.

User Guide

INDEX

Disclaimer

The GIDAI Group and the University of Cantabria make no warranty, expressed or implied, to users of EvacTunnel 3.0, and accept no responsibility for its use. Users of EvacTunnel 3.0 assume sole responsibility for determining the appropriateness of its use in any particular application, for any conclusions drawn from the results of its use, and for any actions taken or not taken as a result of an analysis performed using this tool.

Go to the top

Intent and Use

EvacTunnel 3.0 is intended for use only by those competent in the fields of safety and evacuation of roads tunnels, and is intended only to supplement the informed judgment of qualified users. This software may or may not have predictive capabilities when applied to a specific set of factual circumstances. A lack of accurate predictions may lead to erroneous conclusions with regard to tunnel safety. All results should be evaluated by an informed user.
Users can make free use of the simulation software EvacTunnel 3.0, and can distribute it to third parties. However, if any simulation results from EvacTunnel 3.0 are published, is necessary to explicitly reference its use.

Go to the top

1. Introduction

EvacTunnel 3.0 simulates the process of evacuating one-way road tunnels during an emergency (accident, fire, spill, threat, terrorist attack, etc.). For bidirectional tunnels, the program may be used twice, once for each lane (traffic direction). The program is based on a stochastic simulation approach to evacuation using Monte Carlo simulation methods. For fire incidents, EvacTunnel 3.0 considers the effect of smoke moving inside a tunnel and predicts the number of dead and injured persons. As output variables, the program provides the total number of trapped vehicles by type, and the mean values, standard deviations, and selected percentiles of any trapped, dead, or injured persons and the total evacuation time. EvacTunnel 3.0 was developed by the GIDAI Group at the University of Cantabria.

Go to the top

2. Installation

The EvacTunnel 3.0 model can be installed from a Windows Installer installation package, which can be downloaded from the GIDAI Group Web site (www.gidai.unican.es). After downloading the setup package and double-clicking it, the user will be walked through a series of steps for installing the program. The initial installation window is shown in Figure 1.
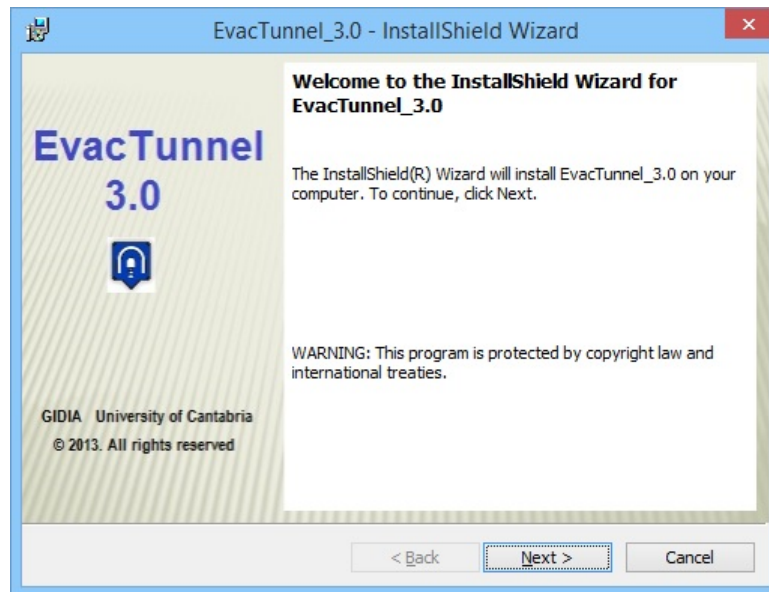
Figure 1. Installation window of EvacTunnel 3.0 package

The hardware requirements are relatively light compared to current PC systems: at least a 1 GHz Pentium III processor and more than 256 MB of RAM. Windows 2000/XP/Vista/7/8/8.1 is required. To run the program, .NET Framework 4.0 must be installed.

Go to
the top

3. Main window

The main program window is shown in Figure 2. This window enables the introduction of the principal input data and the continuation of the simulation process using the buttons and options of the main menu.

The input data are as follows:

∗ *Length to the exit nearest the oncoming traffic [m].* Distance in meters from the location of an incident to the nearest oncoming traffic, emergency exit (cross passage), or tunnel mouth.

∗ *Length of in-tunnel traffic congestion [m].* Depending on the amount of traffic, the length of congestion (vehicle queue) before the tunnel is closed can be equal to or less than the distance to the exit.
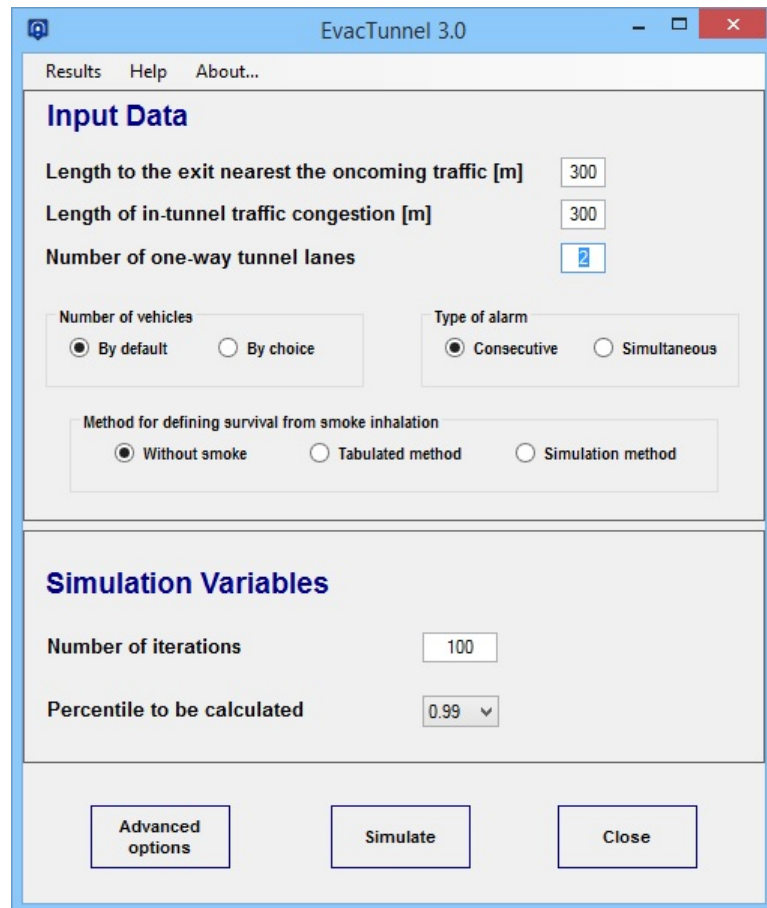
Figure 2. Main window of the EvacTunnel 3.0 program

∗ *Number of one-way tunnel lanes.* Number of parallel same-direction tunnel lanes under analysis.

∗ *Number of vehicles.* Refers to the method for establishing the number of vehicles (by type, i.e. car, truck, or bus) trapped in tunnel traffic congestion. If *By default* is selected, the number of trapped vehicles is calculated based on the length of the traffic congestion, the occupancy distance established for each type of vehicle, and the ratio of each type of vehicle to the total number of vehicles. When *By choice* is selected, a new window, shown in Figure 3, is opened. In this window, the user can enter the desired numbers of cars, trucks, and buses trapped. If the number of vehicles introduced exceeds the real capacity of the established length of the traffic congestion, a warning will appear in a message box (see Figure 4).

∗ *Type of alarm.* Two options can be selected: *Consecutive* or *Simultaneous*. The former assumes that an alarm is backward propagated from the location of the incident with a given time delay and propagation speed, which can be varied by the user in the *Advanced options* window. The second option assumes that all occupants of the tunnel receive an alarm in unison.
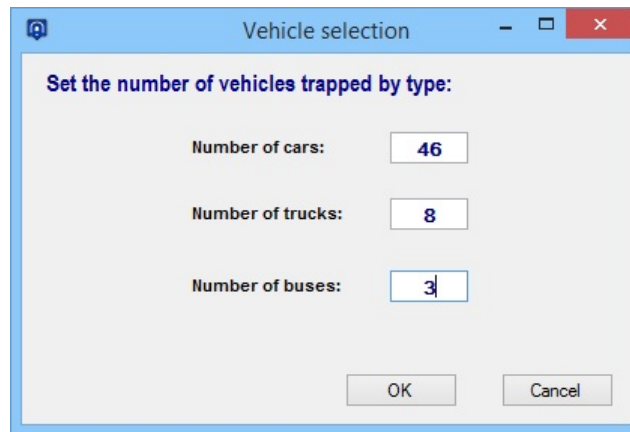
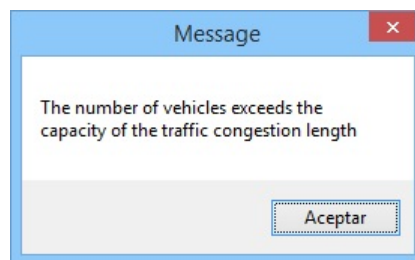*Figure 3. Window for inputting the number of trapped vehicles*

Figure 4. Warning message box

∗ *Method for defining survival from smoke inhalation.* This group box enables the selection of three alternatives for considering the influence of smoke inhalation in the survival of the tunnel occupants: *Without smoke*, a *Tabulated method*, and a *Simulation method*. If the *Without smoke* option is selected, no harm to the occupants from smoke inhalation will be considered. The selection of *Tabulated method* implies that harm from smoke inhalation will be considered based on the survival time elapsed from the moment the incident first occurred. This time is the sum of the time for destratification plus additional time. Both are constant for any distance within the tunnel, and depend only on the fire *Heat Release Rate* selected in the *Advanced options*. If an occupant stays inside the tunnel for longer than the survival time, the occupant is considered to be deceased or injured. When the *Simulation method* option is selected, a message box appears (Figure 5), as does an *Open File Dialog* box in which the user must choose an Excel file (*.xlsx, *.xls) that contains the needed information. An example of the permitted Excel file structure is shown in Appendix 1, which also describes the meaning of the file data.

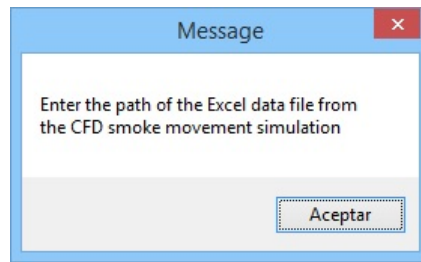∗ *Number of iterations.* The number of iterations to be performed using a Monte Carlo simulation.

Figure 5. Message box

∗ *Percentile to be calculated.* The percentile desired by the user to be calculated for the main output variables. A fixed percentile of 90, 95, or 99% can be selected. The selected value will be applied to such variables as the number of people trapped in the tunnel, the number of deaths and injuries, and the total evacuation time.

The main window has three buttons with the following functions:

∗ *Advanced options*. Allows the modification of many auxiliary variables.

∗ *Simulate*. Starts the simulation process. When completed, the simulation result window is automatically shown.

∗ *Close.* Closes the main window and program.

The main menu has the following items:

∗ *Results -> View on screen.* This menu item displays the *Simulation results* window, which shows the results of the previous simulation.

∗ *Results -> Save simulation report.* This item shows a *Save File Dialog* box that permits the path and name of a text file containing a report of a performed simulation to be selected. An example of this report is shown in Appendix 2.

∗ *Results -> Save sample.* This item displays a *Save File Dialog* box that allows the path and name of an Excel file containing the results of the number of trapped persons, number of dead and injured persons, and the total evacuation time to be determined for each iteration of the sample. An example of this type of file is presented in Appendix 3.

∗ *Help.* This menu item displays the help file in a single-document Web-page format.

∗ *About.* Clicking on this menu item will bring up the *About EvacTunnel 3.0* window.

Go to the top

4. *Advanced options* **window**

The *Advanced options* window has a TabControl-like principal element containing four TabPages. Each of the four TabPage windows is shown in a different figure below. Figure 6 show the *Vehicles* TabPage of the *Advanced options* window.
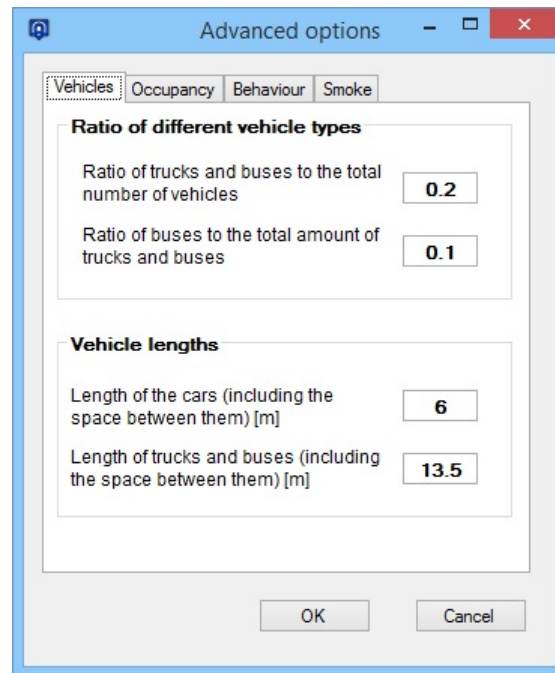

Figure 6. Vehicle TabPage of Advanced options window

In this TabPage, the user can change two types of data: the ratio of different vehicle types and their lengths. The vehicle-type ratio is considered based on two values: the ratio of trucks and buses to the total number of vehicles (i.e. a value of 0.2 means that 20% of the total number of vehicles are trucks or buses), and the ratio of buses to the total number of trucks and buses. The lengths of the vehicles should be entered in meters, with a determined amount of space between vehicles added. For simplicity, the lengths of the trucks and buses are considered to be equal.

Figure 7 shows the *Occupancy* TabPage of the *Advanced options* window. From this page, the user can establish the minimum and maximum occupancy values for each type of vehicle. The program uses these values to randomly generate the mean occupancy for each type of vehicle in each iteration. The generation is performed according to a uniform distribution.

Figure 8 shows the *Behaviour* TabPage of the *Advanced options* window. As expressed earlier, if a consecutive type alarm is selected, it is assumed that the

alarm is propagated backwards from the location of the incident with the pre-alarm delay and propagation speed given.
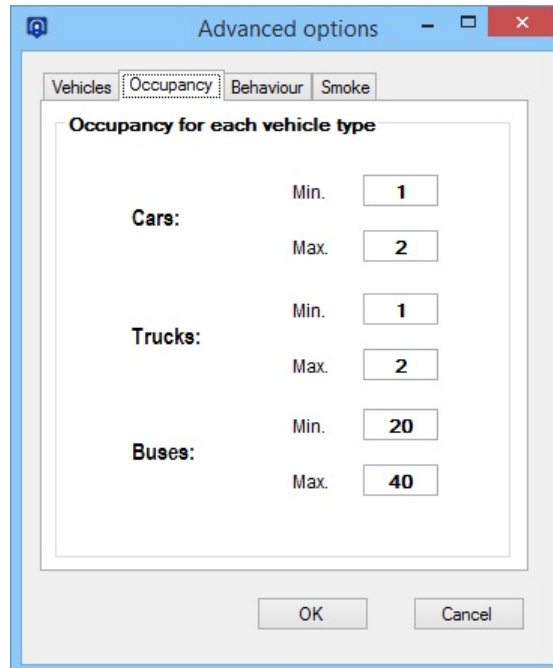

Figure 7. Occupancy TabPage of Advanced options window

The pre-alarm delay should be entered in seconds, and the propagation speed entered in meters per second. Both are treated as constant parameters for all iterations during the simulation process.
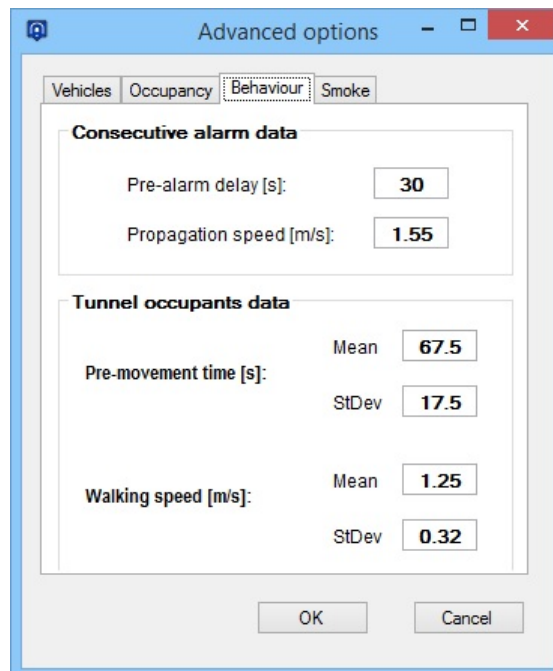

Figure 8. Behaviour TabPage of Advanced options window

Other data that can be entered on this page are related to the occupants of the tunnel, i.e. their pre-movement times and walking speed. Both are assumed to be random variables with a Gaussian distribution. For this reason, it is necessary to introduce their mean values and standard deviations during the simulation process.

The *Smoke* TabPage of the *Advanced options* window is shown in Figure 9. As shown in the figure, the data refer only to the tabulated method for defining the survival from smoke inhalation. This page includes a comboBox called *SCENARIO* with a drop down list. This list includes five scenarios established according to the *Methodology for Risk Analysis for Road Tunnels of Spain*.

Each scenario has a fixed amount of destratification time plus additional time. The user can input the desired destratification time (the time since the incident until the start of the destratification process) and the additional time (the time between the start of the destratification until its completion). Note that the sum of both times determines the time at which the environment throughout the tunnel becomes untenable.
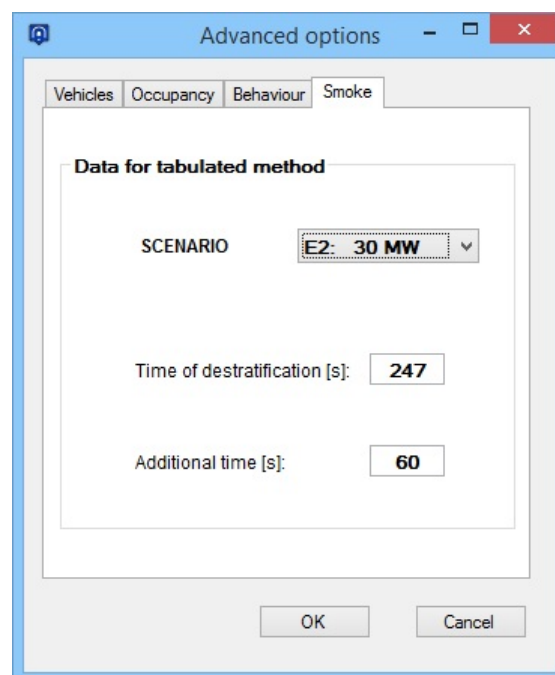

Figure 9. Smoke TabPage of Advanced options window

All variables included in the *Advanced options* window have default values. If the user wants to retain these values, they must click on the *Cancel* button. If any values are changed, the user must click on the *OK* button to accept the changes.

5. *Simulation results* window

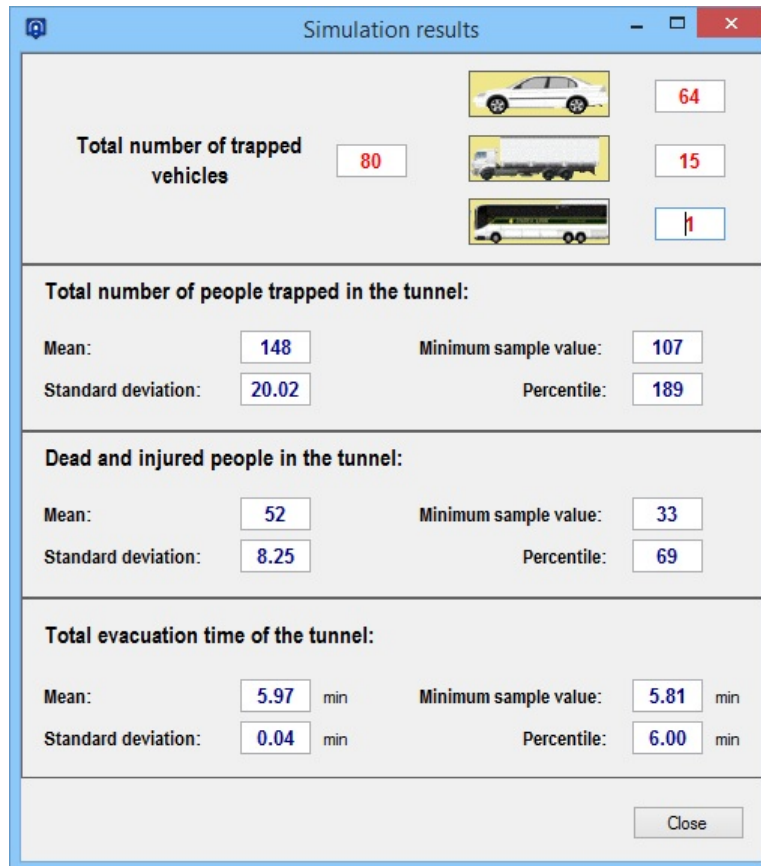The *Simulation results* window is shown in Figure 10.

Figure 10. Simulation results window

The *Simulation results* window shows the following simulation output variables:

- The total number of trapped vehicles and the number of each vehicle type (cars, trucks, and buses).
- The mean value, standard deviation, minimum value of the sample, and selected percentile of the output random variables:
  - people trapped in the tunnel,

- dead and injured people in the tunnel, and
- total evacuation time of the tunnel.

Go to
the top

6. *About EvacTunnel 3.0* window

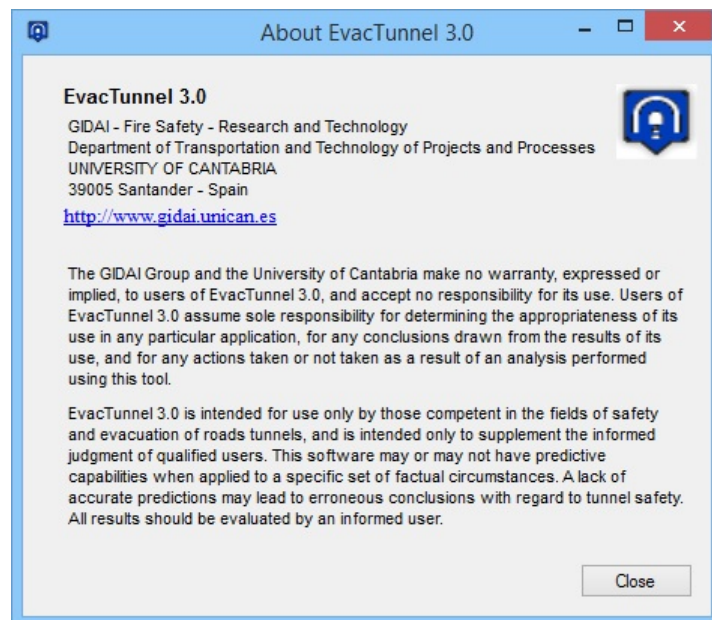The *About EvacTunnel 3.0* window is shown in Figure 11.

Figure 11. About EvacTunnel 3.0 window

Go to
the top

Appendix 1: Required Excel file structure for defining survival from smoke during the simulation.

The required structure of the Excel file is shown in Figure A1.

Figure A1. Required Excel file structure

The Excel file must contain only one worksheet. The first row of this sheet should contain the titles of the first three columns. Any title can be used. The type of data that should be included in each column is as follows:

d [m] (first column): The distance from the location of the incident to different points inside the tunnel in the direction opposite the traffic. The first row should correspond to a zero distance. The remaining rows should be in the ascending order of distance.

t1 [s] (second column): the time from the occurrence of the incident to the moment when the tunnel becomes untenable for the given distance.

t2 [s] (third column): the time from the occurrence of the incident until the moment the environment inside the tunnels becomes tenable again for the given distance. The value of **t2** must be greater than that of **t1**. If for a given distance, the environment remains untenable, **t2** must be a (greater than any possible overall evacuation time) sufficiently large number.

The tenability conditions for determining **t1** and **t2** can any values the user determines, e.g. the air temperature for a given height, the concentration of carbon monoxide, or the level of smoke obscuration. Similarly, the user can freely choose the simulation software used to obtain the required data, e.g. a zone model, unidirectional model, or CFD model.

Appendix 2: Example simulation report.

SIMULATION REPORT

Date and time: 05/03/2014 8:52:20

INPUT DATA:

Length to the exit nearest the oncoming traffic [m]: 300
Length of in-tunnel traffic congestion [m]: 300
Number of one-way tunnel lanes: 2
Method of definition of the number of trapped vehicles in tunnel: By default
Type of alarm to the occupants of the tunnel: Consecutive

Method for defining survival from smoke inhalation: Tabulated method

Simulation variables:
Number of iterations: 100
Percentile to be calculated: 0.99

ADDITIONAL DATA

- Ratio of different vehicles types:
Ratio of trucks and buses to the total number of vehicles: 0.2
Ratio of buses to the total amount of trucks and buses: 0.1

- Vehicle length:
Length of the cars (including the space between them) [m]: 6
Length of trucks and buses (including the space between them) [m] 13.5

- Occupancy for each vehicle type:
Cars: Minimum: 1 Maximum: 2
Trucks: Minimum: 1 Maximum: 2
Buses: Minimum: 20 Maximum: 40

- Consecutive alarm data:
Pre-alarm delay [s]: 30
Propagation speed [m/s]: 1.55

- Tunnel occupant's data (normal distributed random data):
Expected value of pre-movement time [s]: 67.5
Standard deviation of pre-movement time [s]: 17.5
Expected value of the walking speed [m/s]: 1.25
Standard deviation of the walking speed [m/s]: 0.32

- Data for tabulated method:
Time of destratification [s]: 300
Additional time [s]: 60

SIMULATION RESULTS

- Trapped vehicles in tunnel:
Cars: 64
Trucks: 15
Buses: 1
Total number of trapped vehicles: 80

- Total number of people trapped in the tunnel:
Expected value of trapped persons: 150
Standard deviation of trapped persons: 18.44
Minimum sample value of trapped persons: 111
Maximum sample value of trapped persons: 194
Percentile of trapped persons: 193

- Dead and injured people in the tunnel:
Expected value of dead and injured persons: 53
Standard deviation of dead and injured persons: 8.00
Minimum sample value of dead and injured persons: 36
Maximum sample value of dead and injured persons: 71
Percentile of dead and injured persons: 70

- Total evacuation time of the tunnel [min]:
Expected value of total evacuation time: 5.97
Standard deviation of total evacuation time: 0.04
Minimum sample value of total evacuation time: 5.82
Maximum sample value of total evacuation time: 6.00
Percentile of total evacuation time: 6.00

Appendix 3: Example of *Save sample* Excel file.

Iter	Persons	Victims	Tevac
1	139	49	6
2	166	57	5.98
3	193	63	5.96
4	127	44	5.95
5	161	51	5.96
6	185	58	5.98
7	141	46	5.94
8	134	46	5.99
9	127	44	5.99
10	160	50	6
11	164	49	5.93
12	134	55	5.99
13	168	50	6
14	152	50	5.93
15	146	45	5.88
16	173	59	5.99
17	166	54	6
18	176	65	5.99
19	161	54	6
20	177	61	5.97
21	158	61	5.95
22	162	55	5.91
23	176	60	5.99
24	131	40	6
25	123	37	5.91
26	138	48	6
27	178	61	5.97
28	166	65	5.92

Go to
the top