

## WP4–Human factors simulation in BETs and definition of a related behavioral-based (B-based) resilience metric

### T4.1 Development of simulation model including human behavior representation and BETs modifications for selected SLOD/SUOD – SOFTWARE MANUAL

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#### Abstract

This report offers the summary on how to use the software for the evacuation simulation. It includes the description of input files, **variables in the main interface**, tips concerning the use of the variables, **references to some of the main function within the sourcecode**, and the **output files**. In case of software crash and request support, please contact [g.bernardini@staff.univpm.it](mailto:g.bernardini@staff.univpm.it) to provide data on A) PC features, i.e. RAM, processors, number of core, B) input files and C) configuration conditions using inputs.

#### Keywords

Users’ typical exposure; Individual vulnerability; Human exposure; factors characterization;

#### Approvals

Role	Name	Partner
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#### Revision versions

Revision	Date	Short summary of modifications	Name	Partner
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0.1	03.04.2021	Modifications in respect to the improvement to Bernardini the simulation software on earthquake simulation	UNIVPM
1.0	15.07.2022	Revision of the structure to divide the simulation Bernardini indexes from the simulation steps; Final output revision in view of the common revision process	UNIVPM

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**1. System and software requirements relates variable (strings) are word (but not case)-sensitive and should include the “.png” denomination at**

The current simulator version is developed for Netlogo 6.2.

Recommended minimum system requirements according to current tests are: RAM 8GB, Windows 8.1 or newer. GPU recommended.

**2. How to create the MAPS to be uploaded**

The software needs the following png input files. An external editor for the png file definition can be used (e.g. printing in cad + using GIMP or photoshop to check the png consistency), ensuring that the initial resolution of the file (dpi) should be equal or higher than the maximum final *xcell* and *ycell* dimension, and so also depending on the minimum *patchsize-m* values assumed in the simulation software. The color import is solved by *importcolorBET* in both the simulation modules. The following maps are described according to the variables names in the *setup creation* and *simulation from setup* modules. The png files should be supplied in the same folder where the nlogo executable file is allocated. Note that bmp extension can be used instead of png, but jpeg/jpg or tiff ones are deprecated.

**BETmap\_IN:** it concerns the description of the BET, its indoor and outdoor elements including areas use and obstacles. Each element has a specific RGB color depending on its function, according to Table 1

**UTCImap\_IN:** it describes the UTCI conditions according to SLOD simulation outputs, see D4.1.1 – Section 3.1.1. Colors in RGB scale to be imported in the software are resumed in Table 2

**SEISMICmap\_IN:** it describes the areas affected by debris depending on the evaluations due to geometrical and vulnerability issues of buildings facing the square (see D4.1.1 – Section 3.1.2). Colors and use are offered by Table 3

**ATTACKmap\_IN:** it describes the areas where the attack is performed, according to Table 3.

Figure 1 offers an example of these input png files.

Table 1. RGB for geometry/use for BETmap\_IN input as a png file

Geometry/use (Errore. L'origine riferimento non è stata trovata.)	RGB	MAIN USE IN SIMULATIONS
BUILDINGS	0 0 0	To generate people placed indoor in non-special buildings; the area of this color should be equal to the one of the non-special buildings in the BET, depending on D3.2.3 – ABAr (Section 6). They can be damaged because of earthquake
SPECIAL BUILDINGS	200 100 100	To generate people placed indoor in special building uses; the area of this color should be equal to the one of the special buildings to be simulated, according to D3.2.3: 1310m <sup>2</sup> for Theatres, 940m <sup>2</sup> for Museums, 880m <sup>2</sup> for Religious buildings, and 1770 m <sup>2</sup> for Government Buildings (sample mean regardless of the special building use: 1200m <sup>2</sup> ). They can be damaged because of earthquake.
GREEN AREA	150 200 150	People are not generated on such patches, and they represent an obstacle to motion (e.g. trees). To make them



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		usable for pedestrians, change <b>sector</b> value to 2.9 in the <b>importcolorBET</b> function
DEHORS	200 180 150	To generate PO; the area of this color should be equal to the one of the special buildings to be simulated, according to D3.2.3 (in this work, 5% of the outdoor area considering a conservative approach to the Q3 value for all the assessed square sample)
PORTICOES	250 200 150	To be used by people, OO can be generated on them
PEDESTRIAN area (for OO)	225 225 150	To be used by people, OO are generated on them. The dimension depends on D3.2.3 (in this work, 65% of the outdoor area as the median value for all the assessed square sample)
VEHICULAR areas	200 200 200	No people will be generated on these areas, but they will be usable to evacuees. The dimension depends on D3.2.3 (in this work, 30% <sup>1</sup> of the outdoor area as the approximated median value for all the assessed square sample)
WATER	40 100 200	An obstacle to the evacuation process. It should be surrounded by permanent obstacles in case there is a relevant permanent obstacle (e.g. full brick parapet wall). This value is included within the PERMANENT OBSTACLES percentage in D3.2.3 (see below).
TEMPORARY / LOW OBSTACLES (foldable)	140 100 60	Obstacles that can be folded because of people's pressure in case of high crowd density (not comprising chairs or desks, movable benches). It can be used for limiting dehors areas, water areas, vehicular areas and so on, or to represent some obstacles in crowd management (e.g. in massgatherings to divide the areas of the square).
PERMANENT OBSTACLES	70 60 50	Obstacles that cannot be removed or folded by people while moving, e.g. full brick/concrete/still parapets and barriers, low walls, massive benches low sculptures and so on. It can be used for limiting dehors areas, water areas, vehicular areas and so on, as well as to represent new jersey barriers and similar devices in terroristic acts mitigation. The dimension depends on D3.2.3 (in this work, 2% considering a conservative approach to the Q3 value for all the assessed square sample).
ACCESS STREETS	10 255 10	used as safe areas in terrorist act evacuation, that is while people are leaving the BET. It is recommended that the access streets are not placed at the access of the square, but at a distance from the edge equal to the street width, to include the simulation of bottlenecks effects on the pedestrian dynamics "entering" and "leaving" the BET

<sup>1</sup> The mean is 26%, but the value is herein ceiled to the next 5%.

Table 2. RGB for UTCI values: conversion table to produce the *UTCI*map\_IN. RGB values out of the scale should be extended according to specific scenarios

UTCI value (Errore. L'origine riferimento non è stata trovata.) °C	RGB
24	75;107;169
25	101;133;190
26	131;162;215
27	166;196;244
28	183;207;225
29	204;219;186
30	238;235;118
31	249;235;89
32	250;219;66
33	242;172;32
34	237;142;12
35	234;119;0
36	234;88;0

Table 3. Specific input maps, with RGB and use

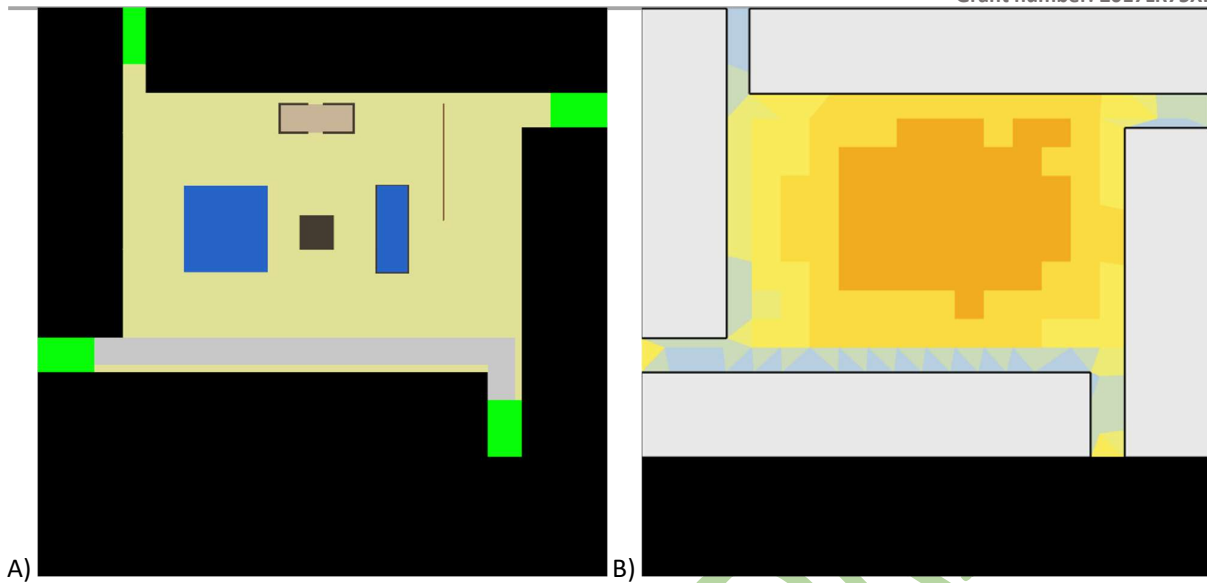
Other risk maps	RGB	MEANING AND USE
DEBRIS AREA	189 0 0	Debris due to the earthquake on buildings and special buildings => <b>SEISMICmap_IN</b> in simulation from setup
ATTACK AREAS	200 100 0	Areas where the attack happens (in case of attacks with weapons or bombs) or where the attack starts and ends (in case of attack with trucks/cars, thus suggesting to use only two colored areas) => <b>ATTACKmap_IN</b> in both setup and simulation from setup



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A)

B)

C)

D)

Figure 1. Input png files example: A) geometry to BETmap\_IN (see Figure 2); B) UTCImap\_IN, showing both the UTCI colors and the surrounding buildings (not uploaded by the setup creation module); C) SEISMICmap\_IN (just representing the debris area); D) ATTACKmap\_IN (just representing two attack areas, e.g. for truck attack)

### 3. Setup creation 2022\_v1 guide

The setup creation module is composed of three main parts as traced in Figure 2, and as discussed in the following sections: 3.1 - BET inputs for FDT/OBSIT; 3.2 - MAPS (png/bmp) to be uploaded; 3.3 - Create the setup: general simulation rules.

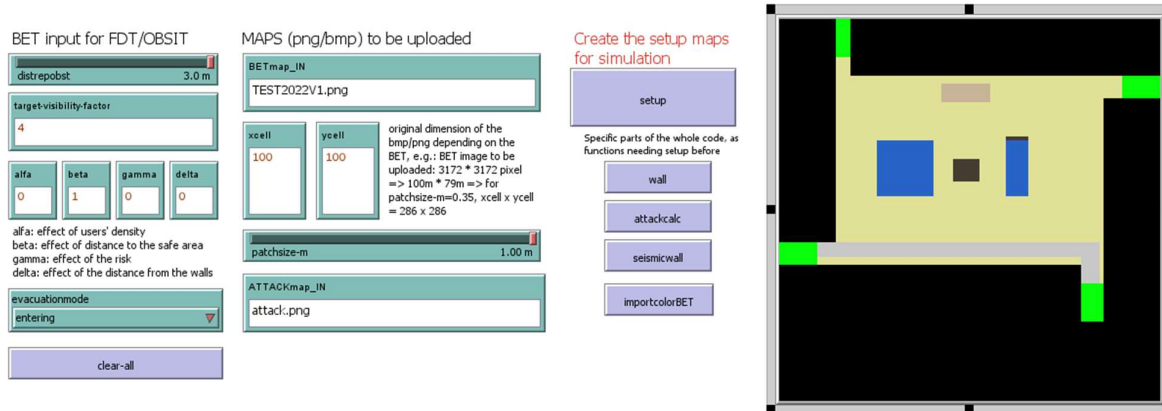


Figure 2. Interface of the setup creation module

### 3.1 BET inputs for FDT/OBSIT

This section includes all the variables concerning the creation of  $F_{d,c,t}$  and  $OR_{c,t}$  [-]:

**Distrepobst** [m]: distance of repulsion from the obstacles. 3 m (recommended value) is its maximum values since people do not care for more distance obstacles according to (Lakoba et al. 2005). The minimum repulsion will appear when the distance between the user and the obstacle is equal or higher than distrepobst. The distrepobst variation implies a possible difference in user's preferred distance with the patches occupied by buildings, special buildings and permanent obstacles

**target-visibility-factor** [-]: this value multiplies the distance to the safe area for a given patch, if the patch does not directly see the safe area because there is an obstacle (a building, a special building, a temporary or permanent obstacle) between their connecting line. Higher the factor, higher the impact of safe areas placed behind a wall and greater the attraction due to visible safe areas (a sort of radial increase effect of the safe area position). A recommended value from empirical evaluations is equal to 4. The value is used only in **evacuationmode** = "leaving", since this condition represents the terrorist act evacuation where safe areas can be visible or not (in earthquake, people just move far from buildings as well as possible).

**alfa, beta, gamma, delta** [-]: Correction factors for the affordance-based choice of the next patch were to move. It refers to: ALFA=effects of the users' density; BETA=effects of the distance to the safe area; GAMMA=effects of risk conditions for the current patch (e.g. because of fire, debris, cascading phenomena, including those of terrorist acts); DELTA=effects of repulsive phenomena with the obstacles/walls. Values should range from 0 (no influence) to 1 (maximum influence, and their sum should be equal to 1. The value area assigned by the user, and not automatically by the software. The function is not used in the setup creation since no outputs files on  $Aff_{c,t}$  is provided herein, but they have been considered in the interface since the code allows to also calculate  $Aff_{c,t}$  via **Fit** variable (in *floorfieldt0*).

**evacuationmode** [chooser]: it can be divided according two conditions:

- evacuation mode for terrorist act evacuation: people exit the square=> *leaving*, so the  $F_{d,c,t}$  will have maximum values for patches near the ACCESS STREETS.
- evacuation mode for seismic evacuation: people move inside the square=> *entering*, so the  $F_{d,c,t}$  will have maximum values for patches far from the buildings/special buildings. In this case, additional



flows from streets to the square are considered (2pp/s generated to maximize entering flows and speeds) into the *simulation from setup* module

The **evacuationmode** should be consistent while generating the scenarios to be uploaded in the *simulation from setup* module since the png upload files are word-sensitive (e.g. generating the “leaving” scenario in *setup creation* implies to use the same variable state in the *simulation from setup* module)

### 3.2 MAPS (png/bmp) to be uploaded

This section includes all the variables to properly upload the scenarios and create the geometry and output data.

See section 1 for general requests on **\*map\_IN** variables (string field). The relates variable (strings) are word (but not case)-sensitive and should include the “.png” denomination at the end. The png files should be supplied in the same folder where the nlogo executable file is allocated. Note that bmp extension can be used instead of png, but jpeg/jpg or tiff ones are deprecated.

**xcell, ycell** [-]: number of cells in the two directions of the image. It should be calculated according to the original dimension of the png depending on the BET. The dimensional values are shown here: [https://univpm.sharepoint.com/:x:/s/be.s2ecure/Eey\\_y5BLoa9HI6qs9sURQUsBCwTuQyT-qHIAKZp2BckCIQ?e=rbFCRY](https://univpm.sharepoint.com/:x:/s/be.s2ecure/Eey_y5BLoa9HI6qs9sURQUsBCwTuQyT-qHIAKZp2BckCIQ?e=rbFCRY)

**patchsize-m** [m]: dimension of the patch in meters; 0.35m is the shoulder dimension of the individual, thus assuming a possible maximum density of 6 to 7 users per square meter in simulation according to the Cellular Automata approach. Maximum dimension is 1m. Ideally, 0.50cm or 0.70cm could be enough to reproduce the crowd evacuation, but in this case, the maximum possible density ranges from 3 to 4 users per square meter.

**xcell, ycell** and **patchsize-m** must correspond with the data on the number of cells along x and y, e.g.: BET image to be uploaded: 3172 \* 3172 pixel => 100m \* 79m => for patchsize-m=0.35, xcell x ycell = 286 x 286.

**importcolorBET** function in the code also ensure to solve problems for pixels/patches with colors not associable to the ones of Table 1 also because of the discretization of the image. In this case, the patch *pcolor* is associated to the one of the surrounding patches.

Take care while simulating (view update in continuous mode) to evaluate how many blue, white or red patches are present in the graphical interface on the right. You can change xcell,ycell to reduce as possible the number of these patches (see the “correct the patches sector value in case there are patches with colors that are different from those of the color assignement process” commands).

The number of pixels in the original png files for a given object, i.e. a line, can be also smaller than the number of output patches. In this case, **importcolorBET** arranges the patches by avoiding smaller elements (so, some thin objects can be suppressed in the model although they are in the original png), that are not considered in the simulation. Take care of the dimension of such elements by modifying the number of pixel in the png editor to ensure the correctness of the geometry.

### 3.3 Create the setup: general simulation rules

The following options on setup creation can be performed by clicking on the right panel bottoms.

**Setup** allows to create all the output files. It performs the general following steps:

- 1) Upload the BET geometry according to the **BETmap\_IN** by **importcolorBET**
- 2) Evaluates the “leaving” or “entering” mode of **evacuationmode** to define if the  $F_{d,c,t}$  should have higher values respectively towards the access streets (terrorist acts) or the center of the square (earthquake evacuation)
- 3) In “leaving”, it will calculate:
  - a. The **risk** of each patch due to the distance from the attack and the visibility of the patch from the areas of attack according to the **ATTACKmap\_IN** (**attackcalc**)
  - b. the  $F_{d,c,t}$  according to the Standard Priority Queue Flood Fill Algorithm (**PQFFA**), starting from the access streets (only the first patches, that are directly adjacent to one of the outdoor patches of the BE (**floorfiledTO**))
- 4) Otherwise, in “entering”, it will calculate the  $F_{d,c,t}$  depending on the distance from the nearest obstacle (building, special building) (**seismicwall**). This function just distinguishes between buildings/special buildings as sources of damages and all the other parts in outdoor as they can be susceptible to debris.

**Wall** just evaluates the wall model to provide  $OR_{c,t}$  [-] (**wall**); **attackcalc** calculates the attack **risk** as defined above (**attackcalc**); **seismicwall** just calculates **seismicwall**; **importcolorBET** just allows the visualization of the png file (**importcolorBET**). These specific functions need to **setup** before, but can be used to repeat some evaluations and provide additional output data.

As a main output during the setup creation, the world shows the ongoing progress based on the maps used in input and provided in output, on the extreme right of the simulation interface, as in Figure 2.

The **setup creation** can be run only once per scenario, and then directly uploaded into *the simulation from setup* folder to perform simulation repetitions. As remarked in Section 4, the same main input values has to be selected to correctly invoke the proper csv files from *setup creation* model.

### 3.4 Outputs of the setup creation

The main output variables to be combined in output files are shown in Table 4. **For Obsit, Fdt, seismicdistance, risk**, maximum values (1) mean minimum affordance for minimum safety conditions of the patch, while ideal conditions refer to minimum value (0).

Table 4. Output variables managed by the setup creation and included in the output files

Variable [unit of measure]	Type, range	Associated to	Meaning
<b>Pxcor, pycor</b> [coordinates]	Integer, world size	Patches – all of them	Patch coordinates according to the inputmap, and so depending on <b>xcell, ycell</b> and <b>patchsize-m</b>
<b>Obsit</b> [-]	Float, 0 to 1	Patches – only those in outdoor where people can move	Higher the value, higher the distance from the building. Values equal to 1 are assumed for all the patches with a distance equal or higher than <b>distrepobst</b> from the buildings
<b>Fdt</b> [-]	Float, 0 to 1	Patches – only those in outdoor where people can move	$F_{d,c,t}$ in leaving simulation – Values equal to 1 are assumed the nearest to a safe area, 0 to the furthest ones

<b>seismicdistance</b> [-]	Float, 0 to 1	Patches – all the patches that are not buildings	Normalized distance values from buildings provoking debris, thus assuming the most distant patches equal to 1 (ideal area to be reached in “entering”)
<b>risk</b> [-]	Float, 0 to 1	Patches – only those in outdoor where people can move	Normalized distance values from the terrorist attack source, thus assuming the most distant patches from the attack source equal to 1 (ideal area to be reached in “leaving”)

This software provides the following csv outputs combining the output variables in Table 4. All the csv files have space as delimitator and uses dot (“.”) as decimal separator, to be setup for the csv import on excel. The files have variable number of columns.

All the csv files are composed to create new files depending on the input main variables discussed above, so as to trace the conditions tested. In this sense, the output files should have consistent variables with performing the *simulation from setup* module, e.g. to upload the correct *setup creation* file named “**seismicwall4-100x100-3\_entering.csv**”, the *simulation from setup* module interface should have the following inputs: **target-visibility-factor** = 4; **xcell** = 100; **ycell** = 100; **distrepobst** = 3; **evacuationmode** = “entering”. The following term *word* in the netlogo code denotes the name of the files by using the related variables according to Table 5.

Table 5. CSV output files from setup creation

Csv:to-file (word)	Number of columns	variables	Use in simulation from setup
"Obsit" <b>target-visibility-factor</b> "-" <b>xcell</b> "x" <b>ycell</b> "-" <b>distrepobst</b> "-" <b>evacuationmode</b> ".csv"	3	pxcor pycor Obsit	Uploaded and used at each <i>tick</i> of the simulation
"Fdt" <b>target-visibility-factor</b> "-" <b>xcell</b> "x" <b>ycell</b> "-" <b>distrepobst</b> "-" <b>evacuationmode</b> ".csv"	3	pxcor pycor Fdt	Uploaded and used at each <i>tick</i> of the simulation ONLY for “leaving” conditions (terrorist acts)
"seismicwall" <b>target-visibility-factor</b> "-" <b>xcell</b> "x" <b>ycell</b> "-" <b>distrepobst</b> "-" <b>evacuationmode</b> ".csv"	3	pxcor pycor seismicdistance	Uploaded and used at each <i>tick</i> of the simulation ONLY for “entering” conditions (earthquake)
"attackrisk" <b>target-visibility-factor</b> "-" <b>xcell</b> "x" <b>ycell</b> "-" <b>distrepobst</b> "-" <b>evacuationmode</b> ".csv"	3	pxcor pycor risk	Uploaded and used at each <i>tick</i> of the simulation ONLY for “leaving” conditions (terrorist acts)

A quick visualization of the outputs is also provided through bmp files, as shown by Table 6. Figure 3 offers examples of the visualization for each of the bmp.

Table 6. BMP output files from setup creation

export-view (word)	Visualization bases	Use
"target" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".bmp"	Buildings, access streets (red patches determining the entrance patches of the access streets), water areas, permanent obstacles	Represents the distance to the target of the patches according to <b>Fdt</b> values (thus, $F_{d,c,t}$ ). Colors ranging from ntelogo <b>pcolor</b> 19 ( <b>Fdt</b> =0) to 10 ( <b>Fdt</b> =1)
"seismicwall" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".bmp"	No difference between the outdoor areas	Represents the distance from the buildings of the patches according to <b>seismicwall</b> values. Colors ranging from ntelogo <b>pcolor</b> 99 ( <b>seismicwall</b> =0) to 90 ( <b>seismicwall</b> =1).
"attackrisk" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".bmp"	Buildings, access streets, water areas, permanent obstacles	Represents the <b>risk</b> depending on the colored areas on the <b>ATTACKmap_IN</b> . Colors ranging from ntelogo <b>pcolor</b> 39 ( <b>risk</b> =0) to 30 ( <b>risk</b> =1).

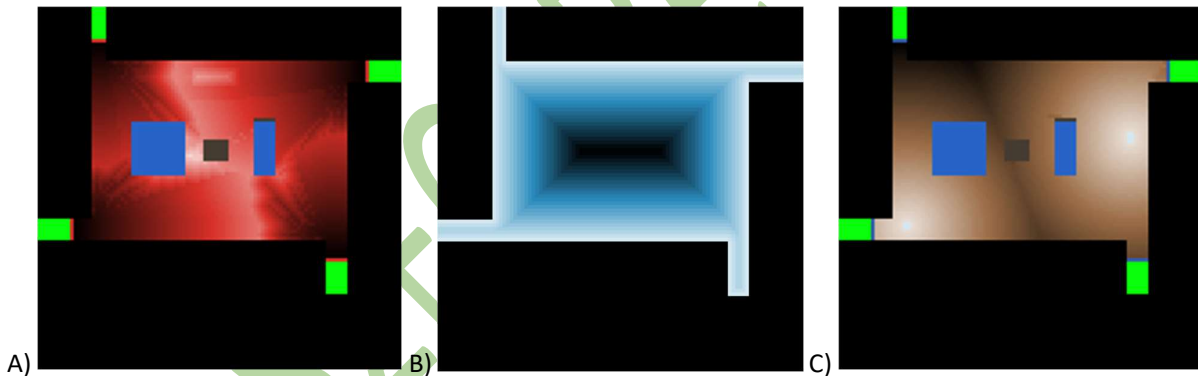


Figure 3. Bmp files example: A) target (**Fdt** representation); B) **seismicwall** (for **evacuationmode** = entering); C) **attackrisk** (for **evacuationmode** = "leaving" and considering two areas as sources of the attack)

#### 4. Simulation from setup 2022\_V1 guide

The setup creation module is composed of four main parts as traced in Figure 4, and as discussed in the following sections: 4.1 - Input data on users; 0 - **position-type**: type depending on the original position: 1=OO, 2=PO, 5=SB, 6=BU

**age-type**: type depending on the age characterization: 0=TU, 1=PC, 2=YA, 4=AU, 5=EU

**gender-type**: type depending on the gender: 0=F, 1=M

**fam-type**: type depending on the familiarity with the BE: 0=NR, 1=R

User's motion; 4.3 - MAPS inputs & simulation repetitions; 4.4 - Other inputs; **Errore. L'origine riferimento non è stata trovata. - Errore. L'origine riferimento non è stata trovata..**

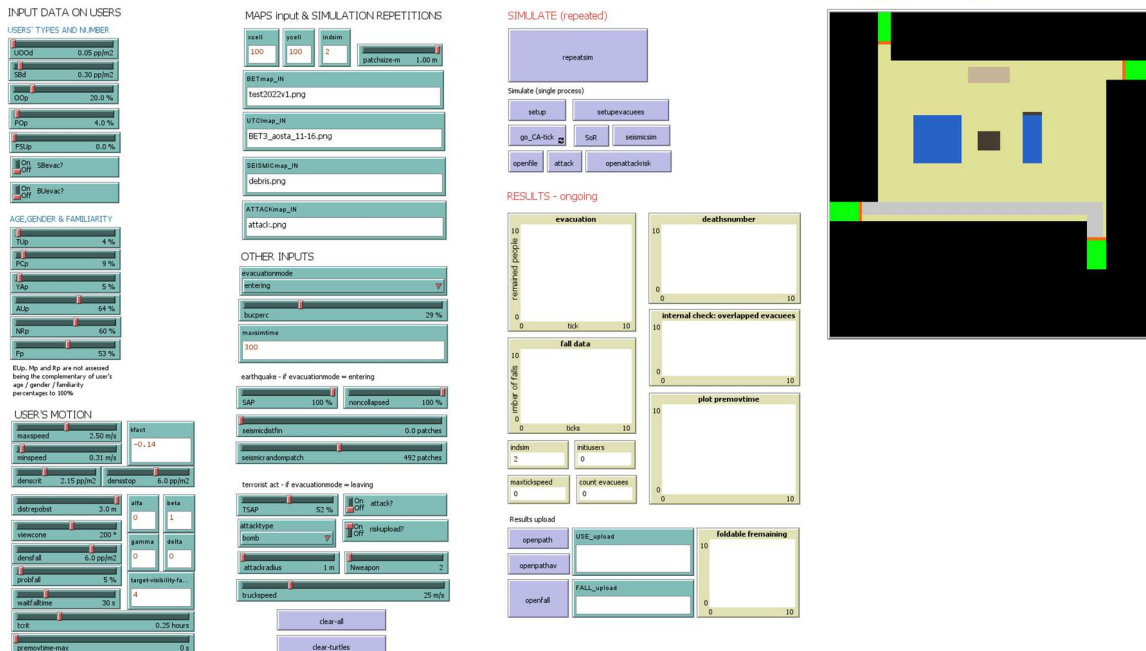


Figure 4. Interface of the simulation from setup module

#### 4.1 Input data on users

This section includes all the variables to populate the scenario with the different types of pedestrian users to be simulated, according to D3.2.3 general statistics and variables names. Please note that a **rapidinput** button has been also introduced (see Section 8) to rapidly select some of the most significant input conditions stated below. Pay attention that **rapidinput** do not include all the parameters!

**UOOD** [pp/m<sup>2</sup>]: overall users' density for the BET, including all the types of people (indoor, outdoor, etc). The overall number of pedestrians to be simulated **simulated-agents** will be equal to **UOOD \* outarea** where **outarea** is directly evaluated by the simulator scaling the number of patches in outdoor (no obstacles) by the **patchsize-m**.

**SBd** [pp/m<sup>2</sup>]: density of people in the special buildings. The overall number of pedestrians in a special building **SB** [pp] will be equal to **SBd** multiplied by the number of patches used as special buildings (**sector** = 5, also see Section 1) scaled by the **patchsize-m**. The users in special buildings will be added to the one derived from **UOod**. **SBd** > 0 if the simulation is referred to the moment in which the special building is open.

Types of pedestrians depending on the initial position are defined by (see also Section 1 for specific areas definition in the **BETmap\_IN**):

**OOp** [%]: percentage of people as outdoor only users (passers-by), generated in a random way in the pedestrian areas and in the porticoes areas

**POp** [%]: percentage of people in the dehors as prevalent outdoor users

**FSUp** [%]: percentage of people coming from the street and entering the square in earthquake evacuation. In case of **evacuationmode**=entering, **FSUp** > 0, if =leaving, please include 0% to ensure avoiding additional people entering the square.

The number of people in buildings (**BU**) is calculated as the difference of the whole number of people (**UOod**-based), and the number of **SB**, **OO** and **PO**.

Considering people placed indoor, their participation to the evacuation process is managed by **SBevac?** / **BUevac?** [boolean]. If **on**, **SB** and **BU** will participate to the evacuation. At the start of the simulation, they will move to the boundaries of the buildings. In **evacuationmode**=entering, please consider to set up **SBevac?** and **BUevac?** equal to **on**, although the model automatically consider their participation to the evacuation. Specific rules for starting the evacuation for indoor users are assessed in Section **Errore. Il segnalibro non è definito**.

Considering age, gender & familiarity, the percentage [%] of users is divided by: 1) age as Toddlers (**TUp**), parent-assisted child (**PCp**), Young Adults (**YAp**) and Adults (**AUp**); 2) non residents (**NRp**); 3) gender (**Fp** as female percentage). Elderly **EUp**, male **Mp** and residents **Rp** percentage values are not assessed being the complementary of user's age / gender / familiarity percentages to 100%.

#### 4.1.1 Users' classification within the code

The users are classified depending on their type into the following numeric conditions:

**position-type**: type depending on the original position: 1=OO, 2=PO, 5=SB, 6=BU

**age-type**: type depending on the age characterization: 0=TU, 1=PC, 2=YA, 4=AU, 5=EU

**gender-type**: type depending on the gender: 0=F, 1=M

**fam-type**: type depending on the familiarity with the BE: 0=NR, 1=R

#### 4.2 User's motion

This section includes all the variables concerning users' motion characterization in each evacuation conditions simulated by the model. They are divided into groups of variables as follow.

##### 4.2.1 Data on the fundamental diagram of pedestrian dynamics

These data reproduce the density-evacuation speed diagram according to the Kladek's formula, as shown in Equation 1:

$$d_{\text{speed}} = (\text{maxspeed} - \text{minspeed}) * \{ 1 - \exp [ -k * ( 1/d_{\text{ens}} - 1/d_{\text{ensstop}} ) ] \} + \text{minspeed} \quad \text{Eq. 1}$$

where **d<sub>speed</sub>** is the desired speed of a single pedestrian depending on the surrounding density conditions. Related values can change depending on terrorist acts (Bernardini and Quagliarini 2021), earthquakes (Bernardini et al. 2016b) and general purposes (Bruno and Venuti 2008) assumed by the researcher. In the following, some recommended values are also shown for these scenarios.

**maxspeed** [m/s]: maximum speed: 2.50m/s for terrorist acts; 3.29m/s for earthquake evacuation; 1.34m/s for general purposes

**minspeed** [m/s]: minimum speed: 0.72m/s for terrorist acts; 0.71m/s for earthquake evacuation; 0m/s for general purposes

**kfact** [-]: shape coefficient of the Kladek's formula: 0.14 for terrorist acts; 0.8 for earthquake evacuation; 1.913 for general purposes

**denscrit** [pp/m<sup>2</sup>]: maximum experimental speed according to the Kladek's formula: 2.67pp/m<sup>2</sup> for terrorist acts; 5.30pp/m<sup>2</sup> for earthquake evacuation; 5.40pp/m<sup>2</sup> for general purposes

**densstop** [pp/m<sup>2</sup>]: maximum density implying the stop of movement for critical overcrowding conditions. It could be reasonably assumed at least equal to 4pp/m<sup>2</sup>, recommended 5.3pp/m<sup>2</sup> or 6pp/m<sup>2</sup> (assuming values for **denscrit** in works concerning general purposes conditions).

However, the **maxspeed** is modified depending on the age as described by Section 4.5, according to the rules of (van der Wal et al. 2017).

#### 4.2.2 Other data

Affordance-based values are **alfa**, **beta**, **gamma** and **delta**, while **distrepobst** replicates the repulsion from obstacles and **target-visibility-factor** concerns the visibility of the safe area. The complete discussion of the parameters is provided in Section 3.2. The same values from the *setup creation* are needed to correctly upload the csv files concerning the same simulation conditions (see Section 3.4 and Section 4.3). Only **alfa**, **beta**, **gamma** and **delta** are effectively used for Fit calculation in the affordance-based approach, while **distrepobst** and **target-visibility-factor** are used only to upload the csv files.

General parameters affecting individual motion are:

**premovtime-max** [s]: maximum premovement time, which is then applied to the individual premovement according to a random uniform distribution. Values equal to 0s correspond to maximum overlapping effects due to the contemporary starting of the evacuation process, thus assuming more critical conditions for simultaneous crowd motion.

**viewcone** [°]: angle of the whole horizontal field of view for the individual's movement, so as to select the patches that are along the head view range. The higher viewcone, the higher the probability to select the next path in a 360° sample, so as representing "excited" people's movement. A recommended value could be equal to about 200° according to [Appendix 11.1.pdf \(epd.gov.hk\)](#) (last access: 3/2/2022).

Specific parameters affecting interactions between the crowd in critical density conditions provoking falling due to physical contacts are:

**densfall** [pp/m<sup>2</sup>]: density for which people can starting fall because of too high pedestrian density. The research should set this value as equal (recommended to replicate critical physical contacts) or lower than **densstop**.

**probfall** [%]: probability that the individual can fall in case of critical density conditions (**densfall**) or counterflows or too high acceleration. Higher the probability, higher the evacuation time in overcrowding conditions.

**waitfalltime** [s]: time for waiting because the pedestrian has been fallen and should restart moving. A recommended value of about 30s could be selected (van der Wal et al. 2017).

Finally, the UTCI-correlated parameter is **tcrit** [h]. The value is the evaluation time for the water loss assessment according to the sweat rate values (UTCI-related assessment). A minimum recommended value of 15 minutes, that is 0.25h to evaluate the UTCI-affected water loss under the transient probability conditions of outdoor areas use.

#### 4.3 MAPS inputs & simulation repetitions

The inputs of this section are the same of Section 3.2. Before starting a simulation, please take care that the following png files (derived according to section 1) and csv files (derived as output of the *setup creation* for the given BET or case study) should be placed in the same folder of the nlogo model, to ensure the correct correspondence with the related variables:

- “\*.png” file about the scenario to be uploaded as **BETmap\_IN**, the same used for *setup creation*
- “\*.png” file about the UTCI data to be uploaded as **UTCImap\_IN**, the same used for *setup creation*
- For EARTHQUAKE EVACUATION:
  - “\*.png” file about the debris data to be uploaded as **SEISMICmap\_IN**, referring to the considered BET map
  - “seismicwall\*.csv” file from *setup creation*, with included the word “entering” to be used as source for **evacuationmode** recall. This file will be used to import **seismicdistance** data and then populate **Fdt** values of patches in earthquake evacuation (i.e. *if evacuationmode = “entering” ask patches [set Fdt seismicdistance]*)
  - “Obsit\*\_entering.csv” file
- For TERRORIST ACT:
  - “\*.png” file about the debris data to be uploaded as **ATTACKmap\_IN**, referring to the considered BET map. This must be the same used in *setup creation* in case **riskupload? = on** (see Section 4.4), which is recommended just for “bomb” attack
  - “attackrisk\*.csv” file from *setup creation*, with included the word “leaving” to be used as source for **evacuationmode** recall
  - “Fdt\*\_leaving.csv” file, to populate **Fdt** values or patches in terrorist acts and general purpose leaving evacuation.
  - “Obsit\*\_leaving.csv” file

An example of these files is shown in Figure 5.

Please remember that the same input png files and **xcell**, **ycell** and **patchsize-m** data from *setup creation* module simulation must be used to start the simulation. The png files must be in the same folder of the nlogo model. Names of files are word but non-case sensitive.



In addition, *indisim* is introduced to define the number of repetitions to be performed. Netlogo essentially works on single core, single thread, using RAM. So, depending on the pc RAM dimension, you can perform more repetitions, but, when the RAM will be filled, the simulator will not work anymore and could crash too without saving files. The RAM filling also depends on the number of agents to be simulated and the xcell/ycell data. Higher these values, higher the data dimension, For 16GB RAM, combinations of up to 3 repetitions with up to 3000 simulated users and xcell=ycell=286 have been verified as a non-filling RAM, but further tests are in progress. Thus, please start limiting the number of repetitions.

*Indsim* reduces over the simulation run, moving to 0. When equal to 0, the simulation repetitions stop, but the number remain 0 at the end of the simulation. Thus, in case of error (e.g. division by zero) at the starting of the simulation (clicking *repeatsim*), please check that *indisim* > 0.

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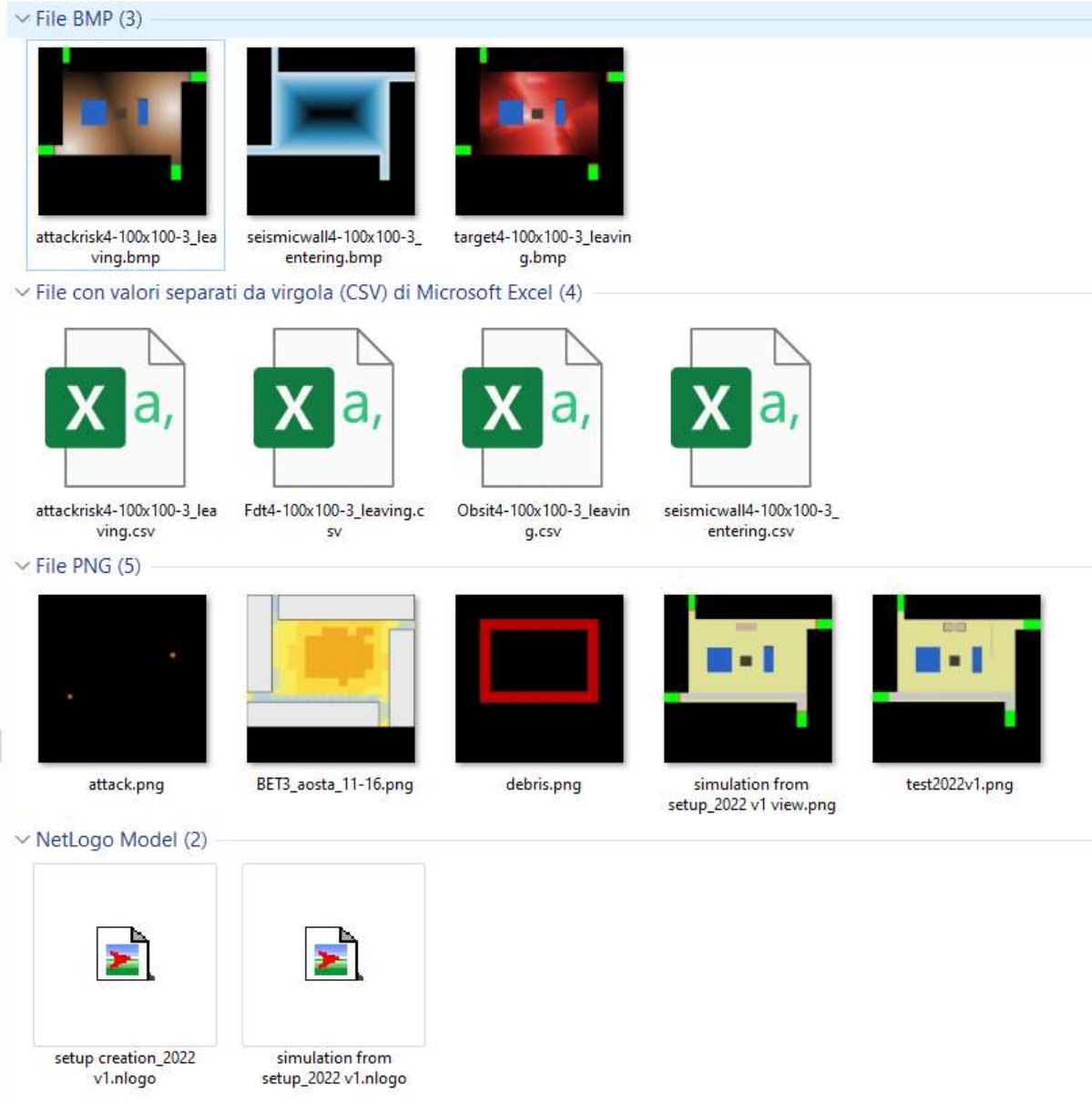


Figure 5. Folder configuration and files before starting the simulation from setup

#### 4.4 Other inputs

General additional inputs are:

**evacuationmode** (as in Section 3.1), being leaving (terrorist acts) or entering (earthquake). The term should correspond to the ones of the csv files to be uploaded, as remarked by Section 4.3.

**bucperc** [%]: percentage of permeability of the building walls, to simulate the door dimensions along the boundaries of the buildings (no special buildings) **BUborder**. Higher **bucperc**, lower the **premovtime-max** associated to BU exiting from buildings in case of **evacuationmode**=entering or **evacuationmode**=leaving and **BUevac?**=on.

**maxsimtime** [s]: maximum simulation time. When the simulation time of the given tick is higher than this value, the simulation will stop and partial data will be saved, as remarked by Section **Errore. L'origine riferimento non è stata trovata.**

Furthermore, specific earthquake-related and terrorist-act-related variables are introduced as discussed above.

#### 4.4.1 Earthquake - **evacuationmode**=entering

**seismicdistfin** [patches]: distance between evacuees gathering in the seismic evacuation simulation. The higher the value, the higher the evacuation time for the seismic simulation, since people will try to reach a free-of-turtles patch where to stop. The value should be calibrated considering **patchsize-m**. If equal to 0, it means that users could occupy adjacent patches, regardless of **patchsize-m**.

**seismicrandompatch** [patches]: number of patches to be chosen for max **Fdt** evaluation before stopping. Lower the value (at least 1), higher the distance between the pedestrian and the border of the buildings at the end of the evacuation. In fact, they will try to choose the most distant patches from the buildings and the debris, thus spontaneously gathering towards the center of the square. Anyway, as in Figure 6, it is worth noticing that:

- too high values (depending on the number of patches in outdoor – no obstacles) could imply higher evacuation time and crowding, since first arrived people will stop far from the center of the square and they will be obstacles for the other people's motion;
- too small value will imply a long tail in the evacuation timing for the last arrived evacuees, who will search for the best **Fdt** conditions, moving in the square.

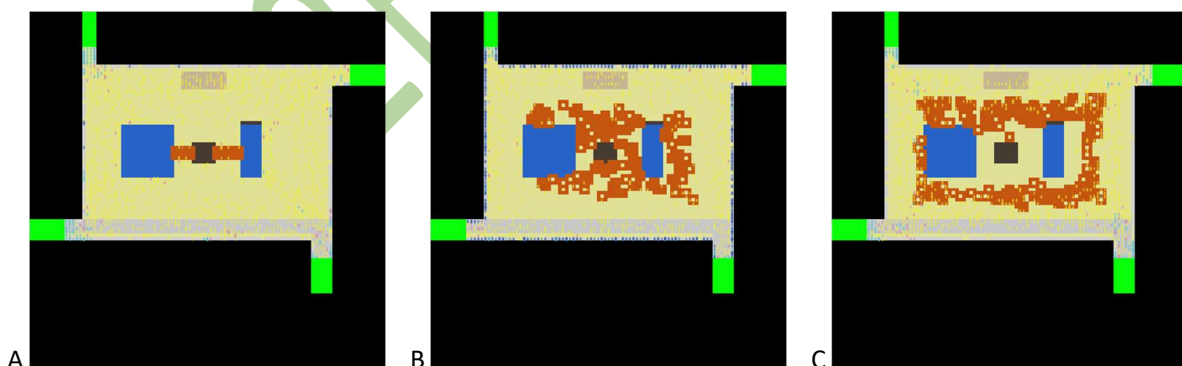


Figure 6. **seismicrandompatch** effects on spontaneous gathering of pedestrians: A-considering **seismicrandompatch**=1; B-considering **seismicrandompatch**=500; C-considering **seismicrandompatch**=1000.

**SAP** [%]: Self-Aid Percentage, that is how many people from the buildings and the debris-affected areas can reach the area without the debris in an autonomous way. It can be assigned as 88% to include self-aid and mutual support by people in the surroundings (Kang et al. 2017).

**noncollapsed** [%]: percentage of buildings that does not collapse, and so that can vary the quantity of people who can be blocked by debris. No effects for **noncollapsed** = 100%.

#### 4.4.2 Terrorist act - evacuationmode=leaving

**attackradius** [m]: it expresses the ratio within which the individuals will suffer the attack and can autonomously leave the space depending on **TSAP** [%] (percentage of users who can leave thanks to anti-terrorist act self-aid). The TSAP percentage inside the **attackradius** will not survive and not participate in the evacuation process

**attack?** [boolean]: if the attack should be simulated, use the switch of this variable in mode “on”

**riskupload?** [boolean]: if true (equal to on), it will upload the risk maps calculated from the setup run and no additional evaluations of visibility effects on attack risks is calculated. This choice can be performed for “bomb” attack type, see below. This can be useful to depict the initial knowledge of the event, e.g. for bombs, and people looking for shelter behind obstacles.

**attacktype** [chooser]: the value could assume different states:

- “*generic*”: users just leave the BE, for general purposes evacuation. In this case, please directly include **riskupload?** = *off* since there is no source of the attack
- “*truck*”: a truck is generated in one of the cells of the **ATTACKmap\_IN** and tries go to the farer one along a straight line with a speed depending on the **truckspeed** [m/s]. In this case, please set **attackradius** = 3m, so as to simulate the truck width. In this case, please directly include **riskupload?** = *off* and the model will calculate here the risk over the time depending on the movement of the truck;
- “*weapon*”: **Nweapon** attackers are generated in the cells of the **ATTACKmap\_IN** and they will try to kill people within their **attackradius** (the survival probability to the attack is **TSAP**). In this case, you can directly include **riskupload?** = *on* assuming that the people are reasonably aware of the initial position of the shooters, and of their movements (by every 10 seconds)
- “*bomb*”: a bomb attack will be generated in the **ATTACKmap\_IN** cells and risk will be dependent on the distance from this source. In this case, please directly include **riskupload?** = *on*.

In addition, this part also includes **clear-all** and **clear-turtles** functions to remove all and all the turtles before the simulation (always recommended).

#### 4.5 Simulation from setup: general simulation rules

The main simulation, including repetitions, can be performed by clicking on the **repeatsim** bottom on the right panel. The simulation involves 4 types of turtles (created through the breed function): **evacuees**, as the users; **trucks** and **weapons** as the two kinds of attackers in case of a terrorist act; **rescuers**, as the support staff in emergency conditions (not yet implemented).

The simulation is performed according to the general following steps:

- 1) Upload the BET geometry according to the **BETmap\_IN** by **importcolorBET**
- 2) Evaluates the SLOD effects depending on the UTCI condition of the outdoor area according to **WLbetOO** which depends on the uploaded **UTCImap\_IN**. The **sweatrate** is calculated for the whole scenario according to D4.2.3 to quantify the water loss in the scenario depending on **tcrit**



- 3) Open the scenario csv inputs to populate **Fdt**, **Obsit** and **risk** data according to the **openfile** routine, as shown in Table 7. In case **attack?** = true (on), **risk** data will be evaluated by the model (see Section 4.5.1 for details).<sup>2</sup>
- 4) The Space of Relevance of Special Buildings **SoR** is calculated in case some **SB** users can be generated (**Sbd** > 0), **SBevac?** = true (SB will be generated while waiting for entering the special building), and considering **evacuationmode** = "entering" (terrorist act evacuation only). **SoR** only depends on the special building area and on **Sbd**, according to D1.3.1. It will be generated closed to the special buildings.
- 5) repetitions of the evacuation process will be performed while **indsim** > 0. Each repetition end when the number of evacuees in the BET is equal to 0, or when **maxsimtime** is reached. At each repetition, the software reduces **indsim** by 1. General rules follow, while specific rules are resumed in Section 4.5.1 for terrorist act and in Section 4.5.2 for earthquake evacuation:

**GENERAL SETUP: only once per simulation repetition:**

- a. generating the **evacuees** depending on the input data on users' type (see Section 4.1), according to **setupturtles**. In particular:
  - i. **OO** will be generated in patches characterized as pedestrian areas (no dehors) depending on the transient acceptability value **valueTR**, calculated as function of the UTCI of the given patch;
  - ii. **PO** will be generated in patches characterized as dehors areas depending on the 1-hour acceptability value **value1H**, calculated as function of the UTCI of the given patch;
  - iii. **BU** will be generated inside the building area. The border of the building where to place **BU** users exiting from the ordinary buildings is calculated (**SoRbuildings**). In **evacuationmode** = "entering" (earthquake evacuation, so **BUevac?** does not matter) or **BUevac?** = true (terrorist act with building users leaving, thus **evacuationmode** = "leaving" is recommended in this case), **BU** users will participate in the evacuation, and they will be generated at the border of the special building patches, on the pedestrian area;
  - iv. **SB** will be generated inside the special building area. Anyway, if **SBevac?** = true and **evacuationmode** = "leaving", they will be generated in the **SoR**. Meanwhile, if **evacuationmode** = "entering", the generation procedure is the same involving **BU** as shown above;
  - v. in case the **SB** and **BU** number will exceed the available patches as special and ordinary buildings, they will be generated as **OO**;
  - vi. **FSU** are generated only in earthquake evacuation (see point *b* of this list)
- b. for each **evacuee**, the maximum evacuation speed is assigned depending on the evacuee's age (**maxspeedage**), according to the rules of (Bosina and Weidmann 2017), that considers different reduction coefficient depending on the age range: EU=0.67; AU=0.87; YA=1; PC=0.87; TU=0.53. No gender effects are considered in this software version;
- c. SUOD effects in terms of deaths/people unable to participate in the evacuation are calculated:
  - i. In case of **evacuationmode** = "leaving", effects of the attack are quantified depending on the **attacktype** (see Section 4.5.1);

<sup>2</sup> Future software development could include the possibility to use **evacuationmode**="entering" while still uploading **risk** data to depict possible cascade effects of earthquake.

- ii. In case of **evacuationmode**= “entering”, **FSU** will be generated and specific procedure for evacuees’ analysis is performed through the **seismic** routine (see Section 4.5.2);
- iii. In any case (thus both for “entering” and for “leaving”), a pre-simulation through the **seismic** routine is performed by statically analyzing the density of users in outdoor free-of-debris area depending on their possibility to reach one of these patches. The users can be damaged (suffer from casualties before starting the evacuation process) depending on: (1) their position, considering all the **FSU**, all the **BU**, all the **SB** and only the **OO** placed in areas with debris; and (2) their probability to perform safety procedures through **SAP**. Damaged users will not be considered to evaluate the density of users, that is reported in the command center (bottom part of the interface)
- d. users who do not participate in the evacuation are removed (**die**) from the simulation, while the speed (**desspeed**) of the others at the first iteration is set up (**speed-OO-setup**) depending on the local density and the input data on the fundamental diagram (see Section 4.2.1). In particular, the local density (**temp-near-density**) is calculated in respect to the free-of-evacuees within the patches placed: (1) at distance reachable by the pedestrian according to the Moore neighborhood with a radius depending on the user’s actual speed (Liu et al. 2016) and (2) within the **viewcone** of the individual, thus focusing only on the effects of other visible people on the user. Equation 1 is applied and a random variation to **desspeed** is also calculated (capped between 0 and **maxspeedage** + 2 \* **minspeed**);
- e. if **premovtime-max** >0, **OO** and **PO** users participating in the evacuation are associated to their specific premovement time **premovtime**. A random uniform distribution between 0 and **premovtime-max** is used to this end. **BU** and **SB** users are associated to their specific **premovtime**, which is calculated considering 1 people per patch per second per **bucperc** entering the square from the **SoRbuildings** patches. This means that the **BU** and **SB** entrance in the square (so their evacuation starting) depends on the permeability of the buildings, so on the quantity of openings at the ground floor. In **evacuationmode** = “entering”, **FSU** users are associated to their specific **premovtime**, which is calculated considering 1 people per patch per second in respect to the width of the access streets, where they are generated at the simulation starting;

**TICK RULES: repeated at each tick of the simulation:**

- f. the main motion subroutine is **go\_CA-tick**, according to the flowchart in Figure 7. The time to the next movement is given by **tickwait**, which depends on **desspeed** and on the maximum speed value assigned to an evacuee (**maxtickspeed**). A user with **maxtickspeed** moves at each simulation iteration (at each tick). A user with null speed, i.e. because of surrounding density conditions, waits 1 tick and the recalculates **desspeed**, thus **tickwait**. The evacuation motion starts only when the users’ premovement time **premovtime** = 0. The user can evaluate if they can move when the **ticklastmove** is reached (the **tickwait** finished) and if they are not fallen at the ground because of density of the surrounding crowd and because they are moving in counterflows. The affordance-based approach to the surrounding patches is solved (to calculate **Fit**) and then the user evaluates if there is a neighboring safe area (i.e. an access street in **evacuationmode** = “leaving” and a patch with maximum **seismicwall** = **Fdt** in **evacuationmode** = “entering” between the **seismicrandompatch** sample). Otherwise, the user selects best conditions (maximum values of the 8 nearest neighbors excluding those that are not in the **viewcone** given the current faced direction of motion) according to the

scheme order in Figure 7, or, if no patch can be selected (e.g. because of crowd conditions), the user does not move. Finally, the probability to fall depends on the surrounding density (over *densstop*) and the possibility to move in counter headings (by evaluating the mean headings of the surrounding *evacuees*). If this probability is  $> \text{probfall}$ , the user falls and the *falltime* starts (up to *waitfalltime*), thus altering *tickwait*;

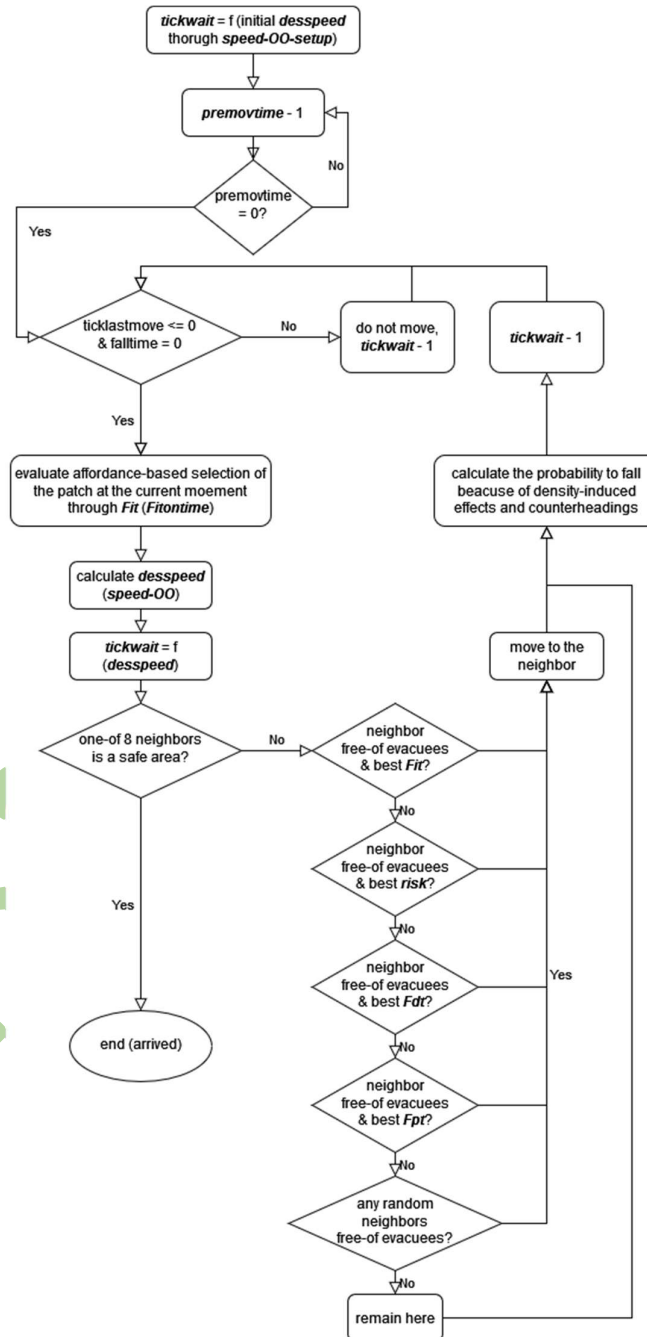


Figure 7. go\_CA-tick subroutine applied to a single user.

- g. in case of **attack?** = true and **attacktype** = "weapon" or **attacktype** = "truck", the **risk** is recalculated once per 10 seconds, so as to describe dynamic conditions in attackers (**calculatederisknow**). During the 10 seconds, the risk linearly decreases by **maxtickspeed**, so as to consider the maximum speed in leaving risk conditions in a given patch by evacuees. The number of users dying because of the attack over the time is calculated and the related people **die** (see rules depending on the **attacktype** in Section 4.5.1);
  - h. the evacuation stops if no more evacuees are present in the scenario (all of them are died or arrived at a safe area, that is at the access street patches in terrorist act evacuation, or they stopped in the square in earthquake evacuation) or the **maxsimtime** value is reached for the current tick.
- 6) The simulation repetitions end when **indsim** = 0 and the outputs are saved in terms of data referring to a specific repetitions and aggregate data, as in Section 4.6.

#### 4.5.1 Terrorist act specific rules

Specific assumptions for terrorist act (**evacuationmode**= "entering") conditions are assumed as following. The **risk** = 0 in case **attack?** is false (off), while, if **attack?** is true (on), it is considered that:

- for **attacktype** = "generic", no map of risk is imported, thus people will not be influenced by the event while leaving the square (**risk** = 0 although **attack?**=on). No people will die because of the attack. The final number of evacuees arrived at the safe area will be equal to the initial one;
- if **riskupload?** = true, the **risk** map derived from setup creation will be uploaded, elsewhere if **riskupload?** = false, the **risk** will be calculated herein depending on the distance from the source of the attack, that are the attack area (RGB: [200 100 0]) described by **ATTACKmap\_IN**. The **attacktype** = "bomb" assumption is here recommended by using **riskupload?** = true to reduce the execution time. In this case, people placed within **attackradius** (starting from the attack area) will can be killed by the bomb only at the starting of the simulation (see **killattackbomb**);
- in case of **attacktype** = "weapon", **Nweapon** attackers will be generated in the attack area (RGB: [200 100 0]) described by **ATTACKmap\_IN**. In this case, **riskupload?** = false is recommended. Attackers will randomly move according to the pedestrian speed through the scenario, by trying killing people within their **attackradius** (see **killattackweapon**). The **deathnumber** will increase over the time;
- in case of **attacktype** = "truck", 1 truck will be generated in one of the attack area (RGB: [200 100 0]) described by **ATTACKmap\_IN** (two distinguished/separated attack areas are recommended). In this case, **riskupload?** = false is recommended. The truck will move towards the furthest attack area along a straight line with a random local variation in the direction of 120° (see **killattacktruck**). The truck will essentially stop when it will face an obstacle and no additional outdoor patches are available in the 8 nearest neighbors. The truck will move people lying on patches within the truck **attackradius** while the truck is moving. The **deathnumber** will increase over the time.

The possibility that an evacuee can be killed by the attack source always depends on **TSAP** (via a random number comparison with the value from the input panel).

Table 7. The patches values upload depending on the scenario conditions

Variables per patch (pxcor pycor)	Condition	Uploaded CSV file (word)
--------------------------------------	-----------	--------------------------



<b>Obsit</b>	always	"Obsit" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".csv"
<b>Fdt</b>	<b>evacuationmode</b> = "leaving" (terrorist act)	"Fdt" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".csv"
	<b>evacuationmode</b> = "entering" (earthquake)	"seismicwall" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".csv"
<b>risk</b>	<b>attack?</b> = true (on) & <b>attacktype</b> != "generic" & <b>riskupload?</b> = true (on)	"attackrisk" target-visibility-factor "-" xcell "x" ycell "-" distrepobst "_" evacuationmode ".csv"

#### 4.5.2 Earthquake specific rules

The *seismic* routine uploads the *SEISMICmap\_IN* data to detect the patches affected by debris. If *evacuationmode* = "entering", FSU are created. The users can be damaged (suffer from casualties before starting the evacuation process) depending on: (1) their position, considering all the *FSU*, all the *BU*, all the *SB* and only the *OO* placed in areas with debris; and (2) their probability to perform safety procedures through *SAP*. Damaged users will not participate in the evacuation (*evacuate?* = false).

In this conditions, *Fdt* = *seismicwall*. The evacuation can stop when an individual reaches a patch that is far enough from the buildings and the debris, depending on *seismicrandompatch*, as discussed in Section 4.4.1.

#### 4.5.3 Other simulation buttons

Specific actions can be performed but will not allow performing a complete simulation. Anyway, they are not recommended to a not expert user, since some errors in file (word sensitive) upload could be shown.

*setup* just uploads the BET scenario, thus importing *BETmap\_IN*.

*setupevacuees* just generates users depending on the users' type and number panel data. This can be performed once setup has been performed, to point out if generation problems from the png file import occur.

*openfile* uploads the *Fdt*, *Obsit* and *risk* map according to the general rules defined above. A visualization of the uploaded csv files is provided in the *world* window on the right. *SoR* calculates the space of relevance for the Special buildings. *attack* perform the attack evaluation according to Section 4.4.2. *openattackrisk* only upload risk data, considering the csv with the same input words from the other inputs and users' motion panel (see above while discussing the input csv format). *seismic* performs earthquake evacuation setup analysis according to Section 4.4.1. *go\_CA-tick* runs a single repetition of the evacuation process, to see if there is any problem for users' motion. These commands imply the setup performing before, are conceived for the software developers quick test, and some errors in file (word sensitive) upload could occur.

### 4.6 Outputs of the simulation

The main outputs are combined between ongoing ones and final (exported csv and image files) ones.

#### 4.6.1 Results – ongoing

The plot and monitor panels show:



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- The number of people remaining in the simulation (not arrived at a safe area, so not “die”) per simulation tick – **evacuation** (also shown by **count evacuees**)
- The number of fallen people per simulation tick – **fall data**
- The number of possible deaths in case of terrorist act – **deathsnumber**
- An internal check about the number of overlapped people. The value could be >1 at the start of the simulation in case BU are generated outdoor, but then the value should decrease and normally be equal to 0 - **internal check: overlapped evacuees**
- The remaining people with **premovtime** > 0, to trace people who are still waiting to start the evacuation - **plot premovtime**
- **Indsim** (at the current simulation repetition, decreasing from the initial value form the MAPS input & simulation repetitions panel), **initusers**, **maxtickspeed**

#### 4.6.2 Final outputs

The main outputs are organized between the output variables in Table 8 and Table 9, and the csv files in Table 10. All the csv files have the comma “,” as delimiter and uses dot (“.”) as decimal separator, to be setup for the csv import on excel. The files have variable number of columns.

All the csv files are composed to create new files depending on the input main variables discussed above, so as to trace the conditions tested. In this sense, the output files will be consistent variables with inputs in the input panels of the simulation from setup model setup and the *simulation from setup* module.



Table 8. *WlbetOO\_result* organization

Column [unit of measure]: meaning					Notes to rows
1	2	3	4	5	
<i>evaluateUTCI</i> [-]: UTCI value to be checked	<i>sweatrate</i> [g/hours]: see D4.2.3	<i>count patches with [sector &lt; 3 and sector &gt; -1 and UTCI = evaluateUTCI]</i> [number of patches]: number of patches with the given UTCI, considering only the outdoor area	<i>transient evaluateUTCI</i> [%]: relating to the OO, so based on transient acceptability, and ranging from 0 to 100	<i>sweatrate * count patches with [sector &lt; 3 and sector &gt; -1 and UTCI = evaluateUTCI] * ((transient evaluateUTCI) / 100)</i> [g/hours * number of patches * %]: sweat rate considering the patches with the given UTCI, and considering the transient acceptability. Equal to <b>Wlnum</b> for a given UTCI	The rows are repeated for the overall number of <i>evaluateUTCI</i> in the model (13 UTCI value in the current model version, ranging from 24 to 37°C). See <b>WlbetOO</b> in the code to modify the values
...	...	...	...		Same as the first line, repeated until maximum evaluated UTCI
<b>Wlnum</b> / <i>totalareaforusers</i> [g/hours]: ratio between the overall sweat rate considering the probability to occupy the patches, and the total area for OO	<b>tcrit</b> * <i>Wlnum</i> / <i>totalareaforusers</i> [g]: ratio of column 1 scaled by the critical evaluation time <b>tcrit</b> . See D4.2.3 for the analysis of the result				The last row shows the synthesis of data



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Table 9. Organization of main variables included in the csv file as reported in Table 10.

Column [unit of measure and meaning]					Notes to rows
<b>starteddata</b>					
<b>1</b>	<b>2, 3, 4</b>	<b>5, 6, 7, 8</b>	<b>9</b>	<b>10</b>	Number of rows = number of initially generated evacuees, including the one who will not participate in the evacuation
<i>indsim</i> [current simulation repetition]	<i>who</i> [identification code of the <i>evacuee</i> ], <i>xcor</i> , <i>ycor</i> [coordinates about the initial position]	<i>fam-type</i> , <i>gender-type</i> , <i>age-type</i> , <i>position-type</i> [characterization according to Section 4.1.1]	<i>premovtime</i> [s]	<i>desspeed</i> [m/s] at the starting moment, <i>maxspeedage</i> [m/s]	
<b>arrivedata</b>					Number of rows = number of evacuees arrived at a safe area. Column7 will be equal to 0 or higher. Column 8 depends on the initial position of the evacuee, on the affordance-based motion rules and on the crowd density
<b>1</b>	<b>2, 3, 4</b>	<b>5</b>	<b>6</b>	<b>7, 8</b>	
<i>indsim</i> [current simulation repetition]	<i>who</i> [identification code of the <i>evacuee</i> ], <i>xcor</i> , <i>ycor</i> [coordinates about the initial position]	<i>position-type</i> [characterization according to Section 4.1.1]	<i>ticks</i> / <i>maxtickspeed</i> [evacuation time in seconds]	<i>fallcounter</i> [number of the users' falls], <i>pathlength</i> [length of the path scaled by the <i>patchsize-m</i> ]	
<b>deathbyattack</b>					Number of rows = number of evacuees killed by the attack in case of terrorist act
<b>1</b>	<b>2, 3, 4</b>	<b>5</b>			
<i>indsim</i> [current simulation repetition]	<i>who</i> [identification code of the <i>evacuee</i> ], <i>xcor</i> , <i>ycor</i> [coordinates about the initial position]	<i>ticks</i> / <i>maxtickspeed</i> [evacuation time to death in seconds]			



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<b>pathusetot_tocsv</b>					
1, 2		3			
<b>pxcor</b> , [coordinates of the patch]	<b>pycor</b>	<b>(patusetot / indsimtot) / maxuse</b> [(total number of times an evacuee occupies the patch for all the simulation repetitions for the given patch / total number of repetitions) / (maximum value, between the patches, of the ratio between total number of times an <b>evacuee</b> occupies the patch / total number of repetition)]			Number of rows = number of patches. Column 3 varies from 0 (not used patch) to 1 (most used patch)
<b>falltot_tocsv</b>					
1, 2		3			
<b>pxcor</b> , [coordinates of the patch]	<b>pycor</b>	<b>(falltot / indsimtot) / maxfall</b> [(number of falls for all the simulation repetitions for the given patch / total number of repetitions) / (maximum value, between the patches, of the ratio between number of falls for all the simulation repetitions for the given patch / total number of repetition)]			Number of rows = number of patches. Column 3 varies from 0 (patch without falls) to 1 (patch with the highest number of falls)
<b>falldata</b>					
1	2	3			
<b>indsim</b> [current simulation repetition]	<b>ticks / maxtickspeed</b> [evacuation time to death in seconds]	<b>falltotpertick</b> [number of fallen evacuee in the current tick]			Number of rows = number of ticks, so of the overall evacuation time
<b>data_all_seismicsim</b>					
1, 2, 3, 4	5, 6, 7	8, 9	10, 11		
<b>indsim</b> [current simulation repetition], <b>SAP</b> , <b>noncollapsed</b> , <b>(count evacuees)</b> [initial number of evacuees, including the ones who	<b>safeevacuees</b> [number of evacuees in outdoor, and in free-of-debris patches], <b>seismicevacPP</b> [number of evacuees who participate in the	<b>outarea</b> [overall outdoor area, no obstacles, but green areas included] <b>area_nodebris</b> [potential safe area, that is the	<b>SA_dens</b> [density of people in the potential safe area <b>area_nodebris</b> ], <b>SA_densFSU</b> [density of people in the potential		First row: statically analyzing the density of users in outdoor free-of-debris area depending on their possibility to reach one of these



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will not participate in the evacuation]	evacuation depending on <i>SAP</i> and <i>noncollapsed</i> ], <b>FSU</b> [number of <i>evacuees</i> entering the square]	outdoor area without debris]	safe area, <i>area_nodebris</i> , including FSU]		patches in any <b>evacuationmode</b> condition
<b>1, 2, 3, 4</b>	<b>5</b>	<b>6</b>	<b>7, 8</b>	<b>9, 10</b>	Second row: final simulation values, only in case of <b>evacuationmode</b> = "entering"
<b>indsim</b> [current simulation repetition], <b>SAP</b> , <b>noncollapsed</b> , ( <b>count evacuees</b> ) [final number of evacuees, that is the ones who did not stop moving]	<b>seismicevacPP</b>	<b>usersdebris_end</b> [final number of <i>evacuees</i> occupying a <i>patch</i> with debris]	<b>outarea, SA_dens</b>	<b>SAspontarea</b> [area occupied by <i>evacuees</i> who stopped the evacuation, considering free-of-debris area], <b>SAspontpers</b> [density of people in the spontaneous area]	

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Table 10. CSV output files from simulation from setup model

Csv:to-file (word)	Number of columns (rows)	Variables [applied to]: definition	Notes
"WLbetOO" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	5 (13 rows) + 2 (last row)	<b>WLbetOO_result</b> [overall results – world]: See Table 8	SLOD conditions evaluations to express, in the last row: (1) the sweat rate depending on the outdoor area conditions (UTCI, area, transient probability) and (2) the related water loss.
"_MAINDATA" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-SAP=" SAP "-noncollapsed=" noncollapsed "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	4	<b>Outputnumbersynth</b> [overall results – world]: <i>indisim</i> , <i>count evacuees</i> , <i>deathsnumber</i> , time now (-1 for the beginning of the simulation, <i>ticks</i> / <i>maxtickspeed</i> when the simulation is performed)	synthesis of the main outputs to save data in csv file. Number of lines = simulated ticks
"evacuees_started" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	8	<b>starteddata</b> [each of the <i>evacuees</i> ]: See Table 9	Data on the starting positions and characterization of the <i>evacuees</i>
"evacuees_arrived" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	8	<b>arriveddata</b> [each of the <i>evacuees</i> ]: See Table 9	Data on the final positions and characterization of the <i>evacuees</i> who arrived at a safe area
"deathbyattack" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	5	<b>deathbyattack</b> [each of the <i>evacuees</i> ]: See Table 9	Data on the final positions and characterization of the <i>evacuees</i> killed by the terrorist act. Only in <i>evacuationmode</i> = "entering" and <i>attack?</i> = on (true)
"space_use" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"	4	<b>space_use</b> [each of the <i>patches</i> ]: <i>indisim</i> , <i>pxcor</i> , <i>pycor</i> , <i>path</i> (total number of times an <i>evacuee</i> occupies the patch in the <i>indisim</i>	Use of the patches by the <i>evacuees</i> in the current simulation repetition



		given <i>indism</i> simulation repetition)	
"space_fall" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	4	<b>space_fall</b> [each of the <i>patches</i> ]: <i>indsim</i> , <i>pxcor</i> , <i>pycor</i> , <i>fallnumber</i> (total number of times an <i>evacuee</i> falls when staying on the patch in the given <i>indism</i> simulation repetition)	Use of the patches by the <i>evacuees</i> in the current simulation repetition <i>indism</i>
"space_usetot" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	3	<b>space_usetot</b> [each of the <i>patches</i> ]: See Table 9	Normalized use of the patches by the <i>evacuees</i> in the whole number of repetitions
"space_falltot" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	3	<b>space_falltot</b> [each of the <i>patches</i> ]: See Table 9	Normalized number of falls for the patches in the whole number of repetitions
"fallpertime" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	3	<b>falldata</b> [each of <i>ticks</i> in the simulation]: See Table 9	Number of <i>evacuees</i> fallen during the evacuation time, for a given simulation repetition
"seismicsim" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-SAP=" SAP "noncollapsed=" noncollapsed "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	11 (first row) + 10 (second row)	<b>data_all_seismicsim</b> : see Table 9	Data on the seismic evacuation in static (first row) and dynamic (second row) conditions
"statsum" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-SAP=" SAP "noncollapsed=" noncollapsed "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "_" evacuationmode ".csv"	33	<b>statsummary_start_evac</b> : <i>indsim</i> , <i>initusers</i> , <i>SB</i> , <i>OO</i> , <i>PO</i> , <i>BU</i> , <i>killedbyattack</i> [in case of terrorist act], <i>notevacuating</i> [number of not evacuating users in any <i>evacuationmode</i> conditions], <i>alfa</i> , <i>beta</i> , <i>gamma</i> , <i>delta</i> , <i>SBevac?</i> ,	List of the variables characterizing the simulation repetition <i>indsim</i> , both considering the input panels and the initial <i>evacuees</i> setup. Number of rows = <i>indsim</i>





		<i>BUevac?, attack?, attackradius, SAP, TSAP, noncollapsed, maxspeed, minspeed, denscrit, densstop, distrepobst, densfall, probfall, waitfalltime, tcrit, premovtime-max, BETmap_IN, UTCImap_IN, SEISMICmap_IN, ATTACKmap_IN</i>	
<i>"insideattheend" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-" SAP=" SAP "-noncollapsed=" noncollapsed "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" evacuationmode ".csv"</i>	3	<i>endpositionslist: pxcor, pycor, (endpositions / indsimtot)</i>	Number of rows = number of patches. It considers the average data on each patch use at the end of each simulation repetition ( <i>endpositions</i> ) for evacuees still inside the BET and who did not reached a safe area
<i>"risk" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "e" FSUp "-" evacuationmode ".csv"</i>	3	<i>riskdata: pxcor, pycor, risk</i>	Number of rows = number of patches. It considers the risk calculated at the beginning of the simulation & thus, Number of rows = number of patches (thus, the one imported from setup creation if <i>riskupload? = true</i> )
<i>"attackriskovertime" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "e" FSUp "-" evacuationmode "=" attacktype "@" redrawrisk "-" indsim ".csv"</i>	4	<i>pxcor, pycor, risk, redrawrisk</i>	A csv file with values of cells each 10s of simulation, for each simulation repetition.

A quick visualization of the outputs is also provided through bmp files, as shown by Table 11. Figure 8 offers examples of the visualization for each of the bmp. *Fdtview*, *Obsitview*, *seismicdistance*, and *Risk of patch* are also visualized and exported to point out *Fdt*, *Obsit*, *Fdt* in *seismicdistance* (earthquake only) and risk values for the patches, according to general remarks of outputs in Section 3.4.

Table 11. BMP output files from simulation from setup model

export-view (word)	Meaning and visualization bases	Conditions & tips
--------------------	---------------------------------	-------------------



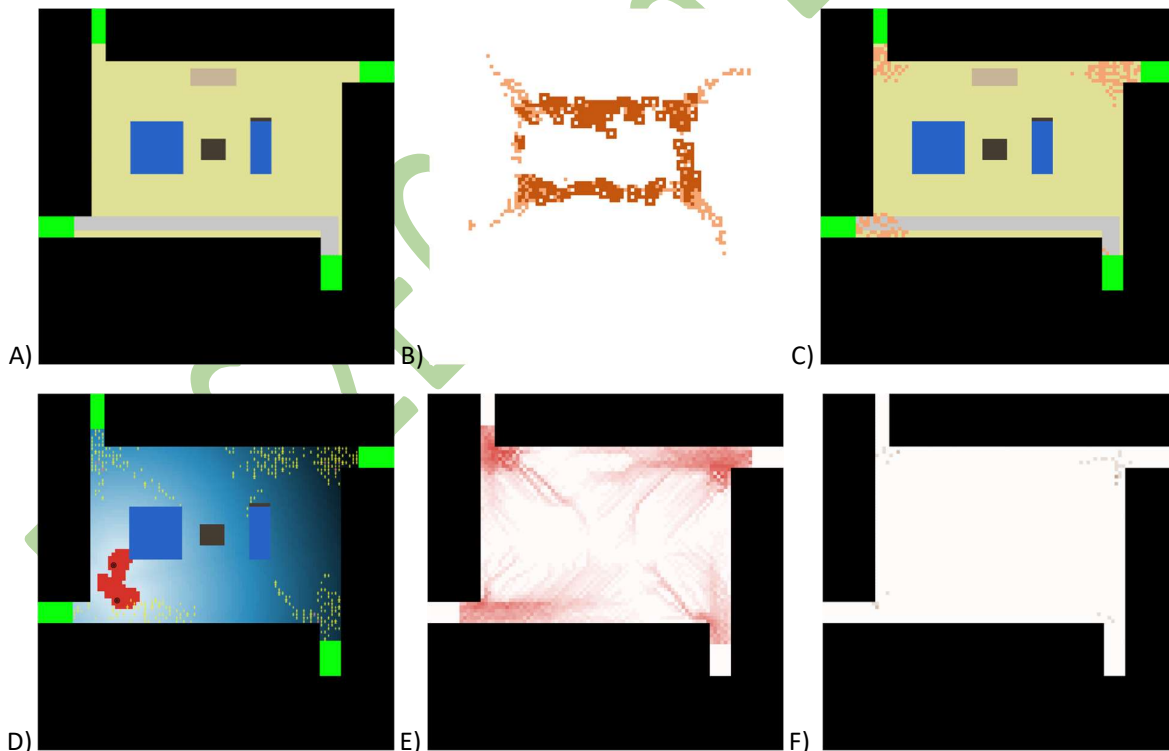
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<p>"Seismicevac" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "_" indsim "_" <b>evacuationmode</b> ".bmp"</p>	<p>The patches where the evacuees spontaneously stop in case of earthquake evacuation (dark orange) and the ones who are still moving at the end of the evacuation (light orange). No other displayed data.</p>	<p>only for <b>evacuationmode</b> = "entering". A bmp file per simulation repetition</p>
<p>Attackevac" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "_" indsim "_" <b>evacuationmode</b> ".bmp"</p>	<p>The patches occupied by evacuees who are still moving at the end of the evacuation (light orange). Including the BET areas visualization from <b>BETmap_IN</b>.</p>	<p>only for <b>evacuationmode</b> = "leaving". A bmp file per simulation repetition</p>
<p>"attackriskovertime" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "_" <b>evacuationmode</b> "=" <b>attacktype</b> "@" redrawrisk "-" indsim ".bmp"</p>	<p>The risk of patches depending on the distance from the source of the attack, dynamically calculated for <b>attacktype</b> = <b>weapon</b> or <b>truck</b>, according to Section 4.4.2. Including the BET areas visualization from <b>BETmap_IN</b>, but the patches outdoor show the risk color from red (maximum risk for killing <b>attackradius</b>) to white (<b>risk</b> = 1) to blue (minimum risk, <b>risk</b> = 0)</p>	<p>A bmp file per 10s of simulation, for each simulation repetition.</p>
<p>"Pathuse" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "_" indsim "_" <b>evacuationmode</b> ".bmp"</p>	<p>Path use conditions as in <b>space_use</b>, using white (no use) to red (maximum use) color scale, showing the buildings background</p>	<p>A bmp file per simulation repetition. For <b>indsim</b> = 1, it generates similar result of <b>Pathusetot</b></p>
<p>"Falls" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "_" indsim "_" <b>evacuationmode</b> ".bmp"</p>	<p>Path use conditions as in <b>space_fall</b>, using white (no use) to dark brown (maximum use) color scale, showing the buildings background</p>	<p>A bmp file per simulation repetition. For <b>indsim</b> = 1, it generates similar result of <b>Falltot</b></p>
<p>"endpositions" <b>target-visibility-factor</b> "-" xcell "x" ycell "-" UOOd "e" FSUp "-"ALFA" alfa "-"BETA" beta "-"GAMMA" gamma "-"DELTA" delta "_" indsim "_" <b>evacuationmode</b> ".bmp"</p>	<p>Average data on the use at the end of the simulation for people still inside the BET according to <b>endpositionslist</b>. No other displayed data.</p>	<p>A bmp file per all the simulation repetitions</p>

<p>"Pathusetot" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" indsim "-" evacuationmode ".bmp"</p>	<p>Overall normalized path use according to <b>space_usetot</b>, using white (no use, 0) to dark red (maximum use, 1) color scale, showing the buildings background</p>	<p>A bmp file per all the simulation repetitions. The file is automatically generated at the ends of the simulations, but the <b>openpath</b> and <b>openpathav</b><sup>3</sup> buttons in <i>results upload</i> interface can be used to generate bmp after simulations, if <b>USE_upload</b> refers to the <b>space_usetot csv</b> file in the same folder of the model</p>
<p>"Falltot" target-visibility-factor "-" xcell "x" ycell "-" UOOd "e" FSUp "-ALFA" alfa "-BETA" beta "-GAMMA" gamma "-DELTA" delta "-" indsim "-" evacuationmode ".bmp"</p>	<p>Overall normalized path use according to <b>space_falltot</b>, using white (no fall, 0) to dark red (maximum falls, 1) color scale, showing the buildings background</p>	<p>A bmp file per all the simulation repetitions. The file is automatically generated at the ends of the simulations, but the <b>openfall</b> button in <i>results upload</i> interface can be used to generate bmp after simulations, if <b>FALL_upload</b> refers to the <b>space_falltot csv</b> file in the same folder of the model</p>



<sup>3</sup> in this case, the use bmp file considers a weighted use conditions for non used cells (**space\_usetot** value = 0) depending on the average conditions of the 4 neighbors.



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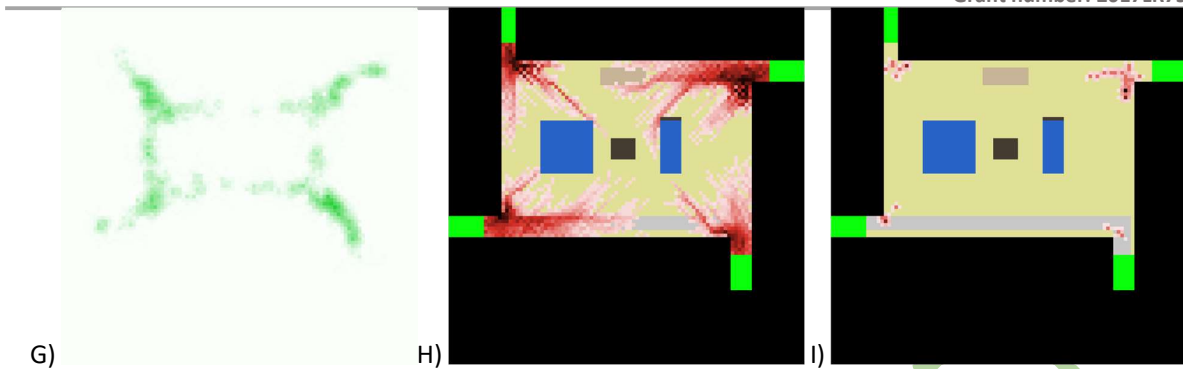


Figure 8. Bmp files example: A) the initial BET with its areas; B) *seismicevac* (only for *evacuationmode* = *entering*); C) *attackedvac* (for *evacuationmode* = *leaving*); D) *attackriskovertime*; E) *Pathuse*; F) *Falls*; G) *endpositions*; H) *pathsuetot*; I) *falltot*

It is worth noticing that all the output csv and bmp files should be copied in a separate folder before re-starting a new simulation session with the same motion variable parameters in inputs, since the files will be overwritten.

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## 5. Simulations to be performed: suggestions

Table 12 resumes the general setup parameters for *simulation from setup* model, while Table 13 includes specific values which can both used in the *setup creation model* and in the *simulation from setup* model. *indsim* could be equal to 1 to reduce computational efforts in multiple simulations, but at least 10 repetitions of the simulation are encouraged (not less than 3, anyway). Stricter rules for defining the number of simulations are reported in (van der Wal et al. 2017), section 3.2 (Simulation experiments setup – number of repetitions).

Table 12. Input data on users: suggested values to simulate working days (W) and holidays (H) depending on D3.2.3 scenarios.

KPI	Max (W : H)	Med (W : H)	Min (W : H)
UOod [pp/m2]	0.55 : 0.36	0.22 : 0.20	0.06 : 0.06
OOp [%]	48 : 49	15 : 23	0 : 0
POp [%]	6 : 4	1 : 1	0 : 0
NRp [%]	82 : 67	48 : 33	0 : 0
<b>Common values in both W and H</b>			
SBd [pp/m2]	0.4 (most common depending on building uses) or 0.7 (conservative, i.e. could be chosen for H)		
Areas dimension for the BET simulation	<i>Special buildings:</i> 1200mq <i>Square area (outdoor):</i> depending on the BET configuration <i>Vehicular area:</i> 30% <i>Pedestrian area:</i> 65% <i>Dehors:</i> 2 to 5% <i>Permanent obstacles:</i> 1 to 2%		
FSUp [%]	<i>For terrorist act:</i> 0 <i>For earthquake:</i> 31 (Q1); 45 (median); 64 (Q3)		
TUp [%]	4		
PCp [%]	9		
YAp [%]	5		
AUp [%]	64		
Fp [%]	52		

Table 13. Suggested variables combinations for relevant simulations.

Variables	Suggested values	Other values to try	Notes
<b>1) GENERAL VARIABLES</b>			
<i>distrepobst</i>	3	n.a.	Patch coordinates according to the inputmap, and so depending on <b>xcell</b> , <b>ycell</b> and <b>patchsize-m</b>
<i>target-visibility-factor</i>	4	1, 2, 8	Higher the value, higher the impact of visibility and possibility to reach the exit from the current patch
<i>patchsize-m</i>	0.5	0.35, 0.7, 1	Lower the value, higher the computation time. 0.35 is the

			minimum grid dimension, to represent the shoulder width and move up to 6 persons per square meter
<i>viewcone</i>	200°		<a href="#">Appendix 11.1.pdf (epd.gov.hk)</a> (last access: 3/2/2022)
<i>densfall</i>	3	0.9 for <i>patchsize-m</i> = 1, 6 for <i>patchsize-m</i> < 1	
<i>probfall</i>	5		(van der Wal et al. 2017)
<i>densfall</i>	3	4.4 (LOS E value (Klüpfel and Meyer-König 2014)), 5.3 (LOS F value (Klüpfel and Meyer-König 2014; Zlateski et al. 2020)) considering limits for waiting individuals	Conservative approach by (Bernardini et al. 2016a). It also depends on the <i>patchsize-m</i> value: i.e., for 0.50m, do not use values > 4pp/m <sup>2</sup>
<i>waitfalltime</i>	30		(van der Wal et al. 2017)
<i>tcrit</i>	0.25		D4.2.3, equal to transient timing limits for acceptability of outdoor UTCI (15') (Cheunga and Jim 2019)
<i>premovtime-max</i>	0		Focusing on simultaneous movement of people, that can increase crowd effects
<i>maxsimtime</i>	600		10 minutes-limit for first evacuation phase
<i>bucperc</i>	20	5 to 50 range	Arbitrarily assumed
<b>2) GENERAL TERRORIST ACT EVACUATION SIMULATION</b>			
<i>Alfa, beta, gamma, delta</i>	0, 0, 1, 0		Leaving in terrorist acts depending on risk as the main driver, thus searching for possible refuge behind obstacles
		0, 1, 0, 0	Just moving towards the target with no surrounding influence
		0, 0.25, 0.75, 0	Moving towards the lower risk patches but distancing from the attack source, thus aiming at reaching an access street
		0.2, 0.2, 0.6, 0	Moving with no influence of permanent obstacles
<i>evacuationmode</i>	leaving		To activate terrorist act
<i>attack?</i>	true		To activate terrorist act
<i>BUevac?</i>	false		People in the other buildings will not suffer from the evacuation needs
<i>riskupload?</i>	false		To recalculate the risk map depending on the <b>ATTACKmap_IN</b>
<i>maxspeed</i>	2.50	1.34	(Bernardini and Quagliarini 2021);
<i>minspeed</i>	0.72	0	second possibility by (Bruno and



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<i>denscrit</i>	2.67	5.4	Venuti 2008) for general purposes motion – conservative for motion speed
<i>kfact</i>	-0.14	1.913	
<i>densstop</i>	5.4	0.9 for <i>patchsize-m</i> = 1	(Bruno and Venuti 2008)
<i>TSAP</i>	50 or 55		Assuming that 50 to 55% of attack did not cause any deaths <sup>4</sup> , but the value depends on the attack source, e.g. for weapon attack / car attack
	100		Bomb or truck attack (recommended in view of the attack conditions), conservative assumptions in terms of casualties' number
<i>SAP, noncollapsed</i>	100		To avoid killing people because of debris. In case debris are generated (e.g. due to an explosion), the SEISMICmap_IN can be used to provide data on where they are located
<b>2.1) TERRORIST ACT TO A SPECIAL BUILDING</b>			
<i>ATTACKmap_IN</i>	One area in the png file		Different positions depending on the area where the attack happens for bomb or weapon attack, near the special building entrance
<i>SBevac?</i>	true		People in the Special Building will evacuate, if the attack happens in it
<i>Attacktype</i> + <i>attackradius</i>	Weapon + 1		Knife attack; ideally 1 or 2 <b>Nweapons</b>
	Bomb + ...		No specific value for the bomb radius attack
<b>2.2) TERRORIST ACT IN THE SQUARE</b>			
<i>ATTACKmap_IN</i>	One area in the png file		Different positions depending on the area where the attack happens for bomb or weapon attack
	Two areas in the png file		Different positions to create the starting and ending point of the attack by truck
<i>Attacktype</i> + <i>attackradius</i>	Weapon + 1		Knife attack; ideally 1 or 2 <b>Nweapons</b>
	Truck + 3		Truck attack
<i>truckspeed</i>	25		To replicate a truck moving at about 90km/h
<b>3) EARTHQUAKE EVACUATION SIMULATION</b>			
<i>Alfa, beta, gamma, delta</i>	0, 0.75, 0, 0.25		Trying to move far from all the obstacles
		0, 1, 0, 0	Just moving towards the target with no surrounding influence

<sup>4</sup> <https://www.economicsandpeace.org/wp-content/uploads/2016/11/Global-Terrorism-Index-2016.2.pdf> (last access: 12/1/2022)

		0.25, 0.75, 0, 0	Trying to move far from crowded areas
		0.15, 0.7, 0, 0.15	Intermediate conditions for crowd and obstacles impact
<i>evacuationmode</i>	entering		
<i>ATTACKmap_IN</i>	Two areas in the png file		To simulate the starting and the arrival point of the truck moving towards the crowd in straight line, near the special building entrance
<i>maxspeed</i>	3.29	1.34	(Bernardini et al. 2016b); second possibility by (Bruno and Venuti 2008) for general purposes motion – conservative for motion speed
<i>minspeed</i>	0.71	0	
<i>denscrit</i>	5.3	5.4	
<i>kfact</i>	-0.8	1.913	
<i>densstop</i>	8	0.9 for <i>patchsize-m</i> = 1	(Hankin and Wright 1958), significantly greater than <i>denscrit</i>
<i>SAP</i>	88		(Kang et al. 2017)
<i>noncollapsed</i>	100		Conservative approach to maximize evacuees' number
<i>seismicdistfin</i> + <i>seismicrandompatch</i>	0 + 500		Arbitrary assumptions confirmed by preliminary verification results

## 6. Main outputs analysis in the simulations from setup model

The following analysis can be carried out for the specific csv and bmp files derived by the *simulation from setup* model multiple running. Details on the MATLAB analysis process are reported in Section 6.1.

**WLbetOO.csv:** Last line of the csv file reports the main results: **(column 1)** except of *tcrit*; **(column 2)** including *tcrit* effects. Multiple simulations are recommended because the computation of water loss SLOD effects adopts a random approach to the *transient evaluateUTCI* calculation, but values of UTCl close to 30°C can generate small differences in view of the transient acceptability equation used in this work (Cheunga and Jim 2019). In case of repeated simulation (so more than one WLbetOO.csv file for the same scenario), you can just copy the last row and append it into a new single file. Statistics of the [WLnum / totalareaforusers] (as the first value of the row) and of [tcrit \* WLnum / totalareaforusers] can be performed (e.g. percentile-based + means and standard deviation).

**\_MAINDATA\*.csv + evacuees\_arrived\*.csv:** tracing the number of evacuees and deaths over time, in each simulation repetitions and in as an overall sample (by means of mean and standard deviation data calculation). The matlab routine “*evacgraph.m*” is provided to visualize and save main data on the process:

```
function [filename, singleevacfile, stattime, syntmeansample, timepercs,
flowsontimepercs, out, meanstdevperc_sim, fallsummary, summary] = evacgraphs
(evacdata, ceilingvalue, singleevacdata)
```

To use the routine, the *\_MAINDATA\*.csv* (that is *evacdata*) and the *evacuees\_arrived\*.csv* (that is *singleevacdata*) must be in the same folder of “*evacgraph.m*”. You can rename the files as you want.



*Ceilingvalue* is the discretization time, and could be posed equal to 1s, 2s, 5s or 10s. Higher *ceilingvalue*, ideally higher the standard deviation at each considered output tick is (because of the time dimension in which statistics are calculated for the given output tick). As an output, the file provides:

**-filename** as the `_MAINDATA*.csv` array file and **singleevacfile** as the `evacuees_arrived*.csv`;

**-stattime** as an array composed of 8 columns, divided into 1 column for the time of output tick according to *ceilingvalue* and 7 columns of statistics of the sample at the given output tick time (min, mean, max, standard deviation, 5<sup>th</sup> percentile, 50<sup>th</sup> percentile=median, 95<sup>th</sup> percentile, percentage of evacuees over the time and referring to the 50<sup>th</sup> percentile). Data for time=0 are not reported (if you want to include it, please save **statgraph** as output of the routine instead of **stattime**);

**-syntmeansample** as an array composed by 4 columns, divided into 1 column for the time of output tick according to *ceilingvalue* and 3 columns of statistics of the sample at the given output tick time (mean, percentage standard deviation [%] calculated as the standard deviation divided by the mean, and standard deviation)

**-timepercs** as an array resuming the percentiles (5,25,50,75,95) of evacuation timings of users. It is composed of a single line, with 5 columns

**-flowsontimepercs** as an array resuming the flows per time percentiles (thus depending on *timepercs*), regardless of dimensions of exits or arrival area. It is composed of a single line, with 5 columns

**-out** as an array containing the simulation data per output tick times, in the following columns: *indsim*, number of people inside, number of death, simulation time (discretization according to *ceilingvalue*), arrived evacuees, simulation time (discretization - repeated)

**-meanstdevperc\_sim** as a two values array, reporting the average percentage standard deviation [%] and the one at the 95<sup>th</sup> percentile of evacuation timings

**-fallsummary** as a single row array reporting the 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentiles of number of falls by the people, the mean number of falls per persons, and the count of people who fall at least one time

**-summary** as a single row array with 7 values that are: the initial number of evacuees in the square; initial number of evacuees participating to the process and including the ones from streets; mean number of arrived evacuees; mean number of non arrived evacuees; time and then flow at the 95<sup>th</sup> percentile of arrived evacuee; counting people who falls at least one time; 50<sup>th</sup> percentile of deaths

The routine also provides 3 graphs to check results for each repetition of the simulation (figure 1= people continuing evacuating over time, per simulation; figure 2= people completing the evacuation over time, per simulation; figure 3=people completing the evacuation over discretized time, per simulation) and 2 graphs to resume aggregate data (figure 4=people completing the evacuation over discretized time: aggregated data; figure 5=people completing the evacuation over discretized time: mean and st.dev). You can save the data as tiff files or fig files.

If you prepared different files of the same scenario in different *evacdata* and *arrived* files, you should append them by changing *indsim* to avoid duplicated data on different simulation. This process should be performed before performing the routine.

**Pathusetot, Falltot, endpositions:** providing maps on the most critical parts of the BET in terms of use (to be included, e.g. for Virtual Reality purposes in addressing the paths of the avatars), falls and final positions of the users. These data can be used only for merged repetitions. In case the simulations are repeated in different sections (so  $\text{indsim} < \text{total number of repetitions}$ ), the related csv data should be merged and assessed by Matlab, e.g. by `hist3` function.

### 6.1 MATLAB analysis procedure: details

The MATLAB-based organization of the data is organized according to the following steps.

First, MAINDATA and ARRIVED csv files should be merged considering the files for the same scenario (all the simulations and repetitions). E.g., you can use automatic procedures of csv appending<sup>5</sup>.

Then, you can import the files in a folder where the `ordersim.m` and `evacgraphs.m` and `renamevars.m` matlab function are uploaded. `Evacgraphs.m` uses `ordersim.m` to reorder the simulations of the csv files (appended files) and then provides some graphs of the simulation evacuation curves (in separate and aggregate manner) and the matlab files discussed above. `Renamevars.m` rename the variables by adding a column with the name of the specific simulation scenario according to the rules in [https://univpm.sharepoint.com/:o:/r/sites/be.s2ecure/Documents/Documenti%20condivisi/WP4/T4.1/model%20example/BET%20setup/Terrorismo\\_risultati/come%20rinominare%20i%20file%20mat%20e%20le%20variabili%20in%20essi?d=w3b7864fa4c124a7a9e949a716c102747&csf=1&web=1&e=kwgORI](https://univpm.sharepoint.com/:o:/r/sites/be.s2ecure/Documents/Documenti%20condivisi/WP4/T4.1/model%20example/BET%20setup/Terrorismo_risultati/come%20rinominare%20i%20file%20mat%20e%20le%20variabili%20in%20essi?d=w3b7864fa4c124a7a9e949a716c102747&csf=1&web=1&e=kwgORI) (for terrorist acts) and <https://univpm.sharepoint.com/:o:/r/sites/be.s2ecure/Documents/Documenti%20condivisi/WP4/T4.1/model%20example/BET%20setup/Scenari%20sisma/come%20rinominare%20i%20risultati%20per%20simulazione%20sisma?d=waa238281e16e4c4f92e551547141c7d3&csf=1&web=1&e=gi2lXe> (for earthquake). The rename process is guided by the `addname` function variable, which should be properly defined by the user according to the rules in the above links. Remember that:

`%addname` is a string, e.g. `'2A_meBN'`

Always check that the `meanstdevperc_sim*` files are composed by 3 columns. In case they are not, check the 95 percentile value directly in the related `syntmeansample` table, column 3, corresponding to the 95% of evacuees (see column 2, "mean"). Create a 2<sup>nd</sup> column in the `meanstdevperc_sim*` files, named `SimName`; move the name of the sim in this last position; copy the value from `syntmeansample` table and paste it as a second column in `meanstdevperc_sim*`, by renaming the column "at95".

Then, you should: (1) perform the lines in "lancia `evacgraph` e `renamevar` per tutti gli scenari.m" changing the codes when needed; and (2) upload all the mat files in the workspace and launch the lines in "creare i file di sintesi.m" changing TUT with the code needed, to create the summary of the tables in the mats.

---

<sup>5</sup> **NOTE TO ITALIAN USERS:** Essenzialmente puoi iniziare facendo il solo `append` dei csv, es. anche tramite `commandwindow` (vedi qui <https://www.exceldeemy.com/merge-excel-files-into-one-using-cmd/#Step-03-Using-Some-Commands-to-Merge-Excel-Files-into-One-Using-CMD>). Non serve che prima di fare l'`append` riordini le simulazioni (cambi i numeri della prima colonna di ogni csv). Una volta creato il file, lo devi aprire con excel e devi rimuovere l'ultima riga del csv. Fai semplicemente salva.

A questo punto hai un file in cui la prima colonna ha numeri ripetuti a seconda delle simulazioni fatte per ogni ripetizione. A questo punto importi il file con il nuovo `evacgraphs.m`, che ti riordina le simulazioni. Il funzionamento della funzione `evacgraph` per il calcolo degli output resta il medesimo. NON FUNZIONA SE PER OGNI RIPETIZIONE HAI UNA SOLA SIMULAZIONE NELL'EXCEL ORIGINARIO.



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### 8. Input rapid configuration in the simulation from setup model

The following algorithm is activated by *rapidinput* button, to rapidly select some of the most significant input conditions. Pay attention that this does not include all the parameters!

to rapidinput

if rapidinputselector = "Working day: leaving - SBd=0.7"

```
[
  set SBd 0.7
  set UOOd 0.22
  set OOp 15
  set POp 1
  set NRp 48
  set FSUp 0
  set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
  set alfa 0 set beta 0 set gamma 1 set delta 0
  set evacuationmode "leaving"
]
```

if rapidinputselector = "Working day: leaving - SBd=0.4"

```
[
  set SBd 0.4
  set UOOd 0.22
  set OOp 15
  set POp 1
  set NRp 48
  set FSUp 0
  set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
  set alfa 0 set beta 0 set gamma 1 set delta 0
  set evacuationmode "leaving"
]
```

if rapidinputselector = "Working day: entering - SBd=0.7"

```
[
  set SBd 0.7
  set UOOd 0.22
  set OOp 15
  set POp 1
  set NRp 48
  set FSUp 45
  set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
  set alfa 0 set beta 0.75 set gamma 0 set delta 0.25
  set evacuationmode "entering"
]
```

if rapidinputselector = "Working day: entering - SBd=0.4"

```
[
  set SBd 0.4
```

```
set UOOd 0.22
set OOp 15
set POp 1
set NRp 48
set FSUp 45
set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
set alfa 0 set beta 0.75 set gamma 0 set delta 0.25
set evacuationmode "entering"
]
```

```
if rapidinputselector = "Holiday: leaving - SBd=0.7"
```

```
[
set SBd 0.7
set UOOd 0.20
set OOp 23
set POp 1
set NRp 33
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Holiday: leaving - SBd=0.4"
```

```
[
set Sbd 0.4
set UOOd 0.20
set OOp 23
set POp 1
set NRp 33
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Holiday: entering - SBd=0.7"
```

```
[
set SBd 0.7
set UOOd 0.20
set OOp 23
set POp 1
set NRp 33
set FSUp 45
set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
set alfa 0 set beta 0.75 set gamma 0 set delta 0.25
set evacuationmode "entering"
]
```

]

if rapidinputselector = "Holiday: entering - SBd=0.4"

[

set SBd 0.4

set UOOd 0.20

set OOp 23

set POp 1

set NRp 33

set FSUp 45

set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88

set alfa 0 set beta 0.75 set gamma 0 set delta 0.25

set evacuationmode "entering"

]

if rapidinputselector = "Working critical - entering"

[

set SBd 0.7

set UOOd 0.55

set OOp 48

set POp 6

set NRp 82

set FSUp 45

set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88

set alfa 0 set beta 0.75 set gamma 0 set delta 0.25

set evacuationmode "entering"

]

if rapidinputselector = "Holiday critical - entering"

[

set SBd 0.7

set UOOd 0.36

set OOp 49

set POp 4

set NRp 67

set FSUp 45

set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88

set alfa 0 set beta 0.75 set gamma 0 set delta 0.25

set evacuationmode "entering"

]

if rapidinputselector = "Working critical - leaving"

[

set SBd 0.7

set UOOd 0.55

set OOp 48

set POp 6



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```
set NRp 82
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Holiday critical - leaving"
```

```
[
set SBd 0.7
set UOOd 0.36
set OOp 49
set POp 4
set NRp 67
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Working non critical - leaving"
```

```
[
set SBd 0
set UOOd 0.22
set OOp 15
set POp 1
set NRp 48
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Holiday non critical - leaving"
```

```
[
set SBd 0
set UOOd 0.20
set OOp 23
set POp 1
set NRp 33
set FSUp 0
set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
set alfa 0 set beta 0 set gamma 1 set delta 0
set evacuationmode "leaving"
]
```

```
if rapidinputselector = "Working non critical - entering"
```



```
[
  set SBd 0
  set UOOd 0.22
  set OOp 15
  set POp 1
  set NRp 48
  set FSUp 45
  set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
  set alfa 0 set beta 0.75 set gamma 0 set delta 0.25
  set evacuationmode "entering"
]

if rapidinputselector = "Holiday non critical - entering"
[
  set SBd 0
  set UOOd 0.20
  set OOp 23
  set POp 1
  set NRp 33
  set FSUp 45
  set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
  set alfa 0 set beta 0.75 set gamma 0 set delta 0.25
  set evacuationmode "entering"
]

if rapidinputselector = "Minimum condition - leaving"
[
  set SBd 0
  set UOOd 0.06
  set OOp 0
  set POp 0
  set NRp 0
  set FSUp 0
  set maxspeed 2.50 set minspeed 0.72 set denscrit 2.67 set kfact -0.14 set densstop 5.4 set TSAP 55
  set alfa 0 set beta 0 set gamma 1 set delta 0
  set evacuationmode "leaving"
]

if rapidinputselector = "Minimum condition - entering"
[
  set SBd 0
  set UOOd 0.06
  set OOp 0
  set POp 0
  set NRp 0
  set FSUp 45
  set maxspeed 3.29 set minspeed 0.71 set denscrit 5.3 set kfact -0.8 set densstop 8 set SAP 88
```



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set alfa 0 set beta 0.75 set gamma 0 set delta 0.25

set evacuationmode "entering"

]

set Tup 4

set PCp 9

set YAp 5

set AUp 64

set Fp 52

end

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