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WP 2 – BE and SLOD: SoA, Risks and human behavior

T.2.2 - SoA on SLOD (heat wave and pollution) in BE and their effect on health and wellbeing of its users. Methods for data collection and analysis (on medium/long term datasets). Correlation between pollution and climate data (e.g. wind, rain, fog). Current mitigation solution analysis. Identification of BE features and users' (inappropriate) behaviors modifying SLOD effects/risk levels. Development of indicators and relative weights for selected SLOD risk levels assessment.

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Abstract

Risk matrixes approach is a diffused and well-documented method for understanding, categorizing, monitoring and managing risk. It enables a rapid integration as well into multiple analyses, the method allows to condensate into one single value or category the superposition of different parameters or conditions. In the case of SLOD risk assessment, and in particular analyzing *increasing temperatures* and *air pollution*, it allows to condensate environmental, built environment and demographic conditions into one unique result that communicated the degree of risk at which one pedestrian/person is exposed. The approach has been carried out while merging qualitative and quantitative insights on the problem, utilizing well-established indexes for allocating severity/criticality. No risk assessment values were yet computed, this is foreseen in future work.

Keywords

Slow-Onset Disasters, Built Environment; Pollution; Urban Heat Island; Climate change; Risk matrix

Approvals

Role	Name	Partner
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Summary

1. Introduction

The risk assessment of a SLow Onset Disaster (SLOD) is a multivariable problem that can be assessed by deconstructing it according to the typology. Starting by analyzing every SLOD independently, that is, a risk matrix assessment has been carried out for each of the SLODs of *increasing temperatures* and *air pollution.* And for each of them, the risk constituents have been recalled from previous reports (i.e. D.2.1.1, D.2.1.2, D.2.2.1, D.2.2.2 and D.2.2.4), these have been organized and grouped according to their severity.

Recalling the definition of risk for SLOD mentioned in Figure 4 within D.2.1.1, the risk is determined by the combination of three main elements: (1) Hazard; (2) Exposure; and, (3) Vulnerability. Thus, it is necessary to individuate for each SLOD, which elements fall in the category of *hazard, exposure* and *vulnerability;* and then, under which settings the risk is higher or lower for the inhabitants of the Built Environment. This analysis is carried out in depth in §2.

The use of risk Matrix has been proposed and studied by researchers and institutions in order to accurately label, compare and acknowledge the risk of a certain situation, or a combination of particular settings. The risk matrix approach (RMA) methodology is robust and can be used in with a diverse range of scopes or goals towards risk assessments. It is, also considered an advantageous approach as it is classified as a *semi-quantitative approach* that integrates, at a certain extent, quantitative analysis (from large databases) and qualitative assessment (from experience and knowledge) (Ni et al. 2010).

For instance, the Department of Defense of the United States of America (2000) adopted this methodology in order to establish a standard procedure for conducting and communicating system safety. They ranked the loss severity according to the resulting costs (mainly in terms of monetary costs, translated into USD), and the probability of occurrence based on statistical data of damages occurred during the systems life expectancy. In brief, they established 4 severity groups (i.e. *Catastrophic, Critical, Marginal* and *Negligible*) and 5 categories of occurrence frequency (*Frequent, Probable, Occasional, Remote* and *Improbable*), resulting in 20 risk assessment values grouped in bins to allocate a risk category (High, Serious, Medium and Low) and a risk handling authority or figure.

However, as stated by Ni et al. (2010), it is necessary to realize and adjustment to the generic RMA to effectively consider and compare the possible conditions/settings that might arise, thus to englobe all possibilities of a certain event. This work proposed a numerical procedure that allocates a risk assessment value to every combination; and, collected information on previously published methodologies which represent attempts on doing so, such as: Rezoning of matrix cells (RMC) and fuzzy risk matrix (FRM) (Markowski and Mannan 2008); and, Borda risk matrix (BM) (Zhu et al. 2003).

In this work, a hybrid of the traditional RMA procedure and the extensions proposed by Ni et al. (2010), has been carried out. A qualitative aspect has been introduced by the selection of the parameters or variables to be considered, based on existing knowledge and published findings in the field. Additionally, quantitative analysis is introduced by the use of outdoor comfort and air quality indexes (i.e. Universal Thermal Climate Index (UTCI) and Air Quality Index (AQI)) to assign a degree of severity to the settings on the microclimate in question.

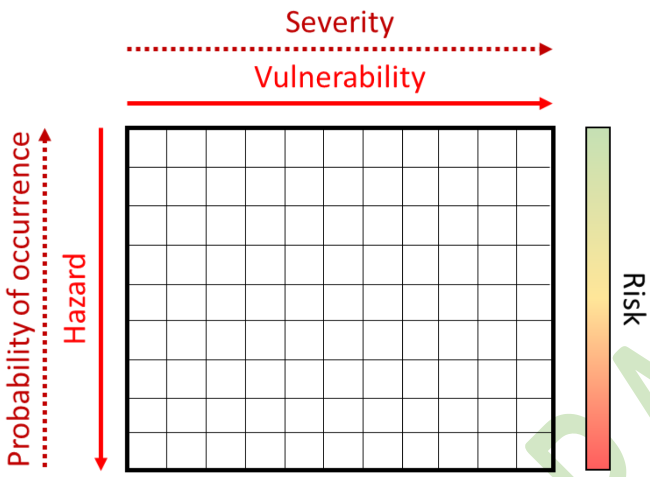


Figure 1: Explanatory schema of the risk matrix approach adopted

In summary, an RMA has been structured and carried out as it was drawn in Figure 1. It includes:

- The hazards identified on the left side, ordered from lower to higher stress that these could generate and from higher to lower probability of occurrence.
- The vulnerability varying from left to right, depending on to what extent are the citizens interacting with or influenced by the risks. Therefore, the higher the vulnerability, the higher the severity.
- The exposure following the traditional risk approach, is meant as the number of people at risk. Thus, this factor would be added at the end of the assessment by modifying the risk values, and in consequence, its category.
- A colormap is used to communicate the degree of risk (risk values) from low (green) to high (red) depending on the risk assessment values allocated to each combination of *Hazard + Probability of occurrence* and *Vulnerability + severity.*

2. Decomposition of critical SLODs for risk assessment

As extensively described in D.2.1.1, the SLODs have a significantly different behavior compared to any other type of risks; they develop in a diverse timeframe, thus intensity and duration. In fact, the SLODs are characterized by a low intensity and lengthy, or recurrent, exposure to adverse health conditions. However, these adverse health conditions are progressively more frequent (given the trends exposed in §3 of D.2.1.1) and in certain areas of the world they have become the norm or the standard.

Hence, the outcome of the decomposition of the risk elements has been modified. That is:

- Hazard is still related to the adverse environmental conditions, only that these are mainly related to events which if isolated, limited risk would be recognized.
- Then, given that environmental conditions (e.g. weather or air pollution) act on a macro scale and their variations are slow, the vulnerability can be associated to two sub-categories instead:

   - one linked to how the surrounding context worsens the adverse conditions *(Physical Vulnerability)*; and,
   - the other is rather associated with how fragile the health of the person is when exposed to the hazard *(Social Vulnerability)*.
- Lastly, exposure remains related to the level of occupation of a certain space, the larger the number of citizens involved in the hazard, the larger the risk.

Every element has been described further in the following sections, including certain parameters that shall be considered when assessed.

2.1 Hazard

In this section, a description is presented about the components which are conditioning the degree of severity of the identified hazards for each SLOD type. That is, establishing and recalling recognized thresholds for every hazardous event (i.e. pollutant concentration and thermal stress parameter).

Moreover, it accounts for an analysis when differentiating between these hazardous events when acting independently, or when they are a consequence of a group of these stressors which when acting simultaneously their generated stress can be considered not negligible.

a. Increasing temperature

For this SLOD type, the parameters identified as significant to survey are the following:

- temperature (both air and surface),
- wind speed,
- relative humidity, and
- solar radiation.

The combination of such parameters determines the way the person perceives the surrounding environment, regardless if this perception is evaluated indoor or outdoor (EN-ISO-7730 2005; Bröde et al. 2009; American Society of Heating 2013). A person would notice higher thermal stress when surrounded by surfaces at high surface temperature (i.e. radiation heat transfer) and/or stricken by solar radiation, or when the air is highly saturated with vapor (i.e. higher relative humidity), or no breeze is flowing to ease the notion of temperature increase (i.e. higher surface humidity evaporation rate).

Moreover, other combination types, related to low thermal stress might generate significant negative effects on people. For instance, high air temperatures and low humidity favor dehydration, as the body would try to balance the water vapor difference with the environment. A summary of the combinations related to thermal stress, impact severity and the probability of occurrence are listed in Table 1.

This summary of disadvantageous weather conditions, related to the SLOD of *increasing temperatures*, serve as an introduction to the construction and assembly of its risk matrix. It makes a review on the possible scenarios that could arise during the year, giving to each parameter the condition at which it might represent a threat. Moreover, it allowed to establish the severity/criticality/intensity of each scenario, thus, to arrange them in the correct order for the matrix later presented in

Vulnerability	*Negligible*	*Low*	*Average*	*High*	*Extreme*

		Severity	*I*			*II*			*III*			*IV*			*V*		
		Green area coverage	*High*	*High*	*High*	*High*	*High*	*High*	*Average*	*Average*	*Average*	*Low*	*Low*	*Low*	*None*	*None*	*None*
		Albedo	*High*	*High*	*High*	*Average*	*Average*	*Average*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*
		Canyon H/W	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*
		Vulnerable population					*Elders*	*Elders*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders, Frail Health and youngsters*	*Elders, Frail Health and youngsters*	*All*	*All*	*All*
		Description	Person on shaded area, surrounded by highly reflective materials and on a path way favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and path way not favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and path way blocking wind flow	Person on shaded area, surrounded by materials with average reflectance, and path way favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and path way not favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and path way blocking wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and path way favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and path way not favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and path way blocking wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and path way favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and path way not favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and path way blocking wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and path way favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and path way not favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and path way blocking wind flow
Combination	**Probability of occurrence**	**Hazard**															
1	*Common*	High direct solar radiation															
2		Wind speed drop															
3		Humidity saturation															
4	*Has occurred*	Surface Heat storage capacity saturation															
5		Air temperature increase															
6	*Most likely*	Air temperature increase combined with wind speed drop															
7		Air temperature increase combined with humidity saturation															
8		Air temperature increase combined with high direct solar radiation															
9		Air temperature															

		increase combined with surface heat storage capacity saturation															
10		Air temperature increase combined with wind speed drop and high direct solar radiation															
11	*Likely*	Air temperature increase combined with wind speed drop and humidity saturation															
12		Air temperature increase combined with wind speed drop and surface heat storage capacity saturation															
13		Air temperature increase combined with surface heat storage capacity and humidity saturation															
14		Air temperature increase combined with surface heat storage capacity saturation and high direct solar radiation															
15	*Has occurred*	Air temperature increase combined with humidity saturation and high direct solar radiation															
16		Air temperature increase combined with low humidity															
17	*Rare*	Air temperature increase combined with wind speed drop, surface heat storage capacity and humidity saturation															

18		Air temperature increase combined with wind speed drop, surface heat storage capacity saturation and high direct solar radiation															
19		Air temperature increase combined with wind speed drop, humidity saturation and high direct solar radiation															
20		Air temperature increase combined with wind speed drop, high direct solar radiation, humidity and surface heat storage capacity saturation															

Table 6.

As described in D2.2.1, the Universal Thermal Climate Index (UTCI) can be used as a global parameter of temperature perception, which incorporates humidity, wind and radiation. This index was incorporated to further rank the scenarios according to their level of threat, and to better understand this Figure 2 is presented for acknowledging the categories.

The parameters were given a simple low (L) and high (H) status, to generalize the fact that these are above or below a certain threshold that has been reported as to guarantee a certain degree of acceptance of the surrounding environmental conditions. Recalling from D.2.2.1, the high and low values states for each parameter are given when the following conditions are met:

- High air temperature, when the values go above 26 °C;
- High surface temperature when Mean Radiant Temperature is 3 °C above air temperature (i.e. high radiant heat transfer asymmetry);
- High solar radiation when global horizontal radiation values go above 300 W/m2;
- Low wind speed when values go below 2 m/s; and,
- High relative humidity when these values go above 70%, or low relative humidity when they drop below 30%.

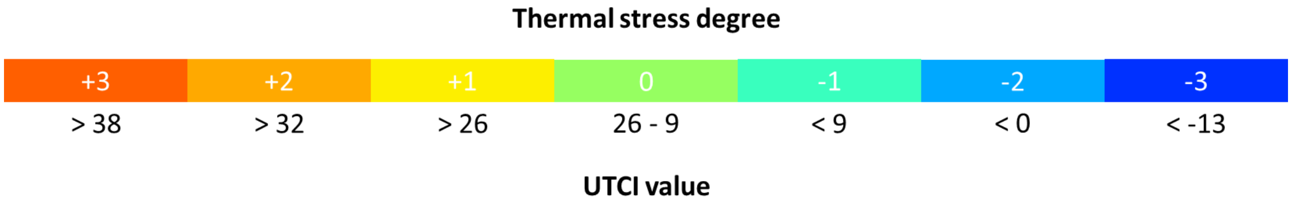


Figure 2: UTCI degree of thermal stress legend.

Combination	Parameter: *Air temperature*	*Surface temperature*	*Wind speed*	*Relative humidity*	*Direct Solar radiation*	UTCI	Severity/ Criticality / Intensity	Probability of occurrence
1					H	<1	Negligible (I)	Common
2			L			<1	Negligible (I)	Common
3				H		<2	Low (II)	Common
4		H				<2	Low (II)	Common
5	H					>1	Average (III)	Common
6	H		L			>1	Average (III)	Most likely
7	H			H		>2	High (IV)	Most likely
8	H				H	>2	High (IV)	Most likely
9	H	H				>2	High (IV)	Likely
10	H		L		H	>2	High (IV)	Likely
11	H		L	H		>2	High (IV)	Likely
12	H	H	L			>2	High (IV)	Likely
13	H	H		H		>2	High (IV)	Likely
14	H	H			H	>2	High (IV)	Has occurred
15	H			H	H	>2	High (IV)	Has occurred
16	H			L		0-3	Extreme (V)	Has occurred
17	H	H	L	H		>3	Extreme (V)	Rare
18	H	H	L		H	>3	Extreme (V)	Rare
19	H		L	H	H	>3	Extreme (V)	Rare
20	H	H	L	H	H	>3	Extreme (V)	Rare

Table 1: increasing temperature hazard parameters, and severity/criticality/intensity. H: High; L: Low.

b. Air pollution

The parameters suggested to survey, according to the deductions made in D.2.2.2 and suggestions on WHO (2005, 2014a), are the ones showed in Table 2.

Guideline levels for each pollutant				***Reference***
$PM_{2.5}$	Primary pollutant	24 h	25 μg/m³	(World Health Organization 2005)
		1 yr	10 μg/m³	
PM_{10}	Primary pollutant	24 h (99th percentile)	50 μg/m³	(World Health Organization 2005)
		1 yr	20 μg/m³	
Ozone O_3	Secondary pollutant	8h daily maximum	100 μg/m³	(World Health Organization 2005)
Nitrogen dioxide, NO_2	Primary and secondary pollutant	1 yr	40 μg/m³	(World Health Organization 2005)
		1h	200 μg/m³	
Black carbon	Primary and secondary pollutant	No value available		
VOC (ex.Formaldehyde)	Primary pollutant	30 min	0.1 μg/m³	(WHO 2014a)
CO	Primary pollutant	15 min	100 μg/m³	(WHO 2014b)
		1h	35 μg/m³	
		8h	10 μg/m³	
		24h	7 μg/m³	
Sulfur dioxide, SO_2	Primary pollutant	24h	20 μg/m³	(World Health Organization 2005)
		10 min	500 μg/m³	

Table 2: Guideline expressing the level of exposure for pollutants. Note: Primary pollutants are those emitted directly into the air, e.g. Sulphur dioxide and volatile organic compounds. Secondary pollutants are those formed by a combination, or reaction (e.g. photochemical), with other primary pollutants, e.g. ground level ozone

The air is a mix of pollutants that come from different sources or are created from different chemical reactions in the atmosphere. Some studies and researches are trying to approach the air pollution in a more complete way taking into account emissions and exposures of multiple pollutants in the atmosphere, called multipollutant mixtures, rather than single pollutants (EPA 2016; Blangiardo et al. 2019). According to Serrano et al. (2017), it is already hard to identify one single pollutant or its right locations to evaluate higher (toxic) or lower exposures (background). Hence, for multiple emission sources the risk assessment is even more complicated. At the moment there are no complete and substantial results that could be used in this investigation. Although, some singular examples have been found in literature:

- O3 is a secondary pollutant coming from by the action of sunlight on primary pollutants (VOC and Sox). As for the Ozone at ground level O_3, which is not the ozone layer in the upper atmosphere – is one of the major constituents of photochemical smog. It is formed in presence of the sunlight that favors the photochemical reaction from pollutants such as nitrogen oxides (NO_x) from vehicles and industry emissions and volatile organic compounds (VOCs) emitted by vehicles, solvents and industry. As a result, the highest levels of ozone pollution occur during periods of sunny weather. The VOC: nitrogen oxides ratio most favorable to ozone formation lies in the range 4 : 1 to 10 : 1. (World Health Organization 2005)
- SO_2 and smoke: worsening of the condition of people with chronic bronchitis, were related to raised levels of smoke and SO_2 (European Environment Agency 2008a).
- NO_2 : The atmospheric conditions which cause an increase in concentrations of NO also cause an increase in concentrations of other pollutants, such as particles and carbon monoxide (European Environment Agency 2008b).

In urban contexts, the limits of concentrations proposed above should be kept under control for health security. A summary of these parameters together with the possible hazards, the relative impact severity and the probability of occurrence are listed in Table 3.

Combination	**Parameter**			**Severity/ Criticality / Intensity**	**Probability of occurrence**
	Pollutant concentration	*Pollutant concentration + solar radiation*	*Pollutant concentration + pollutant transfer from industrial sites carried through breeze*		
1	*H*			High (IV)	*Common*
2	*H*			High (IV)	*Common*
3			*H*	Average (III)	*Common*
4	*H*			Average (III)	*Has occurred*
5	*H*			Average (III)	*Has occurred*
6	*H*			Average (III)	*Likely*
7		*H*		Average (III)	*Likely*
8		*H*		Average (III)	*Most likely*
9	*H*			High (IV)	*Most likely*
10	*H*			High (IV)	*Rare*
11	*H*			Average (III)	*Rare*
12	*H*			Low (II)	*Rare*
13	*H*			Average (III)	*Rare*
14	*H*			Negligible (I)	*Rare*
15	*H*			High (IV)	*Rare*

Table 3: air pollution hazard parameters, and severity/criticality/intensity. H: High; L: Low.

2.2 Physical Vulnerability

The physical vulnerability risk of people/pedestrians is conditioned by the way the built environment has been arranged and is progressively modified. Thus, in this risk component, the properties or characteristics of the BE are assessed as previously done in D.2.1.1 in which the severity of certain urban spaces was determined analyzing certain characteristics.

The physical vulnerability has a strong link with the type of SLOD, and in particular with the type of hazard. It is important to make a distinction between the way people are exposed to the hazard and the hazard itself. The former is the disposition of the surroundings that could favor or worsen the effect of the hazards, and which could prevail or arise independently from the hazard. For instance, the geometry of the space blocking the wind flow (i.e. no breeze present) prevails during the year, under low or high concentration of pollutants; but if the hazard arises it could rise the thermal stress and worse the pollutant dilution, transportation or concentration.

These BE characteristics were identified independently for both SLODs, and only a few of them overlap. Once again, a general and qualitative description of the condition of each parameter was given.

a. Increasing temperatures

For this SLOD, the exposure is related entirely to specific structures/elements/materials present on the BE that protect the people from suffering thermal stress, dehydration or others. For example, the presence of trees has been proved to provide cooler environments (favoring liquid water retention) or at least shade form direct solar radiation; likewise, balconies or protruding elements.

Some of the characteristics have been grouped for reducing the complexity and simplifying the potential number of combinations, and 3 groups have been arranged as follows:

- **Green area coverage:** it has englobed the presence of both green infrastructure (e.g. trees, bushes, grass, green facades, green roofs) and water bodies (e.g. rivers, lakes, fountains). But this parameter was more dedicated onto regulation of water vapor concentration (i.e. Relative Humidity) and direct solar radiation protection to pedestrians.
- **Albedo:** it includes both green and built surfaces. It relates to the radiative heat transfer of the affected population and the surrounding surfaces. These surfaces could provide lower/higher perception of air temperature (i.e. lower UTCI).
- **Canyon H/W:** it encloses the geometry, sky view factor and orientation of the BE. That is, it was intended to mainly account for the disposition of the built environment to allow and favor wind flow.

A summary of the built environment characteristics and possible combinations have been included in Table 4, following the approach taken in §2.1.

C	Parameter	Description	Severity

	Green area coverage	*Albedo*	*Canyon H/W*		
1	H	H	L	Person on shaded area, surrounded by highly reflective materials and on a pathway favoring wind flow.	Negligible (I)
2	H	H	A	Person on shaded area, surrounded by highly reflective materials, and pathway not favoring wind flow.	Negligible (I)
3	H	H	H	Person on shaded area, surrounded by highly reflective materials, and pathway blocking wind flow.	Negligible (I)
4	H	A	L	Person on shaded area, surrounded by materials with average reflectance, and pathway favoring wind flow.	Low (II)
5	H	A	A	Person on shaded area, surrounded by materials with average reflectance, and pathway not favoring wind flow.	Low (II)
6	H	A	H	Person on shaded area, surrounded by materials with average reflectance, and pathway blocking wind flow.	Low (II)
7	H	L	L	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway favoring wind flow.	Average (III)
8	H	L	A	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway not favoring wind flow.	Average (III)
9	H	L	H	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway blocking wind flow.	Average (III)
10	L	L	L	Person on solar exposed area, surrounded by materials with	High (IV)

				low reflectance, and pathway favoring wind flow.	
11	L	L	A	Person on solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow.	High (IV)
12	L	L	H	Person on solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow.	High (IV)
13	N	L	L	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway favoring wind flow.	Extreme (V)
14	N	L	A	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow.	Extreme (V)
15	N	L	H	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow.	Extreme (V)

Table 4: increasing temperature physical vulnerability characteristics, a brief description of the combinations and the severity they represent. H: High; A: Average; L: Low; N: None.

b. Air pollution

On the contrary, for assessing air quality, the physical vulnerability is related to the presence of air pollutant sources within the surroundings. These sources have been fixed in, or are transiting through, the BE given its configuration which exposes people to larger or lower concentrations of air pollutants. Once again, certain structures/elements/materials present on the BE might also generate a larger pollutant absorption, catchment and/or digestion.

For instance, the presence of green structures (e.g. trees) can mitigate the presence of pollutants and, at the same time, they favor the creation of wind tunnels that wipe out polluting agents (or if not properly design, block the wind flow). The same goal can be achieved by embedding the BE with elements or technologies able to capture them into their composition (TiOx surfaces, plants on facades, etc.), or by deviating the household plant outlets away from pedestrian paths. On the contrary, traffic intensity plays a major role in urban air quality. The direct presence of and contact with the gases expelled by the vehicles represent the major risk of exposure for citizens, and for this reason, here it has been classified for the extreme severity for health consequences.

Some of the characteristics have been grouped for reducing the complexity and simplifying the potential number of combinations, and 3 groups have been arranged as follows:

- **Traffic:** typology of street and related traffic grade.
- **Elements capturing pollutants:** green area coverage and absorbing pollutant materials.
- **Canyon / Wind speed:** the wind speed can be affected by the BE configurations (canyon, relationship among height of buildings and depth of street section, urban furniture presence, etc.).

A summary of the built environment characteristics and possible combinations have been included in

Combination	Parameter			Description	Severity
	Traffic	*Elements capturing pollutants*	*Canyon / Wind speed*		
1	N	H	H	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway favoring wind flow	Negligible (I)
2	N	H	A	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway not favoring wind flow	Negligible (I)
3	N	H	L	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway blocking wind flow	Negligible (I)
4	L	A	L	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Low (II)
5	L	A	A	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Low (II)
6	A	A	H	Person in local and private streets, partially surrounded by green area or materials able to	Low (II)

				capture pollutants and on pathway favoring wind flow	
7	A	L	L	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Average (III)
8	A	L	A	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Average (III)
9	A	L	H	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Average (III)
10	H	L	L	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	High (IV)
11	H	L	A	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	High (IV)
12	H	L	H	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	High (IV)
13	H	L	L	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Extreme (V)
14	H	L	A	Person in a highly traffic area (highway), not surrounded by green area or materials able to	Extreme (V)

				capture pollutants and on pathway not favoring wind flow	
15	H	L	H	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Extreme (V)

Table 5, following the approach taken in §2.1.

Combination	**Parameter**			**Description**	**Severity**
	Traffic	***Elements capturing pollutants***	**Canyon /** ***Wind speed***		
1	N	H	H	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway favoring wind flow	Negligible (I)
2	N	H	A	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway not favoring wind flow	Negligible (I)
3	N	H	L	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway blocking wind flow	Negligible (I)
4	L	A	L	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Low (II)
5	L	A	A	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Low (II)

6	A	A	H	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Low (II)
7	A	L	L	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Average (III)
8	A	L	A	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Average (III)
9	A	L	H	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Average (III)
10	H	L	L	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	High (IV)
11	H	L	A	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	High (IV)
12	H	L	H	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	High (IV)
13	H	L	L	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Extreme (V)

14	H	L	A	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Extreme (V)
15	H	L	H	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Extreme (V)

Table 5: Air pollution physical vulnerability characteristics, a brief description of the combinations and the severity they represent. H: High; A: Average; L: Low; N: None.

2.3 Social Vulnerability

According to the annex D2.2.5 definition, Social Vulnerability is composed by two main components. The first regards the whole disaster-prone community named *collective vulnerability* that concerns evacuation and emergency management issues and social issues at the community scale (the latter more related to SLODs). The second component, *individual vulnerability*, concerning citizen habits, gender, age, health fragility, and other features related to the motion, is here furtherly investigated in order to detect SLODs effects on the different agents.

Thus, Individual vulnerability has also been defined as the susceptibility of the person when exposed to certain conditions. It can be separated according to age-groups (e.g. youngsters, adults and elders) and health complications (e.g. respiratory affections, blood pressure); aiming to construct groups that are categorized according to their bodies' capacity to assimilate, balance and recover from the effects of *increasing temperatures* and *air pollution*. Figure 3 displays a detailed analysis on how the population can be categorized, under which parameters people could be allocated into these categories, and also what are the body's processes involved.

The following is a more detailed description of Individual Vulnerability, its established groups and the categories or the type of affections that they consider. These groups refer to the information collected and presented in §3 of D.2.1.1 that go along with the literature collected (Jackson et al. 2010; WHO 2014c; Lee and Kim 2016).

- **Youngsters:** normally for this age-group, body organs are still under development or their systems are not yet accustomed to certain extreme conditions. Prolonged exposure to certain hazards might generate permanent damage, that would be severe for them at older age (De Prado Bert et al. 2018).
- **Elders:** depends also on the style of life they have sustained; however, the majority has a body with reduced capacity for adaption when exposed to extreme conditions. Prolonged exposure to certain hazards could result in a higher risk of mortality (Devlin et al. 2003; Cakmak et al. 2007).
- **Frail health:** people with an especial condition linked to their body functioning, which endangers their health when exposed to certain hazards. This has been linked mainly with respiratory issues (e.g. asthma, allergies) and irregular blood pressure (Delfino et al. 2010).
- **Adults:** any other who does not fall into the previous categories.

More detailed considerations have been performed according to the SLOD assessed.

The constructed risk matrixes will account for each vulnerable group, linked to their susceptibility and the severity of the exposure combined with the potential hazard. These parameters are influenced greatly by the population held in the BE, which is context and time dependent. Educational level and socio-economic conditions of the population were not considered.

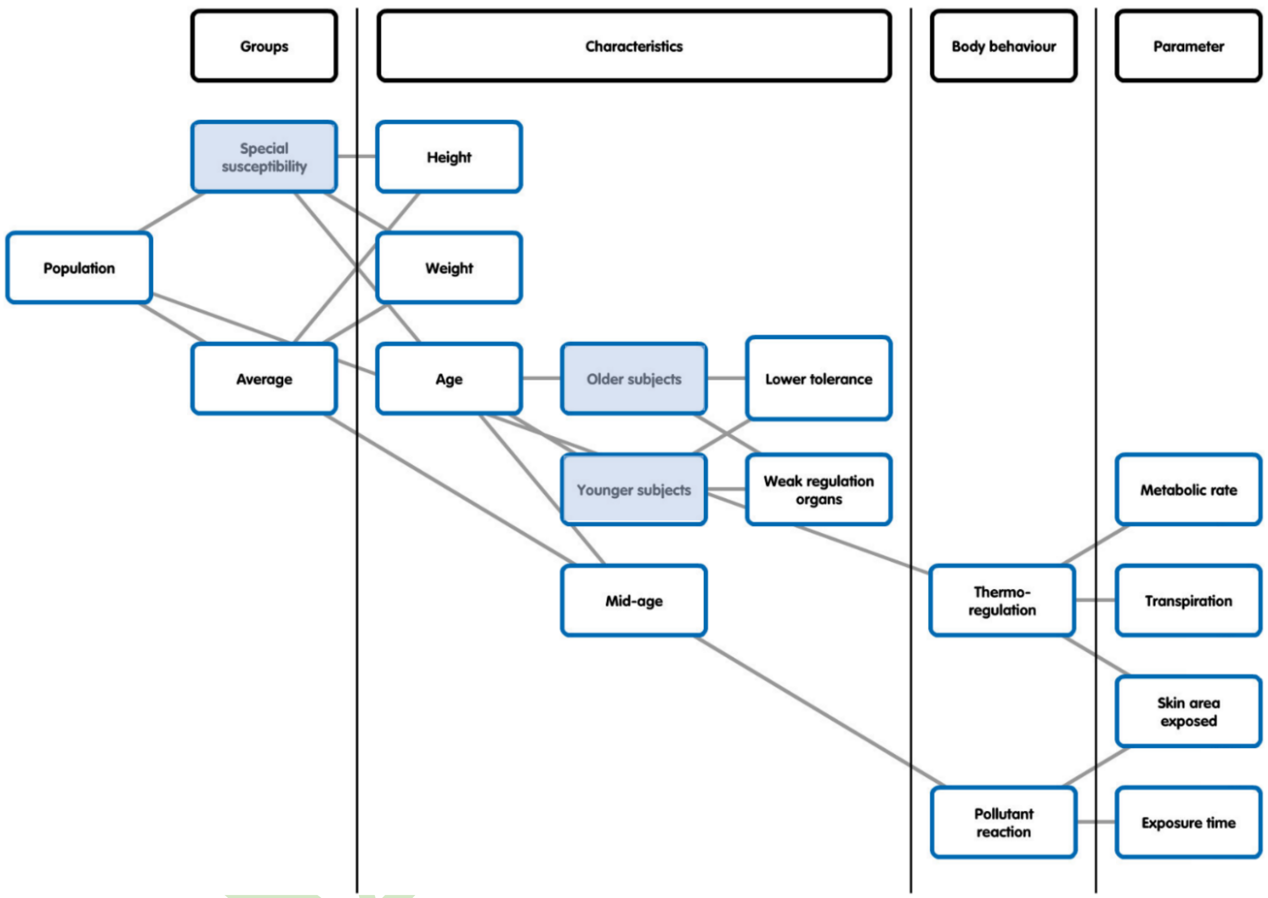


Figure 3: Population deconstruction for easily allocate the degree of individual vulnerability towards SLODs, according to their physiological conditions. The main macro-categories (left-most), are the most generic based on susceptibility; then, within the characteristics, a further deconstruction is performed based on age (describing their vulnerability); finally, the right-most are the most specific characteristics of the population which could highly differ from one group to another, but can be measured and monitored.

a. Increasing temperatures

As mentioned along the previous reports, the most common evidence of this SLOD type arises in summer during heat waves, or when the Urban Heat Island (UHI) is more evident. In this period youngsters and elders seem to be the more frequently affected by heat strokes (complications of body functioning perceived when core body temperature rises above 40.6°C, see Yeo (2004)). In addition to youngsters and elders, those with frail health have a significantly reduced thermal regulation capacity (Barrow and Clark 1998). They are in fact less able to acknowledge the condition and their regulatory systems are less capable of managing the excess heat.

This evidence would rise more frequently given the sustained temperature rise worldwide. Therefore, evading recurrent or constant thermal stress on the human body should be a priority; and, the arrangement of the BE could facilitate so.

b. Air pollution

When inhaled, all these pollutants have different effects on people. The level of vulnerability and risk depend the health conditions and age of subjects, but that doesn't mean that the healthy population is not affected by them. On the contrary, the prolonged exposure to air pollutants, see the time value expressed in the Table 2, suggest that all the population is at risk of developing diseases or sensitivity behavior with different gravity levels in their presence.

In fact, according to a study published by Unicef UK (2018), researchers found that when children are exposed to higher levels of pollution, particularly while walking to school and on the playground, the effects of air pollution are more serious on children than on adults. For the ozone, individuals show an enormous response variations, with asthma sufferers not being significantly more affected than others (European Environment Agency 2008a). For particle matters, their size is directly linked to their potential for causing health problems. Some particles less than 10 micrometers in diameter can get deep into the lungs and some may even get into the bloodstream. Of these, the $PM_{2.5}$, pose the greatest risk to health (EPA 2018).

For these reasons, the vulnerability categories here have been classified as follow: people sensitive to air pollution (such as asthmatics, children, and the elderly), people with respiratory diseases, children, elderly, all.

2.4 Exposure

This risk component has been set as strictly related to the level of occupation of a certain space, the larger the number of citizens involved in the hazard, the larger the risk. Therefore, it does contribute to the risk values and category by means of the country, city, district, neighborhood or area population number or density (Kang 2018; Liang et al. 2020).

This component can be enhanced by the existence of crowding sources within the analyzed context. That is, the presence of:

- public services (e.g. public transportation stations, public services, government buildings, hospitals);
- private services (e.g. cinemas, theaters, clinics, homecare);
- academic institutions (e.g. schools, universities);
- Sports facilities (e.g. stadiums, gymnasiums); and,
- Others (e.g. churches, supermarkets).

This information is key to feed as well the information required on social vulnerability based on the preferred audience of a certain building function or service (mainly related to demographics).

3. Risk matrix development

As previously mentioned in §1, a hybrid of the traditional RMA procedure and the extensions proposed by Ni et al. (2010) have been used. A qualitative aspect has been introduced while deconstructing the SLODs in §2, and quantitative analysis has been partially introduced by the use of UTCI and AQI to assign a degree of severity to probable microclimate settings. Meanwhile, the physical vulnerability has been organized by the severity allocated in §5 of D.2.1.1 given by how much shelter the BE provides to the person; and the social vulnerability, designated based on how fragile the person's health condition is.

The constructed matrixes are, in great part, a combination of the summarizing tables presented for Hazard and physical vulnerability as shown in **Errore. L'origine riferimento non è stata trovata.**. Allocating on the horizontal axis the vulnerability, while positioning the different hazard combinations in the vertical axis. The hazard combinations have been ordered from greater probability of occurrence on top towards the least probable to occur on the bottom, which corresponds as well with the hazard combination of the greatest impact. Meanwhile, the physical vulnerability has been organized from left to right, according to the potential severity of the conditions delivered to the person in case the hazard is presented, going from the least severe to the most severe. Instead, social vulnerability is included as the most affected population groups for the given physical vulnerability; thus, having least or none affected on the leftmost, towards the majority being affected of the rightmost side. Lastly, the risk is escalated by the occupation level of the area studied.

In addition, a brief description of the hazard and of the physical vulnerability has been included for a greater understanding on how this risk can be identified.

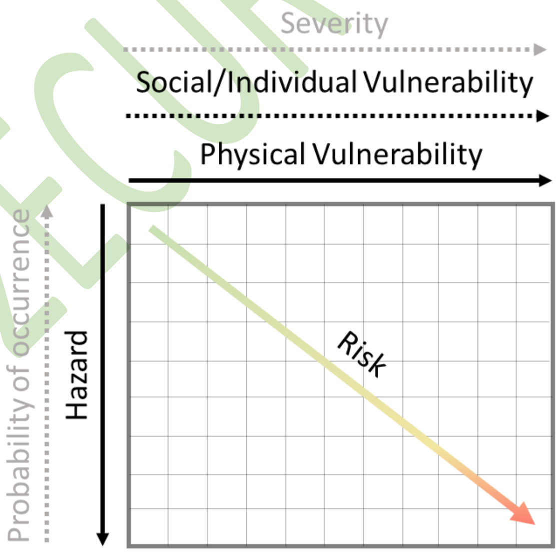


Figure 4: Schema of the RMA constructed for assessing the risk of increasing temperatures and air pollution SLODs

3.1 Increasing temperatures

For *increasing temperatures,* a larger collection of combination resulted, given the higher number of parameters considered; in total, there were 20 combinations describing a specific hazard. No risk assessment values were yet assigned to each hazard – vulnerability combination. Table 6 represents the whole constructed RMA for the SLOD type of *increasing temperatures.*

An example is given to give an insight on how to utilize this matrix as a tool.

a. Example for reading the matrix on increasing temperatures

The matrix in Table 6 can be used or interpret in two different ways (1) starting from the hazard when these arise, or (2) from the vulnerability depending on the area in which the person is located. For instance, considering a *likely* warm and clear sky day, with no or negligible breeze (*combination 10):*

- When using the first approach (*grey* in Figure 5), the type of hazard (or combination) will be identified by monitoring established thresholds as the ones included in D.2.2.1; then, aided by the description present on the physical vulnerability tab and depending on the BE disposition, the location of the occupant would provide a certain risk. For example, a person directly exposed to solar radiation, surrounded by materials with low albedo (most probable, hot surfaces) and wind-flow, if any, blocked (i.e. *High physical vulnerability, severity IV),* could allow to preliminary identify a *high-extreme* degree of risk*.* From this, it is also possible to identify the more susceptible individuals as *elders, youngsters and frail health*. Later, this risk shall be escalated by the number of people exposed to the sinister.
- Differently if starting from acknowledging or allocating a degree of physical vulnerability to a certain specific location (*blue* in Figure 5). For instance, in a different or in the same canyon but different space location, a person partially exposed, or shaded, from solar radiation and surrounded by materials with low albedo (most probable, hot surfaces) (i.e. *Average physical vulnerability, severity III),* will reach an *average-high* degree of risk if hazard combination 10 arises. Under these settings, the most susceptible individuals are identified as *elders and frail health*; then, this risk would be intensified by the number of people exposed.

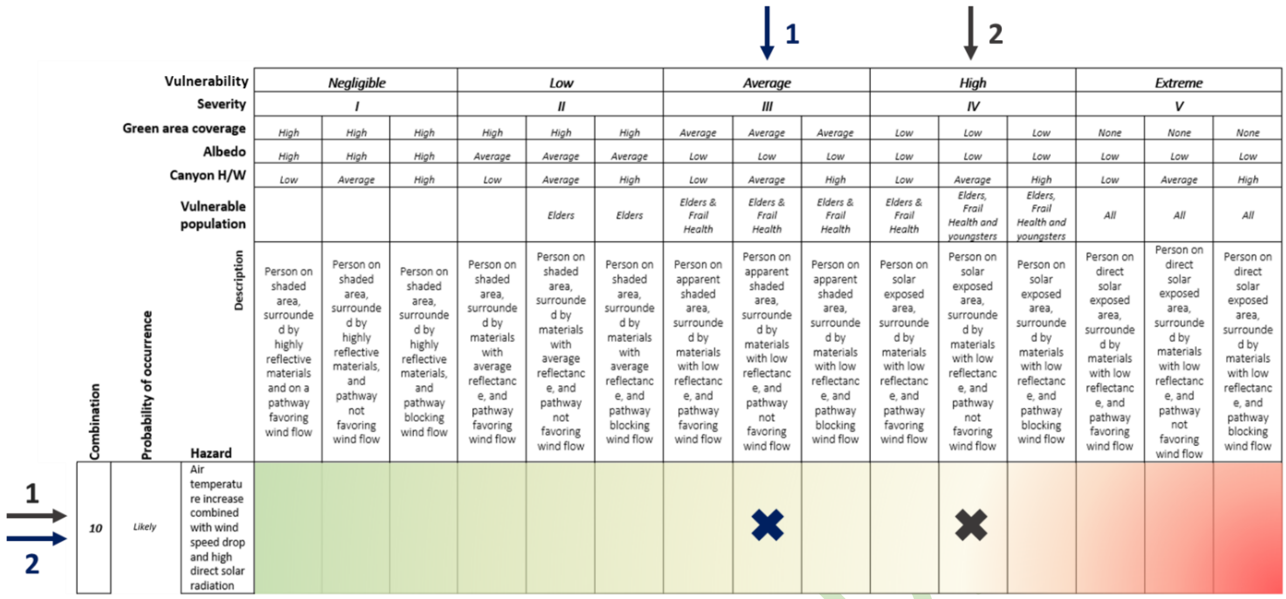
3.2 Air pollution

For *air pollution,* 15 hazard combinations were established describing a specific hazard of single and mixes of air pollutants. No risk assessment values were yet assigned to each hazard –vulnerability combination. Table 7 represents the whole constructed RMA for the SLOD type of *air pollution.*

Once again, an example is given as insight on how to interpret and utilize the risk matrix.

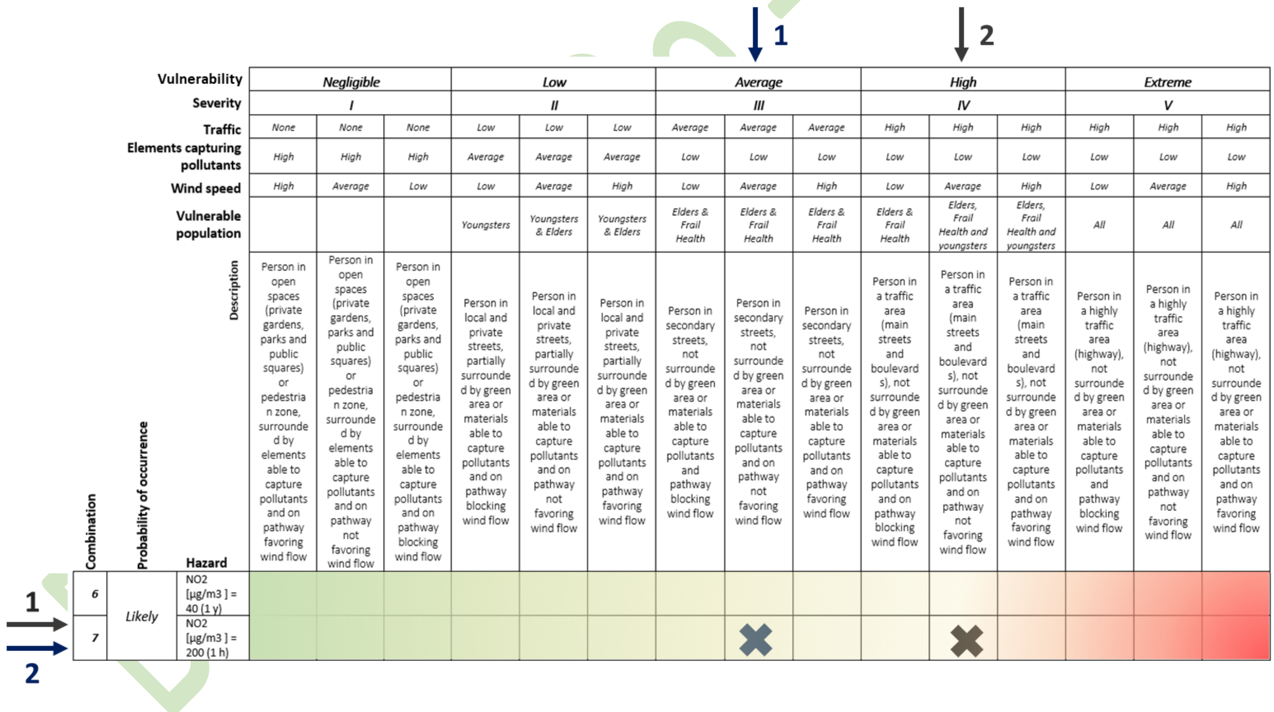
a. Site-specific example for reading the matrix on air pollution

Similar to what has been presented in §3.1, Table 7 can be interpreted likewise. For example, considering again an arousal of a *likely* hazardous scenario of NO2 concentrations over 200 µg/m3 for 1 h (combination 6) or over 40 µg/m3 for a year exposure (combination 7) the risk can be identified by:



Vulnerability	Negligible			Low			Average			High			Extreme		
Severity	I			II			III			IV			V		
Green area coverage	High	High	High	High	High	High	Average	Average	Average	Low	Low	Low	None	None	None
Albedo	High	High	High	Average	Average	Average	Low	Low	Low	Low	Low	Low	Low	Low	Low
Canyon H/W	Low	Average	High	Low	Average	High	Low	Average	High	Low	Average	High	Low	Average	High
Vulnerable population					Elders	Elders	Elders & Frail Health	Elders & Frail Health	Elders & Frail Health	Elders & Frail Health	Elders, Frail Health and youngsters	Elders, Frail Health and youngsters	All	All	All
Description	Person on shaded area, surrounded by highly reflective materials and on a pathway favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and pathway not favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and pathway blocking wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway not favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway blocking wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway blocking wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow
Combination: 10; Probability of occurrence: Likely; Hazard: Air temperature increase combined with wind speed drop and high direct solar radiation								✖			✖				

Figure 5: Increasing temperature SLOD Risk matrix reading example. Starting from the hazard (grey) or from the exposure (blue).



Vulnerability	Negligible			Low			Average			High			Extreme		
Severity	I			II			III			IV			V		
Traffic	None	None	None	Low	Low	Low	Average	Average	Average	High	High	High	High	High	High
Elements capturing pollutants	High	High	High	Average	Average	Average	Low	Low	Low	Low	Low	Low	Low	Low	Low
Wind speed	High	Average	Low	Low	Average	High	Low	Average	High	Low	Average	High	Low	Average	High
Vulnerable population				Youngsters	Youngsters & Elders	Youngsters & Elders	Elders & Frail Health	Elders & Frail Health	Elders & Frail Health	Elders & Frail Health	Elders, Frail Health and youngsters	Elders, Frail Health and youngsters	All	All	All
Description	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway favoring wind flow	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway not favoring wind flow	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway blocking wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and pathway blocking wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow
Combination: 6; Probability of occurrence: Likely; Hazard: NO_2 [μg/m3] = 40 (1 y)															
Combination: 7; Probability of occurrence: Likely; Hazard: NO_2 [μg/m3] = 200 (1 h)								✖			✖				

Figure 6: Air pollution SLOD Risk matrix reading example. Starting from the hazard (grey) or from the exposure (blue).

- Using the first approach (*grey* in Figure 6), the type of hazard is identified from monitoring air quality thresholds; then, looking at the descriptions on the vulnerability tab and depending on the BE disposition, the location of the occupant would provide a certain risk. That is, a person walking next to a trafficked street, with no adjacent pollution absorbents nor barriers, and wind-flow, if any, not favored (i.e. *High physical vulnerability, severity IV),* could allow to preliminary identify a *high-extreme* degree of risk. Also, *elders, youngsters and frail health* individuals are threatened. Later, this risk shall be escalated by the space occupation condition.

- Differently if the vulnerability is assessed first on, or allocated to, a certain specific location (*blue* in Figure 6). For instance, someone in a secondary street that diverts from a trafficked one, with no adjacent pollution absorbents and wind-flow, if any, not favored (i.e. *Average physical vulnerability, severity III),* will reach an *average* degree of risk if hazard combination 6 or 7 arises. And the most susceptible individuals are recognized as *elders* and *frail health.* Under these settings, the demographics of the area shall be surveyed to weight the risk values.

4. Conclusions

Risk matrixes approach is a diffused and well-documented method for understanding, categorizing, monitoring and managing risk. The method enables rapid integration into analyses that consider other aspects of risk and safety. The method allows to condensate into one single value, or category, the superposition of different parameters. In the case of SLOD risk assessment, and in particular, analyzing *increasing temperatures* and *air pollution*, it allows to condensate environmental, built environment and demographic conditions into one unique result that communicated the degree of risk at which one pedestrian/person is exposed.

However, one of the main weaknesses listed by Ni et al. (2010) is that normally when constructing these matrixes, no ranking or severity is given to the hazards, exposure or vulnerability through the use of quantitative analysis.

The use of quantitative data for completing the risk matrix assessment has been roughly applied in this work, through the approximative calculation of AQI and UTCI for determining the severity of the combined pollutants and thermal stressors. Moreover, the probability of occurrence has been determined from the values encountered in D.2.2.1 for one or up to 3 years data, which is not significantly representative, and a much larger database shall be used to effectively establish these probabilities of occurrence.

Having structured and singled out the parameters composing the hazards, the exposure, the vulnerable settings and groups from the population, it is possible to further study this matter for deeper analysis on the delineated site. Demographic data, on-site measurements and surveys, and climate-based modeling are foreseen as complementary activities that will help to complement the risk matrixes presented in Table 6 and Table 7.

Having a structure with the correct parameters allows to proceed into decipher the risk assessment values, to then use a heatmap to establish the zones of the matrix which recall a non-dangerous, risky and extreme conditions from the SLODs perspective. But above all, to tell what extent it is riskier than any other type of hazard – exposure – vulnerability combination. Moreover, this structure and configuration consents a multi-level analysis of risk, combining different aspects by overlapping the risk degree encountered for each aspect.

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Annex

		Vulnerability	*Negligible*			*Low*			*Average*			*High*			*Extreme*		
		Severity	*I*			*II*			*III*			*IV*			*V*		
		Green area coverage	*High*	*High*	*High*	*High*	*High*	*High*	*Average*	*Average*	*Average*	*Low*	*Low*	*Low*	*None*	*None*	*None*
		Albedo	*High*	*High*	*High*	*Average*	*Average*	*Average*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*
		Canyon H/W	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*
		Vulnerable population					*Elders*	*Elders*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders, Frail Health and youngsters*	*Elders, Frail Health and youngsters*	*All*	*All*	*All*
Combination	**Probability of occurrence**	**Hazard** / **Description**	Person on shaded area, surrounded by highly reflective materials and on a pathway favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and pathway not favoring wind flow	Person on shaded area, surrounded by highly reflective materials, and pathway blocking wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway not favoring wind flow	Person on shaded area, surrounded by materials with average reflectance, and pathway blocking wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on apparent shaded area, surrounded by materials with low reflectance, and pathway blocking wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway not favoring wind flow	Person on direct solar exposed area, surrounded by materials with low reflectance, and pathway blocking wind flow
1	*Common*	High direct solar radiation															
2		Wind speed drop															
3		Humidity saturation															
4	*Has occurred*	Surface Heat storage capacity saturation															
5		Air temperature increase															
6	*Most likely*	Air temperature increase combined with wind speed drop															
7		Air temperature increase combined with humidity saturation															
8		Air temperature increase combined with high direct solar radiation															
9	*Likely*	Air temperature increase combined with surface heat storage capacity saturation															
10		Air temperature increase combined with wind speed drop and high direct solar radiation															
11		Air temperature increase combined with wind speed drop and humidity saturation															
12		Air temperature increase combined with wind speed drop and surface heat storage capacity saturation															
13		Air temperature increase combined with surface heat storage capacity and humidity saturation															
14	*Has occurred*	Air temperature increase combined with surface heat storage capacity saturation and high direct solar radiation															
15		Air temperature increase combined with humidity saturation and high direct solar radiation															
16		Air temperature increase combined with low humidity															
17	*Rare*	Air temperature increase combined with wind speed drop, surface heat storage capacity and humidity saturation															
18		Air temperature increase combined with wind speed drop, surface heat storage capacity saturation and high direct solar radiation															
19		Air temperature increase combined with wind speed drop, humidity saturation and high direct solar radiation															
20		Air temperature increase combined with wind speed drop, high direct solar radiation, humidity and surface heat storage capacity saturation															

Table 6: Risk matrix of the SLOD of increasing temperature. The Matrix vulnerability will be unique for each location ranging only few columns from left to right, but any of the mentioned hazard could arise. For instance, the area delimited in D.2.1.2 is presenting an exposure which ranges from Average (III) to High (IV), depending on the time of the year (i.e. season) and the canyon considered.

Vulnerability	*Negligible*	*Low*	*Average*	*High*	*Extreme*

		Severity	*I*			*II*			*III*			*IV*			*V*		
		Traffic	*None*	*None*	*None*	*Low*	*Low*	*Low*	*Average*	*Average*	*Average*	*High*	*High*	*High*	*High*	*High*	*High*
		Elements capturing pollutants	*High*	*High*	*High*	*Average*	*Average*	*Average*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*	*Low*
		Wind speed	*High*	*Average*	*Low*	*High*	*Average*	*Low*	*High*	*Average*	*Low*	*High*	*Average*	*Low*	*High*	*Average*	*Low*
		Vulnerable population				*Youngsters*	*Youngsters & Elders*	*Youngsters & Elders*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders & Frail Health*	*Elders, Frail Health and youngsters*	*Elders, Frail Health and youngsters*	*All*	*All*	*All*
		Description	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway favoring wind flow	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway not favoring wind flow	Person in open spaces (private gardens, parks and public squares) or pedestrian zone, surrounded by elements able to capture pollutants and on pathway blocking wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in local and private streets, partially surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and pathway favoring wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in secondary streets, not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway favoring wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in a traffic area (main streets and boulevards), not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and pathway favoring wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway not favoring wind flow	Person in a highly traffic area (highway), not surrounded by green area or materials able to capture pollutants and on pathway blocking wind flow
Combination	**Probability of occurrence**	**Hazard**															
1	*Common*	PM 2.5 [µg/m3] = 25 (24 h)															
2		PM 10 [µg/m3] = 10 (1 y)															
3		SO2 and smoke															
4	*Has occurred*	higher concentration of NO2 and CO															
5		O3 [µg/m3] = 100 (8 h)															
6	*Likely*	NO2 [µg/m3] = 40 (1 y)															
7		NO2 [µg/m3] = 200 (1 h)															
8	*Most likely*	combination solar radiation + NOx = O3															
9		combination solar radiation + VOC = O3															
10	*Rare*	VOC - Formaldehyde [mg/m3] = 0,1 (30 min)															
11		CO [mg/m3] = 100 (15 min)															
12		CO [mg/m3] = 35 (1 h)															
13		CO [mg/m3] = 10 (8 h)															
14		CO [mg/m3] = 7 (24 h)															
15		SO2 [µg/m3] = 20 (24h)															
16		SO2 [µg/m3] = 500 (10 min)															

Table 7: Risk matrix of the SLOD of air pollution. The Matrix vulnerability varies for each location, ranging from left to right, but any of the mentioned hazard could arise. For instance, the area delimited in D.2.1.2 is presenting an exposure which ranges from Low (II) to High (IV), depending on the time of the day (i.e. traffic peaks) and the canyon consider