WP 1 – BE and SUOD: State of the Art (SoA), risks and human behavior

T1.1 - SoA-based definition and characterization of BE as network of buildings, infrastructures, connecting space in reference to SUOD occurrence and users' typologies

DELIVERABLE ID	D1.1.1
Deliverable Title	BE prone to SUOD definitions report
Delivery month	M3
Revision	1.0
Main partner	UNIRM UNIPG
Additional partners	POLIBA
Authors of the contribution	Currà Edoardo (UNIRM); D'Amico Alessandro (UNIRM); Russo Martina (UNIRM); Angelosanti Marco (UNIRM); Mochi Giovanni (UNIPG); Fatiguso Fabio (POLIBA); Cantatore Elena (POLIBA)
Deliverable type	report
Number of pages	46

Abstract

The first task of the WP1 focuses on the state of the art concerning the relation between Built Environment (BE) and Sudden-onset disasters (SUOD) considering the risks and human behavior. To this end, the activities are divided in two parts, so as to outline a consolidated state of the art on these issues, and a first characterization of main factors characterizing the relation between BEs, their composing elements and the risks (i.e. SUODs). The first part of the investigation involves the detection and transposition of the various classification of risks of the scientific literature and international disaster risk reduction and assessment organizations. The second step interested the BE, which can be defined as human-made surroundings that provide a setting for human activity, ranging in scale from personal shelter to neighborhoods, and large-scale civic surroundings.

Results on the disaster classification affecting the BE underline how one of the most significant categorizations distinguishes between SUOD and SLOD (Slow-Onset Disasters) according to the timing of the consequences, while other ratings consider source, frequency, scale, and predictability.

In particular, the Sudden-onset disasters are those events: whose occurrence cannot be predicted far in advance (e.g. from seconds for earthquakes, to weeks or months for volcanos activities); as an alternative definition, which take a short time to produce emergency conditions. Secondly, if considering the source of the disaster (natural and technological disasters), the specific SUOD affecting BE are organized by evaluating: predictability reaction time to alarm, source of risk for humans, influence between built environment and safety, and the reciprocal correlation between a couple of SUODs (primary/secondary). These relations are illustrated, showing a database on European natural and technological disasters of the last century in which the primary and secondary disasters were correlated.

Results concerning the characterization of BE prone to SUODs underline how the primary importance of open spaces in the Built Environment as elements for characterizing them also in respect to the possible

emergency phases and the behavior of the BEs users. A particular attention is given to the BEs constituting the base elements for urban areas (i.e. compact historic city) because of the related risk-affecting specific conditions (i.e. crowding, complexity of the overall BEs form, built element features, BEs uses).Moving from different classifications of types of open spaces in the Built Environment), we proceeded to identify the morphological classes of BE representative of the variables of urban systems that interact with the identified SUODs risks. The criteria are typology, geometric-Space characters, constructive characteristics, characteristics of use, environmental characteristics. Finally, ten main types of BE morphology have been identified and grouped into two categories: Areal BE (Squares) and Linear BE (paths). In conclusion, thanks to this deliverable, the next step of the research will can take advantages of these results in the characterization of significant real SUOD-affected BE, by involving case studies and moving towards the definition of BE-Typologies prone to SUOD.

Keywords

Built Environment; Disaster classification; Open Spaces in the Built Environment; Sudden-onset disasters

Approvals

Role	Name	Partner
Coordinator	Enrico Quagliarini	UNIVPM
Task leader	Giovanni Mochi	UNIPG
	Edoardo Currà	UNIRM

Revision versions

Revision	Date	Short summary of modifications	Name	Partner
0.1	24.01.2020	Integration with abstract and revision of the criteria for open space classification	Giovanni Mochi Edoardo Currà Alessandro D'Amico	UNIPG UNIRM UNIRM
0.2	29.01.2020	Integration of additional analysis on BE features when prone to terrorist acts		POLIBA
0.3	30.01.2020	Conclusions improvement after previous revision		UNIPG
1.0	31.01.2020	Modification to abstract, introduction and section 3, text editing and proofreading, keyword revision	Enrico Quagliarini	UNIVPM

Summary

1. Introduction

The concept of Resilience, initially introduced in the scientific literature in the context of ecology as a way to understand the nonlinear dynamics observed in ecosystems (Holling 1973, 1996), has evolved following independent paths in various disciplines and is today closely related to Disaster Risk Reduction (DRR) (UNISDR 2015).

Resilience describes the ability of a system to withstand or accommodate stresses and shocks such as climate impacts, while still maintaining its function (United Nations Office for Disaster Risk Reduction (UNISDR) 2009). In the Built Environment (BE), especially while focusing to large scales (e.g. urban areas), resilience depends on the ability to maintain essential assets, as well as to ensure access to services and functions that support the wellbeing of the hosted users (in the urban area, of the citizens) (Dickson et al. 2012). Hosted populations depend on interrelated and interdependent built environment systems in urban areas (buildings, open spaces, infrastructure, ecosystems, institutions, and knowledge networks) that support and are supported by actors or social agents (at the urban scale i.e. individuals, households, and private and public sectors). The resilience of a built environment (e.g. at a wider scale, of a city centre) depends on both the its fragility and the social agents' capacity to anticipate and to take action in order to adjust to changes and stresses, recognizing that their ability to act is constrained by access to resources and supporting systems.
Built Environment (BE) that may be considered resilient exhibit a great number of characteristics, especially if considering wider scales like the urban ones, and also in respect of the critical risk conditions they could face (D'Amico e Currà 2014; Miller 2015; Santamouris et al. 2015; Fatiguso et al. 2017; Cerè et al. 2017). In general terms, some common features can be highlighted. First of all, flexibility and diversity are the BE ability to perform essential tasks under a wide range of conditions, and to convert assets or modify structures to introduce new ways of achieving essential goals. Then, redundancy and modularity include the capacity for contingency situations, to accommodate increasing or extreme events, unexpected demand, or surge pressures. While considering failures of the system which have no adverse effect on the safety function of the system itself (the so-called "safe failures"), one of the most significant feature is the ability to absorb shocks and the cumulative effects of slow-onset challenges in ways that avoid catastrophic failures. Then, some characteristics have an organizational character, in the long and in the short term, such as resourcefulness, which is the capacities to visualize and act, as well as to identify problems, establish priorities, and mobilize resources, or to recognize and devise strategies that relate to different incentives and operational models of different groups. Responsiveness and rapidity correspond to the capacity to organize and reorganize, as well as to establish function and sense of order in a timely manner both in advance of and following a failure. Finally, learning through formal and informal processes means to internalize past experiences and failures and alter strategies based on knowledge and experience.

In addition, the specific disaster conditions to be faced by the BE affect such features by varying their quality depending on the disaster-BE (induced) interactions and the hosted users' response. In particular, the impact of natural and technological disasters is potentially greater in BEs placed in urban areas, where the high population density increases the seriousness of the socio-economic consequences due to the interruption of essential services (Desouza e Flanery 2013; Santamouris et al. 2015; Cerè et al. 2017; Bernardini et al. 2018; Koren e Rus 2019; Kim e Newman 2019). In these contexts, it is therefore necessary to strengthen the resilience characteristics, in order to increase the system capacity to absorb disturbance and change, reorganize and preserve basic structures and essential services to cope with natural disasters. The construction industry is traditionally associated with the reconstruction phase. However, today there is a growing awareness of how different professionals of the built environment play a crucial role in anticipating, evaluating and preparing response and post-disaster recovery. In this sense, the importance of existing BE role in defining and increasing the urban disasters resilience is actually outlined by previous studies, which underline, in particular, the built heritage key function in the overall BE context (Desouza e Flanery 2013; Jha et al. 2013; Jabareen 2013; Valdés et al. 2013; Arup et al. 2014; Lewis et al. 2014).

Other man-made disasters can influence the effective risk level both of hosted users and of/in BE, also depending on the specific social and cultural factors. For instance, the increasing funding in the Focus Area of 'Boosting the effectiveness of the Security Union' in the H2020 project calls allows highlighting the outstanding relevance of security and safety of and in the BE, adding terrorism near to the traditional natural disaster affecting the BEs and their population. In fact, even if terrorism is not a phenomenon of modern times (Combs e Slann 2009), the current meaning of the term and the growing relevance of that threat are strictly related to the recent events, i.e., afterward the 9/11 attack. Starting from this terrorist attack, the meaning of resilience in BE has been extended including terrorism to the other widespread threats (as flooding and global warming), because of similarities in term of vulnerability, insecurity and change (Coaffee et al. 2009b).

The built environment is characterized by protective features, which can represent an important element to reduce the disaster risk. On the contrary, the corruption of these features, such as the loss of strategic buildings or infrastructure, can increase a community’s vulnerability. With the term “built environment”, which came into widespread use in 1990s, we refer to the result of human activities, describing it in one holistic and integrated concept. Research in the built environment encompasses the fields of architecture, building science and building engineering, construction, landscape, urbanism, as described by the Research Assessment Exercise in the UK. Based on the review of historical events, the performance of the built environment, and the codes and standards used to design and construct the built environment, the following guidance and metrics are needed to promote the development of a resilient built environment (D’Amico e Currà 2014, 2018).

This report tries to link together such aspects… To this end, the definition of a disaster is offered in Section 2, by focusing on the possible classification of disasters according to literature works, and evidencing their features in terms of impact on the BE, i.e. according to a time-based classification (PreventionWeb - UNDRR), by distinguishing Sudden and Slow onset disasters. This classification will be adopted as base element for the D2.1.1-related activities, which relate to SLow-Onset Disasters (SLODs), while this report will stress the attention on SUdden Onset Disasters (SUODs). In this context, the interrelation between the BE and SUODs is assessed in Section 3, so as to outline the main features of SUODs-prone BE, which a specific focus on Open Spaces in the Built Environment categorization.

2. Disasters: definitions and classifications

The etymological origin of the term disaster indicates "anything that befalls of ruinous or distressing nature; any unfortunate event" especially a sudden or great misfortune, 1590s, from Middle French désastre (1560s), from Italian disastro, literally "ill-starred," from dis-, here merely pejorative, equivalent to English mis- "ill” + astro "star, planet," from Latin astrum, from Greek astron "star" (Figure 1).

The original sense is connected to astrological terms, since it refers to a calamity blamed on an unfavourable position of a planet, and "star" here is probably meant in the astrological sense of "destiny, fortune, fate." On this issue, please compare Medieval Latin astrum sinistrum "misfortune", that is literally "unlucky star" and English ill-starred (Online Etymology Dictionary).

Several definitions of the concept of “disaster” are detectable in the scientific literature (in brackets, the acronym of the main organization dealing with the definition):

- A disaster is an occurrence disrupting the normal conditions of existence and causing a level of suffering that exceeds the capacity of adjustment of the affected community (WHO).
- A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (ISDR).
- Situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance (CRED).
- Serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UNDRR).

“Disaster” is a term describing an event that can be defined spatially and geographically, but that demands observation to produce evidence. It implies the interaction of an external stressor with a human community and it carries the implicit concept of non-manageability. The term is used in the entire range of risk-reduction activities, but it is possibly the least appropriate for response.

Despite the differences in each single definition, it could be possible to recognize some common characteristics:

- Collective nature of the event, which affects population groups
- The idea of gravity, of sudden beginning; an accidental event that disturbs the normal course of social life
- Feature of an event not common by nature.

Concept of collective damage and destruction DISASTER can be referred to the Protection Agenda: disasters refer to disruptions triggered by or linked to hydro-metrological and climatological natural hazards, including hazards linked to anthropogenic global warming, as well as geophysical hazards (UNDRR).

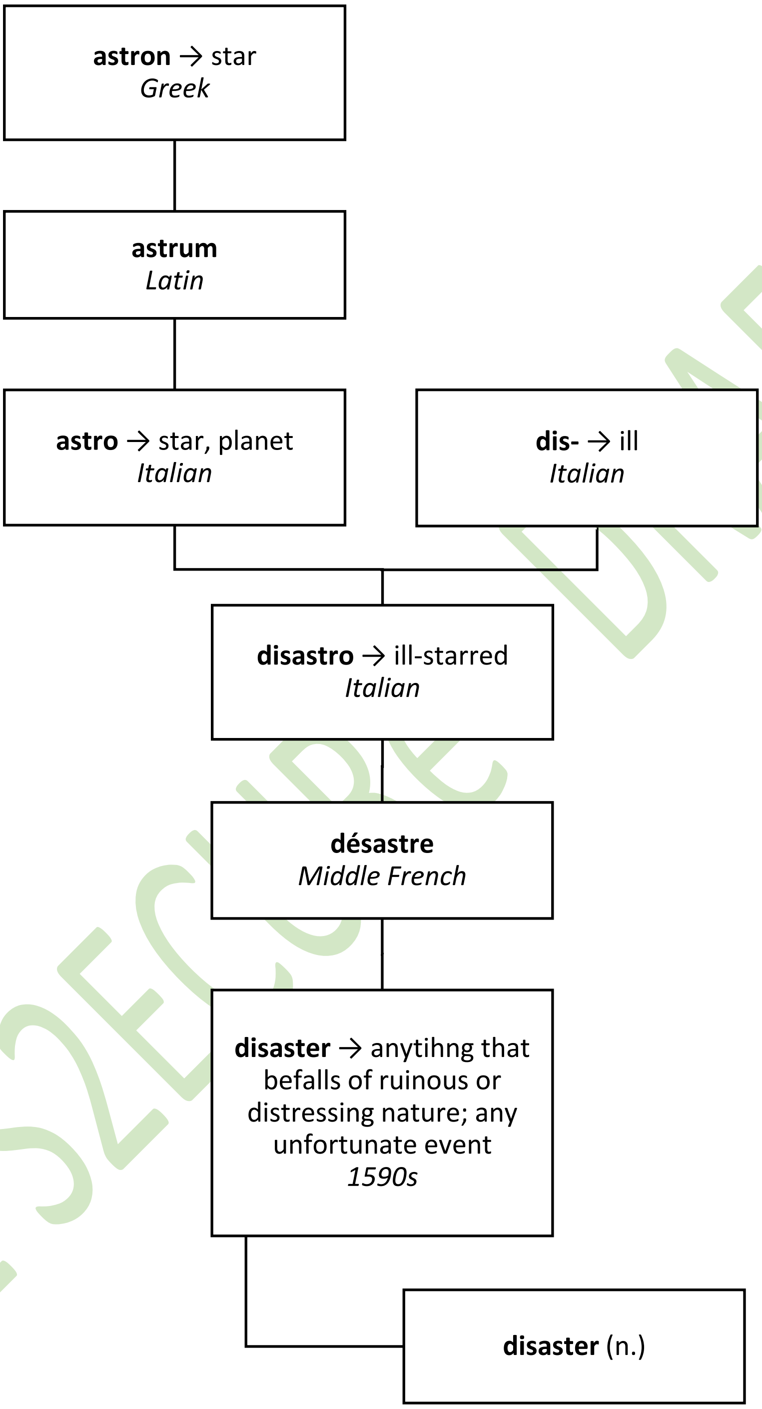


Figure 1: scheme of etymology of the term "disaster".

2.1 Disasters classification based on cause: Natural VS human-made

Official disaster statistics are normally provided by UNDP, UNISDR, the World Bank, or other insurance companies such as the Munich Re Insurance Company (Figure 2) or the Swiss Re Insurance Company. According to Ranke (Ranke 2016) the most comprehensive database exists with the industrial countries, especially the United States of America, that have collected an enormous databank to serve the needs of the national Natural Disaster Risk Assessment Program "Hazus 99" (FEMA 2013) or the United Nations Global Assessment Report on Disaster Risk Reduction (UNDRR 2019) that every two years comprehensively reviews and analyses the world disaster risk and the international initiatives of disaster risk management.

Disaster categorizations, such as official disaster statistics, are provided in the scientific literature from research institutions, statistical data collection agencies (CRED-EMDAT and START) (Figure 6), international organizations (UNDP, UNISDR, the World Bank, WHO) (Figure 5). The most common classification divides disasters according to the cause (CRED 2018; Centre for Research on the Epidemiology of Disasters (CRED) 2019):

- **Natural disasters** are those determined by the energy released by natural elements: water, earth, air, fire.
- **Technological / human-made (anthropic) disasters** are those related to human activity, linked to the industrial, energy and transport sectors, and human will as well as terrorist attacks.

At Global scale, the EMDAT database is one of the most complete and today contains core data on the occurrence and impacts of about 16,000 disaster events in the world dating back to 1900 (Below et al. 2007). For this reason, in this report is used the classification proposed by CRED-EMDAT (EM-DAT) (Table

Table 1).

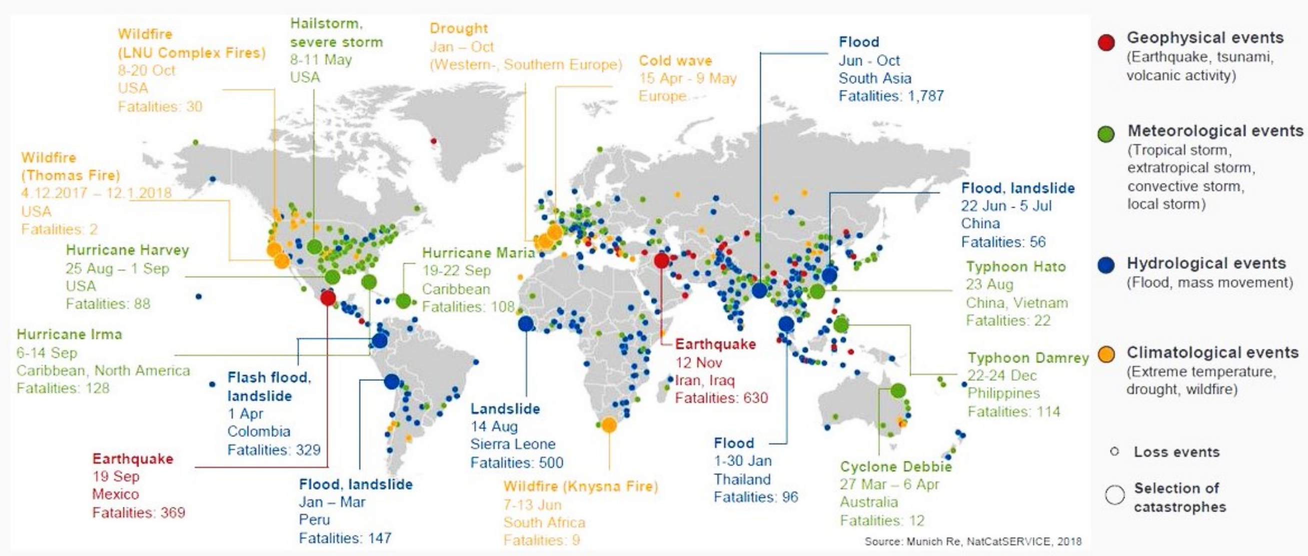


Figure 2: Map of natural disasters occurred in 2017 (MunichRE).

In particular, the definition of "natural" for disaster has long been disputed (Figure 7). In a paper entitled "Taking the 'naturalness' out of natural disasters" O'Kefee (1976) identified the cause of the increase in documented disasters as "the growing vulnerability of the population to extreme physical events", instead of changes in nature. Nevertheless, referring to the earthquake and tsunami that struck Portugal in 1755 Kelman (Kelman 2010) observes that nature did not build collapsed houses and identifies in the high population density of Lisbon the factor that has most contributed to the high losses, as previously did Rousseau in a letter to Voltaire in 1756 (Haigh e Amaratunga 2010; D'Amico 2016).

For what concerning the anthropic disasters, if adapting the meaning of "threat" to the events in the last century, the "terrorism" can be introduced as a particular threat that is affecting BEs (mainly, those in urban areas) and population. It is introduced as a sub-types of human-man disasters by its nature: according to several scientific authors (Kurrild-Klitgaard et al. 2006; Piazza 2008), terrorism is a political and demographic phenomenon rooted in political repression, state failure, ethnic conflict and foreign policy behaviour (Freytag et al. 2011).

Nowadays, Terrorism is a very complex issue and there are several definitions that derive from the possibility to highlight the generated disasters in a material (physical, economic damages etc) or immaterial (psychological, political effects) point of view. In that sense, the National Consortium for the Study of Terrorism and Responses to Terrorism (START) at the University of Maryland contribute in defining the threat and condensing and coding all terrorist attacks along 1970-2018. In detail, the START Consortium developed the Global Terrorism Database™ , an open access database in which the records of terrorist attacks from multiple sources are collected and coded for several features (attack, target, weapon types, number of fatalities, etc). Currently, it represents the most complete database associate to a specific codebook related to global terrorist attacks (National Consortium for the Study of Terrorism and Responses to Terrorism (START) 2019) (Figure 3, Figure 4).

Figure 3: chart results of Terrorist attack in the world classified over the time (GTD).

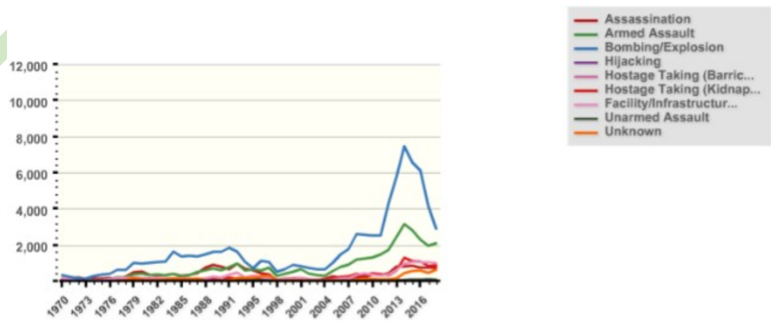
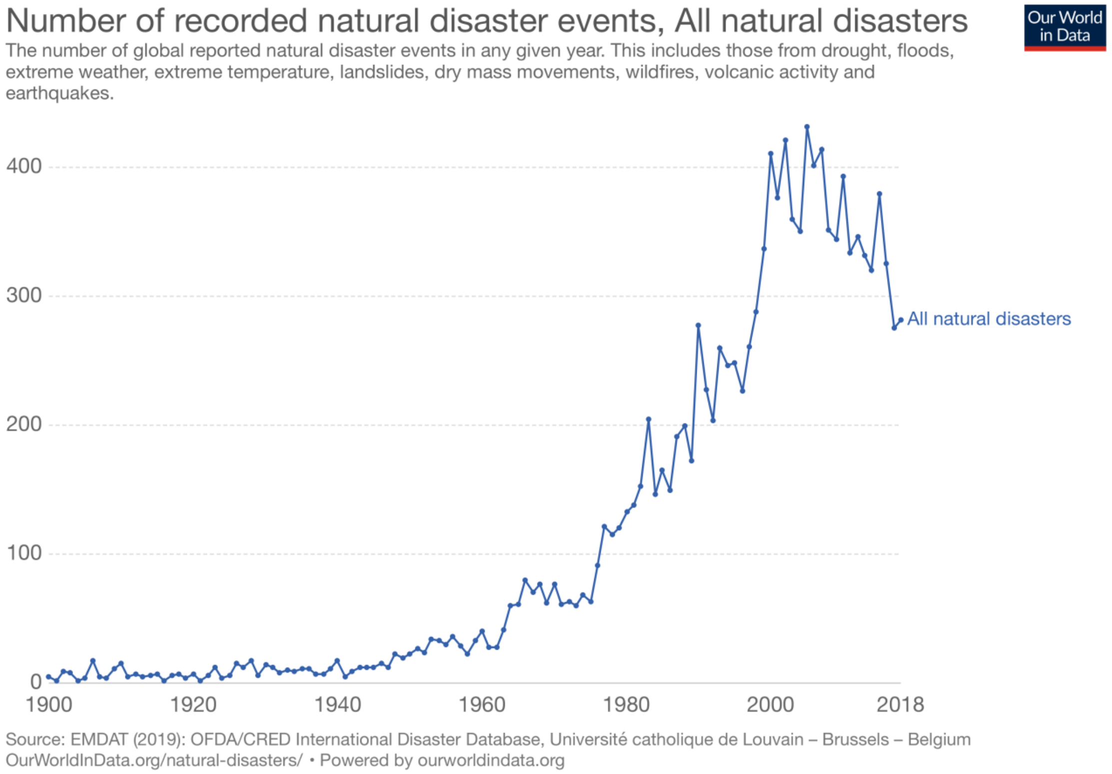


Figure 4: chart results of Terrorist attack in the world classified for attack types (GTD).

Table 1: Classification of disasters according to EMDAT and GTD. Elaborated by authors D'Amico, Russo, Angelosanti, Cantatore.

Disaster Group	Disaster Subgroup	Disaster Main Type	Disaster Sub-Type
Natural Disaster	Geophysical	Earthquake	Ground movement
			Tsunami
		Mass Movement (dry)	Rock fall
			Landslide
		Volcanic activity	Ash fall
			Lahar
			Pyroclastic flow
			Lava flow
	Meteorological	Storm	Extra-tropical storm
			Tropical storm
			Convective Storm
		Extreme temperature	Cold wave
			Heat wave
			Severe winter conditions
		Fog	
	Hydrological	Flood	Coastal flood
			Riverine flood
			Flash flood
			Ice jam flood
		Landslide	Avalanche (snow, debris, mudflow, rockfall)
		Wave action	Rogue wave
			Seiche
	Climatological	Drought	
		Glacial Lake Outburst	
		Wildfire	Forest Fire
			Land fire: Brush, bush,
			Pasture
	Biological	Epidemic	Viral Disease
			Bacterial Disease
			Parasitic Disease
			Fungal Disease
			Prion Disease
		Insect	Grasshopper

		infestation	Locust
		Animal Accident	
	Extraterrestrial	Impact	Airburst
		Space weather	Energetic particles
			Geomagnetic storm
			Shockwave
Technological	Industrial accident		Chemical spill
			Collapse
			Explosion
			Fire
			Gas leak
			Poisoning
			Radiation
			Oil spill
			Other
	Transport accident		Air
			Road
			Rail
			Water
	Terrorist attack		Assassination
			Armed assault
			Bombing/explosion
			Hijacking
			Hostage taking
			Facility/infrastructure attack
			Unarmed Assault
			Unknown
	Miscellaneous accident		Collapse
			Explosion
			Fire
			Other



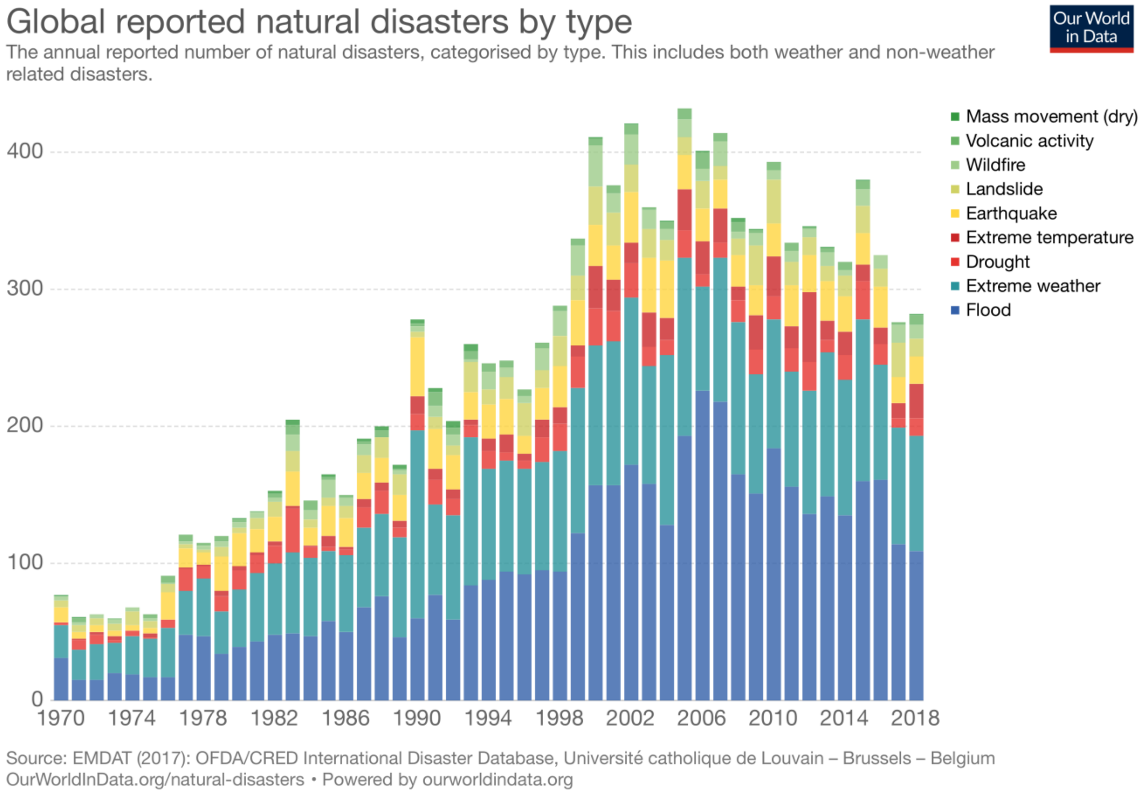


Figure 5: Number of recorded natural disasters (above), global report natural disasters by type (below) (University of Oxford).

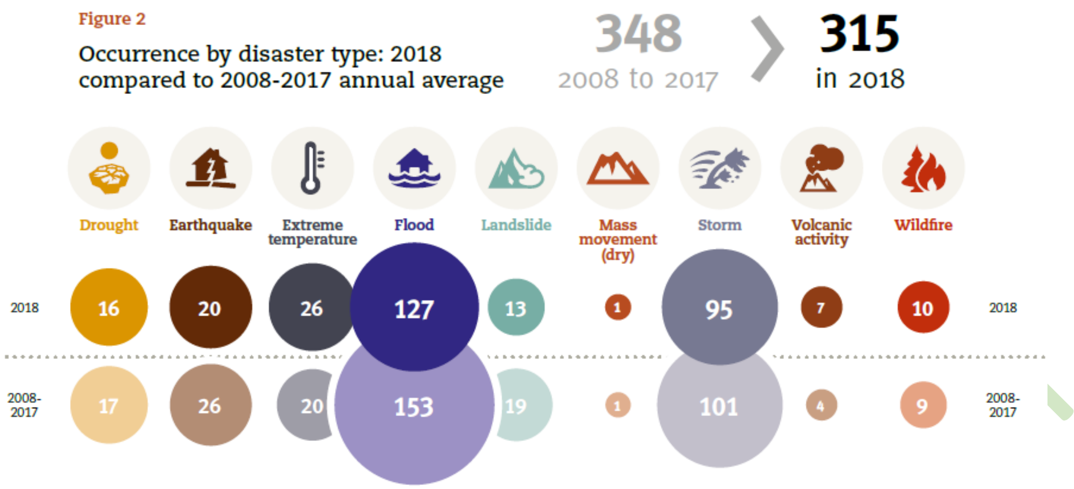


Figure 6: Occurrence by disaster type: 2018 compared to 2008-2017 (CRED 2018).

Referring to the exposure of BEs and population to human-made disasters, the terrorist attack represents a particular case in managing and preventing. In fact, mean differences between terrorism and natural threats exist in term of "will"; even if both natural and terrorist attacks cannot be predictable, natural threats have not the "intent". In addition, previous works highlighted the relevance of the impact in a terrorist attack considering the willpower of terrorists to maximize the effects in term of fatalities, material, economic and symbolic damages (Woo 2015).

Figure 7: Understanding the "naturaless" of disasters (UNDRR).

2.2 Disasters classification based on consequences timing: Sudden-onset VS Slow-onset

Another useful classification of disasters is the now provided by WHO, that classified the calamities according to the consequences timing (PreventionWeb - UNDRR; WHO 2014):

- **Sudden-onset disasters (SUOD).** Both "natural" disasters (e.g. earthquakes, hurricanes, floods) and man-made or "complex" disasters (e.g. sudden conflict situations arising from varied political factors), for which there is little or no warning.

- **Slow-onset disaster (SLOD).** Disasters that take a long time to produce emergency conditions, for instance natural disasters such as drought or socio-economic decline, which are normally accompanied by early warning signs.

Emergency events, usually referred as SUdden-Onset Disasters (SUOD) (e.g. natural as earthquake; man-made as terrorist acts) are catastrophic because of their immediate consequences on BE, with human, social, economic, cultural losses for the community (and its identity). But our cities and inhabitants are also subject to SLow-Onset Disasters (SLOD) mainly induced by anthropic factors: i.e. the combination of strong and prolonged summer heat waves with poor air quality greatly compounds negative effects and can pose major (and invisible) risks to human health with poor life quality and high social costs.

Also, the UNDRR (formerly known as UNISDR) in the Sendai Framework for Disaster Risk Reduction 2015-2030 cites this classification:

- A slow-onset disaster is defined as one that emerges gradually over time. Slow-onset disasters could be associated with, e.g., drought, desertification, sea-level rise, epidemic disease.
- A sudden-onset disaster is one triggered by a hazardous event that emerges quickly or unexpectedly. Sudden-onset disasters could be associated with, e.g., earthquake, volcanic eruption, flash flood, chemical explosion, critical infrastructure failure, transport accident and terrorist attacks.

2.3 Other disasters classification

For the purpose of the scope of the Sendai Framework for Disaster Risk Reduction 2015-2030 (paragraph 15), the following classification are also considered:

- On the base of the scale:
  - Small-scale disaster: a type of disaster only affecting local communities which require assistance beyond the affected community.
  - Large-scale disaster: a type of disaster affecting a society which requires national or international assistance.
- On the base of the frequency:
  - Frequent and infrequent disasters: depend on the probability of occurrence and the return period of a given hazard and its impacts. The impact of frequent disasters could be cumulative or become chronic for a community or a society.

3. Built environment and disasters

The term BE means human-made surroundings that provide a setting for human activity, ranging in scale from personal shelter to neighbourhoods and large-scale civic surroundings. In summary, whatever is human made is the built environment. In a similar manner, the world that is not human-made or anthropogenically influenced can be referred to as the natural environment.
The relationship between built and natural environments can mathematically be expressed as follows:

Total Environment = Natural Environment + Built Environment
Or
Built Environment = Total Environment - Natural Environment

(Butt et al. 2015)

The term BE is also widely used to describe the interdisciplinary field of study which addresses the design, construction, management and use of the human-made surroundings and their relationship to the human activities which take place within them over time. This does not necessarily mean only buildings, structures, canals, bridges, housing stock and offices, but also individual commodities that are used in these buildings and structures, industries and their associated manufacturing and processing plants, technologies (embodied/physical and disembodied/non-physical), inventories and stock, and supply chains. Moreover, the complexity of BE located in disaster-prone areas means considering the interactions between its site-connected (i.e. site characteristics), physical (i.e., buildings, urban fabric and paths networks), human (i.e., hosted population), organizational (i.e., spaces planning and management also in ordinary conditions), intangible (i.e., cultural and social), population-based (i.e. number and features of the exposed individuals) factors and the type of disaster which can occur into it, so as to assess the possible risk levels and to determine which solutions should be adopted to mitigate the disaster impact (Spence 2004; Moore 2008; Kappes et al. 2012; Bosher 2014; Cerè et al. 2017).
In this context, the main attention on resilience and DDR research is focused on buildings, infrastructure and social community, as highlighted by recent literature review works (Koren e Rus 2019). Koren and Rus analysed that there are some research activities focused on the role of open spaces in building resilience (Figure 8).

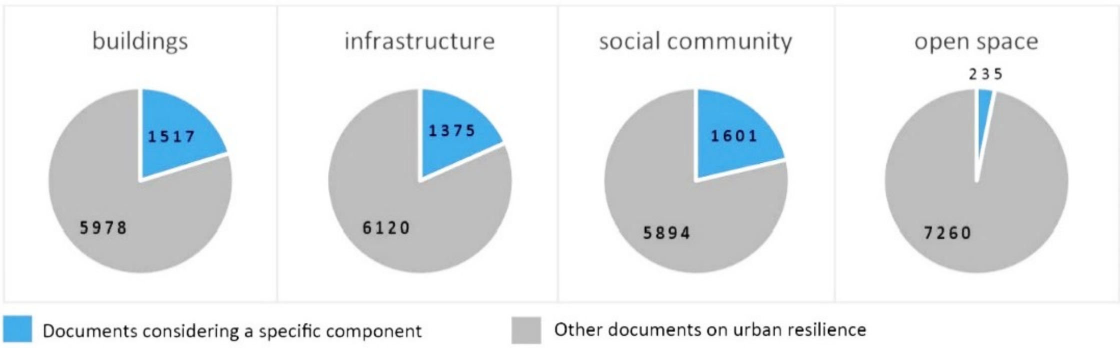


Figure 8: Distribution of individual components considered in research on urban resilience (Koren e Rus 2019).

In their study, Koren and Rus investigated 7495 documents related to urban resilience. The results show that 20% of the papers consider buildings, 18% infrastructure, 21% social community, and just 3% of the documents deal with open space as main individual components for the urban resilience. Among these, they performed a more detailed analysis on 180 documents, investigating the co-occurrences of terms (Figure 9).

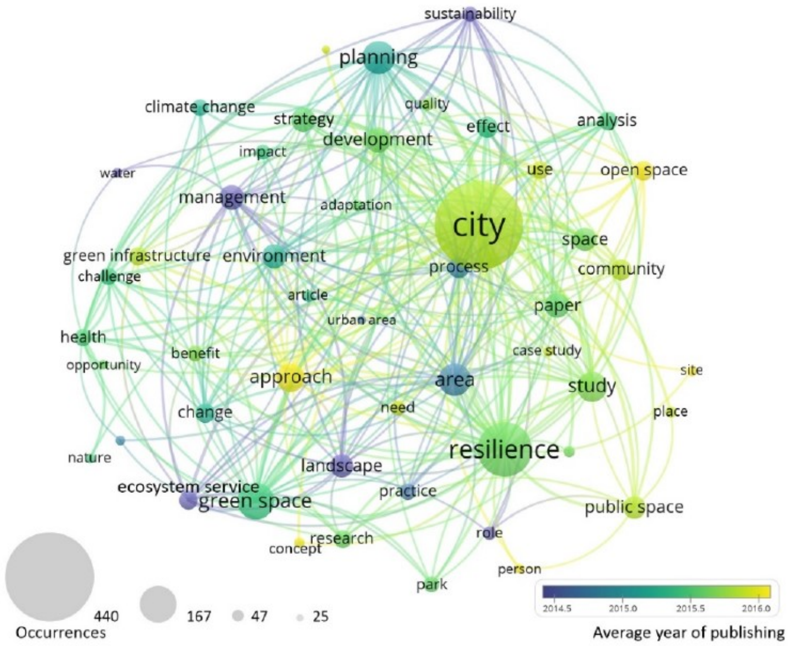


Figure 9: Results of a preformed co-occurrence analysis of the terms in 180 documents reviewed on open space related to urban resilience (Koren e Rus 2019).

Between them, Jon Coaffee (Coaffee et al. 2009a) – one of the most important scientist in planning resilience in cities against terrorist risk – highlighted the importance and the exposure of open spaces in critical cities in UK. Moreover, Coaffee reported solutions as urban elements - already introduced - near critical open spaces in UK aimed at decreasing the exposure or mitigating the vulnerability (e.g. vehicle ramming) and that highlight the necessity to intervene in that part of cities (see Figure 10).

Figure 10: Two cases of protection in open spaces in UK. a) US Embassy, Grosvenor Square, London (2006); b) Ornamental Security Façade for the Emirates Stadium (July 2003) (Coaffee et al. 2009a).

3.1 Disasters affecting the Built Environment

3.1.1 SUODs affecting the Built Environment

According to the general classification of Section 2.2 and to the SUOD definitions reported in literature (Figure 11), the main characteristics that define the Sudden-onset disasters are:

- The occurrence cannot be predicted far in advance (from seconds for earthquakes to weeks or months for volcanos activities);
- Disasters that take a short time to produce emergency conditions.

Despite the unanimous opinion on the SUOD events characteristics, there is no shared cataloguing method of these events. UNIDRR generally collects data on earthquake, volcanic eruption, flash flood, chemical explosion, critical infrastructure failure, transport accident. WHO refers to earthquakes, hurricanes, floods (among the natural disasters) and sudden conflict situations arising from varied political factors (among the human-made disasters).

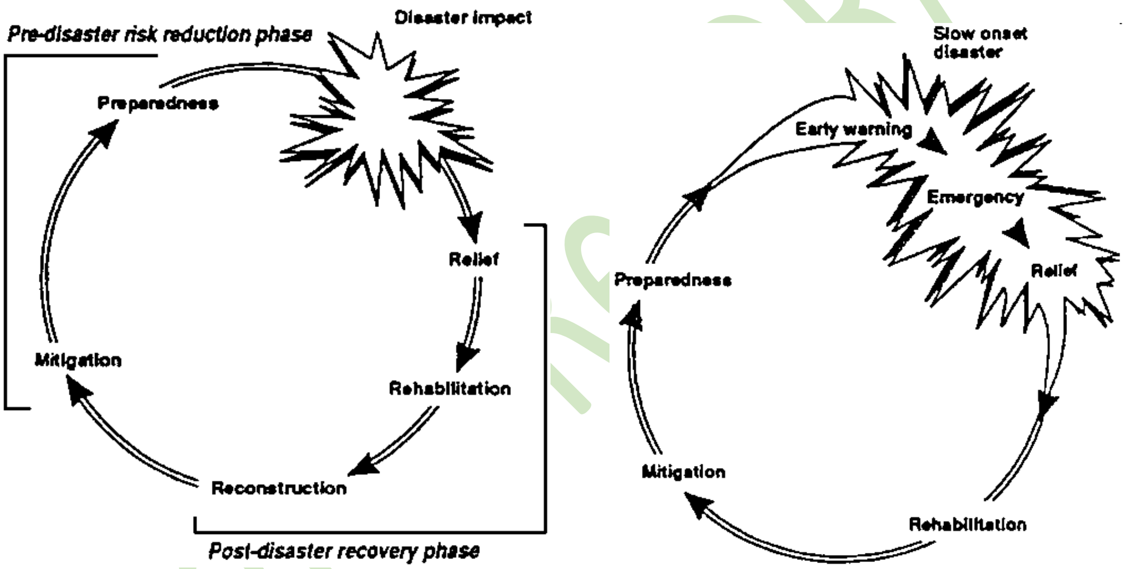


Figure 11: Rapid onset disaster management continuum and Slow onset disaster management continuum (Department of Humanitarian Affairs/United Nations Disaster Relief Office 1992).

In this report, we try to make order in this classification establishing as criteria two parameters, mainly referred to the built environment situation (Table 2):

1. Predictability of the disaster (John Twigg; Humanitarian Practice Network 2015) (cap.15):

low	0	seconds to few minutes
medium	1	several days
high	2	week or months

2. Effect timing to arise emergency condition or permit alarm warning:

short	0	immediately after the disaster occurs
medium	1	there is time from seconds to minutes for alarm warning
long	2	there is time for prepare reaction to disaster, from hours to days

Table 2: SUODs definition. Elaborated by authors on EMDAT and GTD databases (D'Amico, Russo, Angelosanti, Cantatore).

Group	Disaster Subgroup	Disaster Main Type	Disaster Sub-Type	Predictability		Effects timing	
Natural Disaster	Geophysical	Earthquake	Ground movement	low	0	short	0
			Tsunami	low	0	medium	1
		Mass Movement (dry)	Rock fall	low	0	medium	1
			Landslide				
		Volcanic activity	Ash fall	high	2	long	2
			Lahar				
			Pyroclastic flow				
			Lava flow				
	Meteorological	Storm	Extra-tropical storm	medium	1	short	0
			Tropical storm				
			Convective Storm/Tornado	medium	1	medium	1
		Extreme temperature	Cold wave	medium	1	long	2
			Heat wave				
			Severe winter conditions				
	Hydrological	Flood	Coastal flood	medium	1	medium	1
			Riverine flood				
			Flash flood				
			Ice jam flood				
		Landslide	Avalanche	low	0	medium	1
	Climatological	Wildfire	Forest Fire	low	0	medium	1
			Land fire: Brush, bush,				
			Pasture				
Technological	Industrial accident		Chemical spill	low	0	short	0
			Collapse				
			Explosion				
			Fire				
			Gas leak				
			Radiation				
			Oil spill				
			Other				
	Transport accident		Air	low	0	short	0
			Road				
			Rail				
			Water				
	Terrorist attack		Assassination	low	0	short	0
			Armed assault				
			Bombing/explosion				
			Hijacking				
			Hostage taking				
			Facility/infrastr attack				
			Unknown				
	Miscellaneous accident		Collapse	low	0	short	0
			Explosion				
			Fire				
			Other				

3.1.2 Definition and selection of the SUODs affecting BE

According to the classification of Section 2.2 and to the general SOUDs catalogue of Section 3.1.1 (compare to Table 2), the type of disasters identified such SUOD can be defined as following (UNDRR; National Consortium for the Study of Terrorism and Responses to Terrorism (START) 2019) (the colours are the same of Table 2 and Table 3 related classifications):

Earthquake (Ground movement): Surface displacement of earthen materials due to ground shaking triggered by earthquakes or volcanic eruptions.

Earthquake (Tsunami): A series of waves (with long wavelengths when traveling across the deep ocean) that are generated by a displacement of massive amounts of water through underwater earthquakes, volcanic eruptions or landslides. Tsunami waves travel at very high speed across the ocean but as they begin to reach shallow water they slow down and the wave grows steeper.

Mass Movement (dry): Any type of downslope movement of earth materials.

Volcanic activity: A type of volcanic event near an opening/vent in the Earth's surface including volcanic eruptions of lava, ash, hot vapour, gas, and pyroclastic material.

Extra-tropical storm: A type of low-pressure cyclonic system in the middle and high latitudes (also called mid-latitude cyclone) that primarily gets its energy from the horizontal temperature contrasts (fronts) in the atmosphere. When associated with cold fronts, extratropical cyclones may be particularly damaging.

Convective Storm / Tornado: A type of meteorological hazard generated by the heating of air and the availability of moist and unstable air masses. Convective storms range from localised thunderstorms (with heavy rain and/or hail, lightning, high winds, tornadoes) to meso-scale, multi-day events.

Extreme temperature: A general term for temperature variations above (extreme heat) or below (extreme cold) normal conditions.

Flood: A general term for the overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than normal levels along the coast and in lakes or reservoirs (coastal flooding) as well as ponding of water at or near the point where the rain fell (flash floods).

Landslide: Independent of the presence of water, mass movement may also be triggered by earthquakes.

Wildfire: Any uncontrolled and non-prescribed combustion or burning of plants in a natural setting such as a forest, grassland, brush land or tundra, which consumes the natural fuels and spreads based on environmental conditions (e.g., wind, topography). Wildfires can be triggered by lightning or human actions.

Industrial accident: technological accidents of an industrial nature/involving industrial buildings (e.g. factories).

Transport accident: Automobile, rail, aircraft or navigation accidents. Limited to accidents induced by natural phenomena, such as landslides, earthquakes, hurricanes, rain, etc. Includes transportation accidents generating spills or leaks of harmful substances, regardless of the cause.

Terrorist attack: the threatened or actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation. Therefore, the incident is featured by intentionality, violence (or immediate threat of violence) and perpetrators as sub-national actor.

Two tables of analysis and lecture regarding the defined SUODs are reported. Table 3 resumes the qualitative analysis about predictability, reaction time to alarm systems, source of risk for humans and influence between built environment and safety. Table 4 is structured as a matrix to define and to count the interactions between different types of SUODs reported in the historical disaster events recorded from the begin of 1900.

1. In particular, Table 3 classification is based on the following variables scales: Predictability of the disaster (John Twigg; Humanitarian Practice Network 2015) (cap.15):
   low 0 seconds to few minutes
   medium 1 several days
   high 2 week or months

2. Reaction time to alarm:
   none 0 no time for alarm
   scarce 1 limited time (less than a few hours)
   sufficient 2 from hours to days

3. Source of risk for humans:
   direct a actions that can cause injury to humans
   indirect b actions that cannot directly cause human injury
   both c actions that can cause injury to humans or not

4. Influence between built environment and safety:
   negative -1 the built environment is dangerous for safety
   positive 1 the built environment is not dangerous for safety
   both 0 the built environment can be dangerous for safety or not

Table 3: Analysis of SUOD affecting BE in terms of predictability, reaction time to alarm, source of risk for humans and influence between the BE and the safety.

Disaster Group	Disaster Subgroup	Disaster Main Type	Predictability		Reaction time to alarm		Source of risk for humans		Influence between built environment and safety	
Natural	Geophysical	Earthquake	none	0	none	0	both	b	negative	-1
		Tsunami	sufficient	1	scarce	1	both	c	both	0
		Mass Movement (dry)	scarce	1	scarce	1	both	c	both	0
		Volcanic activity	sufficient	2	sufficient	2	both	c	both	0
	Meteorological	Storm/tornado	sufficient	2	sufficient	2	direct	a	both	0
		Extreme Temperature	sufficient	2	sufficient	2	indirect	b	both	0

	Hydrological	Flood	scarce	1	scarce	1	direct	a	both	0
		Landslide	scarce	1	scarce	1	direct	a	both	0
	Climatological	Wildfire	none	0	sufficient	2	direct	a	both	0
Technological	Industrial accident	Chemical/poisoning spill	none	0	none	0	direct	a	positive	1
		Explosion/fire	none	0	none	0	both	c	both	0
	Transport accident		none	0	none	0	both	c	both	0
	Terrorist attack		none	0	none	0	both	c	both	0
	Miscellaneous accident		none	0	none	0	both	c	both	0

Table 4: Correlation of different type of SUODs (D'Amico, Russo, Angelosanti). The number of events from the begin of 1900 is show inside the grey cells

Disaster Group	Disaster Subgroup	Disaster Main Type	Earthquake	Tsunami	Mass Movement (dry)	Volcanic activity	Storm/tornado	Extreme Temperature	Flood	Landslide	Wildfire	Chemical/poisoning spill	Explosion/fire	Transport accident	Terrorist attack	Miscellaneous accident
Natural	Geophysical	Earthquake		12	15				1	1	*	*				
		Tsunami														
		Mass Movement(dry)														
		Volcanic activity	1	*	1											
	Meteorological	Storm/tornado		1				13	37	15	1			7		
		Extreme Temperature									7					
	Hydrological	Flood					1			64						
		Landslide			2				2							
	Climatological	Wildfire					1	10								
Technological	Industrial accident	Chemical										2				
		Explosion/fire										1	1			
	Transport accident										1	1	1			
	Terrorist attack												3	2		
	Miscellaneous accident															

**in addition to the EMDAT and GTD databases analysed forward, the disastrous event that struck Lisbon in 1755 (Earthquake-Tsunami-Wildfire), Tirreno Region in 2002 (Stromboli vulcanic eruption-Tsunami) and Japan in 2011 (Earthquake-Tsunami-Nuclear disaster) should be mentioned. Number of occurrences of interactions between different types of disasters as recorded in EMDAT and GDT database has reported in each cell.*

Meanwhile, Table 4 is based on data from the EMDAT database on European natural and technological disasters of the last century in which the primary and secondary disasters were correlated. The database is organized by single main disaster type, highlining only the records with other types of associated disasters. For each record, the following data are reported: start date, end date, ISO Country code, Location, Disaster type, Disaster subtype, Associated Disasters, Total damage and Disaster No. to permit the identification of each event. In the following, main disaster-related database is reported

Natural Disasters:

Earthquake (Ground movement):

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
18/01/2017	19/01/2017	ITA	Avezzano, Campotosto, M	Earthquake	Ground movement	Avalanche (Snow, Deb	--	18000	2017-0015
29/04/1991	29/04/1991	SUN	Kutaisi, Dahava, Kraisi, On	Earthquake	Ground movement	Flood	Slide (land, mud	1700000	1991-0117
10/03/1981	10/03/1981	GRC	Greece-Albania border reg	Earthquake	Ground movement	Slide (land, mud, snow	--	0	1981-0122
16/10/1988	16/10/1988	GRC	Near Killini, Vartholomion	Earthquake	Ground movement	Slide (land, mud, snow	--	0	1988-0467
14/08/2003	14/08/2003	GRC	Lefkados district, Ionioi Ni	Earthquake	Ground movement	Slide (land, mud, snow	--	0	2003-0400
08/06/2008	08/06/2008	GRC	Achaïe (Achaias district, D	Earthquake	Ground movement	Slide (land, mud, snow	--	0	2008-0226
12/06/2017	12/06/2017	GRC	Vrisa, Plomarion,Plagias, (	Earthquake	Ground movement	Slide (land, mud, snow	--	0	2017-0182
31/10/2002	31/10/2002	ITA	San Guliano di Puglia towi	Earthquake	Ground movement	Slide (land, mud, snow	--	796000	2002-0690
11/04/2003	11/04/2003	ITA	Alessandria Province (Pier	Earthquake	Ground movement	Slide (land, mud, snow	--	561352	2003-0184
06/04/2009	06/04/2009	ITA	Aquila, Villa Sant'Angelo, I	Earthquake	Ground movement	Slide (land, mud, snow	--	2500000	2009-0136
18/07/1991	18/07/1991	ROU	Orosova area	Earthquake	Ground movement	Slide (land, mud, snow	--	0	1991-0774
04/08/2000	04/08/2000	RUS	Ougklegorsk region (Sakha	Earthquake	Ground movement	Slide (land, mud, snow	--	920	2000-0480
27/09/2003	27/09/2003	RUS	Kosh-Agachsky, Ust'-Ulaga	Earthquake	Ground movement	Slide (land, mud, snow	--	10600	2003-0497
12/07/2004	12/07/2004	SVN	Kobarid, Bovec districts (G	Earthquake	Ground movement	Slide (land, mud, snow	--	10000	2004-0670
23/01/1989	23/01/1989	SUN	Sharora, Okulibolo, Okulip	Earthquake	Ground movement	Slide (land, mud, snow	--	24800	1989-0027
31/01/1991	31/01/1991	SUN	Khorog area (Tajikistan)	Earthquake	Ground movement	Slide (land, mud, snow	--	0	1991-0033
17/05/1980	17/05/1980	YUG	Mt Kopaonik, Aleksandrov	Earthquake	Ground movement	Slide (land, mud, snow	--	0	1980-0046
27/11/1930	27/11/1930	GRC	Leukas Isl.	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1914-0030
26/09/1932	26/09/1932	GRC	Hierissos-Strantonion (Cha	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1932-0020
06/10/1947	06/10/1947	GRC	Pylia (Messinia)	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1947-0028
22/04/1948	22/04/1948	GRC	Vasiliki (Leukas)	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1948-0032
12/08/1953	12/08/1953	GRC	Zakinthos (Zante), Céphal	Earthquake	Ground movement	Tsunami/Tidal wave	--	100000	1953-0001
19/04/1955	19/04/1955	GRC	Drakia-Agria (Magnesia)	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1955-0056
09/07/1956	09/07/1956	GRC	Santorini, Islands of Amor	Earthquake	Ground movement	Tsunami/Tidal wave	Volcanic activity	0	1956-0037
21/07/2017	21/07/2017	GRC	Kos Island	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	2017-0280
28/12/1908	28/12/1908	ITA	Messina, Regio, Calabria, !	Earthquake	Ground movement	Tsunami/Tidal wave	--	116000	1908-0007
04/10/1994	04/10/1994	RUS	Iturup, Kunashir, Shikotan	Earthquake	Ground movement	Tsunami/Tidal wave	--	0	1994-0342
02/08/2007	02/08/2007	RUS	Yuzhno-Sakhalinsk, Nevels	Earthquake	Ground movement	Tsunami/Tidal wave	Slide (land, mud	420000	2007-0334
15/04/1979	15/04/1979	YUG	Montenegro	Earthquake	Ground movement	Tsunami/Tidal wave	--	450000	1979-0039

Mass Movement (dry):

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
16/03/1987	16/03/1987	SUN	Argazan (Tajikistan)	Mass movemen	Landslide	--	--	0	1987-0074
/03/1989	/03/1989	SUN	Checheno-Ingush (Russian	Mass movemen	Landslide	--	--	0	1989-0035
04/05/1991	04/05/1991	SUN	Near Angren (Uzbekistan)	Mass movemen	Landslide	--	--	0	1991-0155
23/08/2017	23/08/2017	CHE	Bregaglia Valley, Bondo in	Mass movemen	Rockfall	--	--	0	2017-0350

Volcanic activity:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
23/01/1973	10/02/1973	ISL	Heimaey Is.	Volcanic activit	Ash fall	--	--	24700	1973-0012
29/05/1983	29/05/1983	ISL	South-East region	Volcanic activit	Ash fall	--	--	0	1983-0361
05/09/1984	05/09/1984	ISL		Volcanic activit	Ash fall	--	--	0	1984-0269
01/10/1996	07/11/1996	ISL	North	Volcanic activit	Ash fall	--	--	16500	1996-0237
/03/2010	/04/2010	ISL	Fljotshlid, Eyjafjöll, and La	Volcanic activit	Ash fall	Flood	--	0	2010-0170
18/04/1906	18/04/1906	ITA		Volcanic activit	Ash fall	--	--	0	1906-0012
18/03/1944	18/03/1944	ITA	Napoli	Volcanic activit	Ash fall	--	--	0	1944-0044
12/09/1979	12/09/1979	ITA	Sicily	Volcanic activit	Ash fall	--	--	0	1979-0087
15/12/1991	15/12/1991	ITA	Zafferana	Volcanic activit	Ash fall	--	--	0	1991-0759
18/07/2001	18/07/2001	ITA	Nicolosi municipality (Cata	Volcanic activit	Ash fall	--	--	3100	2001-0378
24/12/2018	26/12/2018	ITA	Acicatena, Acireale, Aci Sa	Volcanic activit	--	Earthquake	--	115000	2018-0461
20/03/1956	20/03/1956	SUN	Kamchatka (Russian Feder	Volcanic activit	Ash fall	--	--	0	1956-0006

Extreme temperature:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
11/01/2019	30/01/2019	MDA	Edinet, Telenesti, Calaras,	Extreme tempe	Severe winter condit	Cold wave	--	0	2019-0055
01/08/2003	15/08/2003	BEL	Region de Bruxelles-Capit	Extreme tempe	Heat wave	Drought	--	0	2003-0391
/07/2003	/07/2003	HRV	Bjelovar-bilogora, Dubrov	Extreme tempe	Heat wave	Drought	--	0	2003-0391
01/08/2003	20/08/2003	FRA	Alsace, Aquitaine, Auvergn	Extreme tempe	Heat wave	Drought	--	4400000	2003-0391
/08/2003	/08/2003	DEU	Baden-Wuerttemberg, Ba	Extreme tempe	Heat wave	Drought	--	1650000	2003-0391
16/07/2003	15/08/2003	ITA	Milano, Varese districts (L	Extreme tempe	Heat wave	Drought	--	4400000	2003-0391
/06/2007	/07/2007	ROU	Caras-severin, Dolj, Olt, Te	Extreme tempe	Heat wave	Drought	--	0	2007-0235
/07/2003	/08/2003	SVK	Banka Bystrica, Bratislava	Extreme tempe	Heat wave	Drought	--	150000	2003-0391
/07/2003	/08/2003	SVN	Gorenjska, Goriska, Jugov	Extreme tempe	Heat wave	Drought	Wildfire	80000	2003-0391
01/08/2003	11/08/2003	ESP	Andaloucia province	Extreme tempe	Heat wave	Drought	--	880000	2003-0391
/07/2003	/07/2003	CHE	Aargau, Appenzll Ausser-r	Extreme tempe	Heat wave	Drought	--	280000	2003-0391
20/01/2017	20/01/2017	ALB	Peshkopi, Bulqiza, Kukes, I	Extreme tempe	Severe winter condit	Snow/ice	--	0	2017-0010
27/12/2005	/01/2006	AUT	Burgenland, Karnten, Nied	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/01/2006	/01/2006	BLR	Minsk province	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
05/01/2017	20/01/2017	BLR	Vitebsk, Minsk, Gomel, Gr	Extreme tempe	Severe winter condit	Snow/ice	--	0	2017-0010
25/11/2005	26/11/2005	BEL	Region Bruxelles-Capitale,	Extreme tempe	Cold wave	Snow/ice	--	0	2005-0655
27/12/2005	30/12/2005	BEL	Region de Bruxelles-Capit	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/01/2008	/01/2008	BGR	Sopot area (Karlovo	Extreme tempe	Cold wave	Snow/ice	Rain	0	2008-0007
27/12/2005	30/12/2005	HRV	Bjelovar-bilogora, Dubrov	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
23/11/2005	27/11/2005	FRA	Alsace, Aquitaine, Auvergn	Extreme tempe	Cold wave	Snow/ice	--	0	2005-0655
27/12/2005	30/12/2005	FRA	Alsace, Aquitaine, Auvergn	Extreme tempe	Severe winter condit	Snow/ice	Snow/ice	0	2005-0713
25/11/2005	27/11/2005	DEU	Nordrhein-Westfalen prov	Extreme tempe	Cold wave	Snow/ice	--	300000	2005-0655
20/01/2017	20/01/2017	GRC	Aegean Islands	Extreme tempe	Severe winter condit	Snow/ice	--	0	2017-0010
27/12/2005	/01/2006	HUN	Bacs-kiskun, Baranya, Bek	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
27/12/2005	/01/2006	ITA	Emilia-romagna, Friuli-ver	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
05/01/2017	20/01/2017	MKD	Skopje, Negotino, Kavadar	Extreme tempe	Severe winter condit	Snow/ice	--	0	2017-0010
20/01/2006	24/01/2006	MDA	Chisinau province	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
27/12/2005	30/12/2005	NLD	Amsterdam (Noord-Hollar	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/10/2005	06/02/2006	POL	Dolnoslaskie, Kujawsko-Po	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/01/2006	/01/2006	RUS	Oblast, Sankt-peterburg,	Extreme tempe	Severe winter condit	Snow/ice	--	1000000	2005-0713
20/01/2017	20/01/2017	SRB	Belgrade	Extreme tempe	Severe winter condit	Snow/ice	--	0	2017-0010
27/12/2005	/01/2006	ESP	Aragón, Cataluña/Catalun	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
16/01/2006	06/02/2006	UKR	Cherkas'ka, Chernihivs'ka,	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/01/2017	13/01/2017	UKR	Eastern Ukraine	Extreme tempe	Severe winter condit	Snow/ice	Cold wave	0	2017-0010
27/12/2005	30/12/2005	GBR	Cleveland, Durham, North	Extreme tempe	Severe winter condit	Snow/ice	--	0	2005-0713
/07/2003	/08/2003	AUT	Burgenland, Karnten, Nied	Extreme tempe	Heat wave	Wildfire	Drought	280000	2003-0391
/06/2007	/07/2007	BGR	Blagoevgrad, Burgas, Dob	Extreme tempe	Heat wave	Wildfire	Drought	0	2007-0235
/06/2007	/07/2007	GRC	Corfu Isl. (kerkyras district	Extreme tempe	Heat wave	Wildfire	--	0	2007-0235
/06/2007	/06/2007	ITA	Calabria, Sicilia, Trentino-a	Extreme tempe	Heat wave	Wildfire	--	0	2007-0235
/07/2007	/07/2007	MKD	Bitola district (Bitola prov	Extreme tempe	Heat wave	Wildfire	--	0	2007-0235
/07/2007	/07/2007	SRB	Borski, Branicevski, Grad E	Extreme tempe	Heat wave	Wildfire	--	0	2007-0235

Storm:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
03/01/2018	04/01/2018	FRA	Alps, Morillon (Haute Sav	Storm	Convective storm	Wildfire	Slide (land, mu	200000	2018-0002
04/12/2013	07/12/2013	DEU	Hamburg, Schleswig-Holst	Storm	Extra-tropical storm	Tsunami/Tidal wave	Flood	0	2013-0517
03/01/2018	04/01/2018	CHE	Fribourg (west), Bern (Len	Storm	Convective storm	Transport accident	--	0	2018-0002
07/01/2005	09/01/2005	DNK	Aarhus, Bornholm, Freder	Storm	Extra-tropical storm	Transport accident	--	1300000	2005-0011
15/12/2011	16/12/2011	FRA	Bretagne province	Storm	Extra-tropical storm	Transport accident	--	0	2011-0518
17/01/2018	18/01/2018	DEU	Nordrhein-Westfalen (Em	Storm	Extra-tropical storm	Transport accident	--	588475	2018-0025
16/12/2011	16/12/2011	CHE	Juras Bernois, Alpes Bernc	Storm	Extra-tropical storm	Transport accident	--	0	2011-0518
07/01/2005	08/01/2005	GBR	Appleby, Longtown, Shap,	Storm	Extra-tropical storm	Transport accident	--	650000	2005-0011
10/09/2004	10/09/2004	RUS	Kouriles Isl. (Sakhalinskaya	Storm	Tropical cyclone	Transport accident	--	0	2004-0459
03/01/2018	04/01/2018	ESP	Pays Basque, Deba, Mutril	Storm	Convective storm	Surge	--	0	2018-0002
02/03/2015	09/03/2015	ITA	Milano district (Lombardia	Storm	Convective storm	Snow/ice	Flood	869000	2015-0081
13/07/1991	14/07/1991	AUT		Storm	Convective storm	Slide (land, mud, snow	--	28000	1991-0520
10/06/2008	10/06/2008	FRA	Avignon, Thor cities (Vauc	Storm	Convective storm	Slide (land, mud, snow	Flood	0	2008-0237
12/11/2014	16/11/2014	ITA	Moscazzano town (Cremo	Storm	Convective storm	Slide (land, mud, snow	Flood	250000	2014-0458
18/01/2013	19/01/2013	PRT	Abrantes district (Santare	Storm	Convective storm	Slide (land, mud, snow	--	0	2013-0155
10/07/2004	14/07/2004	ROU	Satu-Mare, Harghita, Iasi,	Storm	Convective storm	Slide (land, mud, snow	--	0	2004-0336
26/12/1999	28/12/1999	FRA	South-Western, Western	Storm	Extra-tropical storm	Slide (land, mud, snow	--	8000000	1999-0571
24/01/2009	25/01/2009	ITA	Salerno district (Campania	Storm	Extra-tropical storm	Slide (land, mud, snow	--	0	2009-0014
22/08/2019	22/08/2019	POL	Tatra mountains	Storm	Convective storm	Lightening	--	0	2019-0396
23/07/2009	24/07/2009	AUT	Kufstein district (Tirol pro	Storm	Convective storm	Hail	Flood	500000	2009-0273
23/06/2016	24/06/2016	NLD	Utrecht province and Sout	Storm	Convective storm	Hail	Flood	844000	2016-0211
05/08/2017	09/08/2017	AUT	Tirol, Karnten, Liezen (Söl	Storm	Convective storm	Flood	Slide (land, mu	1200	2017-0328
11/09/2017	11/09/2017	HRV	Zadar region, Bibinje, Suk	Storm	Convective storm	Flood	--	161000	2017-0408
18/09/2014	18/09/2014	FRA	Lamalou-les-Bains city (He	Storm	Convective storm	Flood	Slide (land, mu	182000	2014-0388
13/11/2004	14/11/2004	ITA	Lampedusa Island (Agrige	Storm	Convective storm	Flood	Slide (land, mu	0	2004-0568
31/10/2010	02/11/2010	ITA	Veneto, Toscana, Liguria, '	Storm	Convective storm	Flood	Slide (land, mu	872000	2010-0692
05/08/2017	06/08/2017	ITA	Tramontina (Pordenone &	Storm	Convective storm	Flood	Hail	3500	2017-0328
09/09/2017	10/09/2017	ITA	Livourne, Rosignano, Chio	Storm	Convective storm	Flood	Slide (land, mu	216000	2017-0408
18/04/2019	22/04/2019	ESP	Valencia; Xabia, Denia mu	Storm	Convective storm	Flood	--	0	2019-0186
15/12/1995	31/12/1995	GBR	Scotland	Storm	Convective storm	Flood	--	650000	1995-0451
28/10/2000	29/10/2000	GBR	Larkhill city (Wiltshire dist	Storm	Convective storm	Flood	--	1500000	2000-0714
10/03/2008	10/03/2008	GBR	All country affected	Storm	Convective storm	Flood	--	0	2008-0165
13/11/2009	04/12/2009	GBR	Dorsetshire, Hampshire, Is	Storm	Convective storm	Flood	--	0	2009-0506
04/12/2015	06/12/2015	GBR	Lancashire, Cumbria distri	Storm	Convective storm	Flood	--	1200000	2015-0525
29/02/2008	02/03/2008	AUT	Tirol, Salzburg, Niederoste	Storm	Extra-tropical storm	Flood	--	500000	2008-0082
23/01/2009	26/01/2009	FRA	Landes, Pyrénées-Atlantiq	Storm	Extra-tropical storm	Flood	Slide (land, mu	3200000	2009-0014
28/02/2010	02/03/2010	FRA	Charente-Maritime, Vienn	Storm	Extra-tropical storm	Flood	--	4230000	2010-0088
23/12/2013	25/12/2013	FRA	Alpes-Maritimes district (I	Storm	Extra-tropical storm	Flood	Rain	0	2013-0530
29/02/2008	02/03/2008	DEU	Bayern	Storm	Extra-tropical storm	Flood	--	1200000	2008-0082
29/10/2018	04/11/2018	ITA	Liguria and Lazio municipa	Storm	Extra-tropical storm	Flood	Slide (land, mu	1100000	2018-0397
04/12/2013	07/12/2013	NLD	Dordrecht, Totterdam, Vla	Storm	Extra-tropical storm	Flood	--	10000	2013-0517
29/02/2008	02/03/2008	ROU	Constanta, Mangalia, Mid	Storm	Extra-tropical storm	Flood	--	0	2008-0082
26/12/2013	26/12/2013	GBR	East Sussex, West Sussex (	Storm	Extra-tropical storm	Flood	Rain	0	2013-0530
14/02/2014	15/02/2014	GBR	All country selected/affec	Storm	Extra-tropical storm	Flood	--	100000	2014-0067
08/01/2002	08/01/2002	ALB	Diber, Bulqize, Mat, Shkoc	Storm	Convective storm	Cold wave	--	0	2002-0010
23/01/2005	28/02/2005	ALB	Kukes, Has, Tropoje, Diber	Storm	Convective storm	Cold wave	Avalanche (Snc	0	2005-0045
05/01/2019	16/01/2019	AUT	Land du Vorarlberg, alpes	Storm	Convective storm	Avalanche (Snow, Deb	--	0	2019-0001
13/01/2019	15/01/2019	CHE	Alpes valaisannes, Verbier	Storm	Convective storm	Avalanche (Snow, Deb	--	0	2019-0001

Wildfire:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
/06/1998	/08/1998	GRC	Central, North and South	Wildfire	Land fire (Brush, Bus	Heat wave	--	675000	1998-0230
23/07/2018	24/07/2018	GRC	Neos Voutzas, Agia Marin	Wildfire	Forest fire	Heat wave	--	0	2018-0223
18/07/2018	22/07/2018	LVA	Kurzeme	Wildfire	Forest fire	Heat wave	--	0	2018-0224
/07/2004	/08/2004	PRT	Vila Real, Santarem, Faro,	Wildfire	Forest fire	Heat wave	--	0	2004-0383
17/06/2017	21/06/2017	PRT	Pedrogao Grande (Leiria),	Wildfire	Forest fire	Heat wave	Drought	232000	2017-0176
03/08/2018	08/08/2018	PRT	Perma da Negra (Monchic	Wildfire	Forest fire	Heat wave	--	0	2018-0259
/07/2010	06/08/2010	RUS	Nizhniy city (Krasnodarski	Wildfire	Land fire (Brush, Bus	Heat wave	--	1800000	2010-0352
20/07/2009	24/07/2009	ESP	Teruel district (Aragon prc	Wildfire	Forest fire	Heat wave	Storm	0	2009-0271
24/06/2017	28/06/2017	ESP	Near Moguer and Mazagc	Wildfire	Forest fire	Heat wave	--	0	2017-0228
08/07/2018	25/07/2018	SWE	Gävleborg, Jämtland, Dala	Wildfire	Forest fire	Heat wave	--	102000	2018-0224

Flood:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
07/08/2010	08/08/2010	CZE	Liberec district (Severoces	Flood	Flash flood	Flood	--	157560	2010-0380
07/08/2010	07/08/2010	DEU	Chemnitz district (Sachser	Flood	Flash flood	Flood	--	0	2010-0380
30/11/2017	04/12/2017	ALB	Fushë- Krujë, Ura e Gjoles	Flood	Flash flood	Slide (land, mud, snow	--	8900	2017-0504
10/09/2005	11/09/2005	BEL	La Roche-en-Ardenne city	Flood	Flash flood	Slide (land, mud, snow	--	0	2005-0512
18/03/2018	18/03/2018	HRV	Kosinj region; Gopsic regic	Flood	Flash flood	Slide (land, mud, snow	--	0	2018-0087
12/11/1999	15/11/1999	FRA	Aude, Tarn, Herault, Pyrer	Flood	Flash flood	Slide (land, mud, snow	--	500000	1999-0450
02/12/2003	03/12/2003	FRA	Herault, Gard districts (La	Flood	Flash flood	Slide (land, mud, snow	--	1500000	2003-0586
07/09/2005	09/09/2005	FRA	Hérault, Gard districts (La	Flood	Flash flood	Slide (land, mud, snow	--	0	2005-0516
15/06/2010	16/06/2010	FRA	Draguignan, Les Arcs, Figa	Flood	Flash flood	Slide (land, mud, snow	--	1500000	2010-0233
11/11/2017	20/11/2017	GRC	Mandra, Nea Peramos, M	Flood	Flash flood	Slide (land, mud, snow	--	0	2017-0444
19/06/1996	21/06/1996	ITA	Tuscany, Lucca, Massa, Ca	Flood	Flash flood	Slide (land, mud, snow	--	32000	1996-0148
06/06/2002	09/06/2002	ITA	Frioul-venezia Giulia provi	Flood	Flash flood	Slide (land, mud, snow	--	0	2002-0343
26/10/2011	26/10/2011	ITA	Cinque Terre, Borghetto V	Flood	Flash flood	Slide (land, mud, snow	--	545000	2011-0416
18/01/2014	31/01/2014	ITA	Bastiglia, Carpi, Medolla, I	Flood	Flash flood	Slide (land, mud, snow	--	120000	2014-0026
08/10/2014	11/10/2014	ITA	Genova district (Liguria pr	Flood	Flash flood	Slide (land, mud, snow	--	303000	2014-0448
14/10/2015	16/10/2015	ITA	L'Aquila district (Abruzzi p	Flood	Flash flood	Slide (land, mud, snow	--	163000	2015-0465
20/06/2006	26/06/2006	ROU	Bistrita-Nasaud, Maramur	Flood	Flash flood	Slide (land, mud, snow	--	0	2006-0312
12/02/2007	12/02/2007	ROU	Bistrita-nasaud province	Flood	Flash flood	Slide (land, mud, snow	--	0	2007-0068
19/06/2002	01/07/2002	RUS	Stavropolskiy Kray, Krasnc	Flood	Flash flood	Slide (land, mud, snow	--	443000	2002-0376
15/09/2014	16/09/2014	SRB	Klavodo, Majdanpek, Neg	Flood	Flash flood	Slide (land, mud, snow	--	0	2014-0329
31/03/2002	01/04/2002	ESP	Santa Cruz de Tenerife dis	Flood	Flash flood	Slide (land, mud, snow	--	87000	2002-0879
01/02/2015	02/02/2015	ALB	Berat, Kucove, Skrapar prc	Flood	Riverine flood	Slide (land, mud, snow	--	0	2015-0023
22/06/2009	28/06/2009	AUT	Burgenland, Niederosterre	Flood	Riverine flood	Slide (land, mud, snow	--	200000	2009-0228
02/06/2013	03/06/2013	AUT	Salzburg,Tirol, Vorarlberg	Flood	Riverine flood	Slide (land, mud, snow	--	1000000	2013-0205
11/11/2010	15/11/2010	BEL	Region de Bruxelles-Capit	Flood	Riverine flood	Slide (land, mud, snow	--	238146	2010-0601
06/04/2004	14/04/2004	BIH	Posavski, Srednjebosanski	Flood	Riverine flood	Slide (land, mud, snow	--	0	2004-0163
03/12/2010	05/12/2010	BIH	Tomislavgrad, Drvar muni	Flood	Riverine flood	Slide (land, mud, snow	--	0	2010-0619
13/05/2014	20/05/2014	BIH	Sanski Most municipality (	Flood	Riverine flood	Slide (land, mud, snow	--	436580	2014-0164
04/08/2005	11/08/2005	BGR	Pazardzhik, Smoljan, Vratc	Flood	Riverine flood	Slide (land, mud, snow	--	0	2005-0727
31/03/2002	02/04/2002	SPI	Santa Cruz de Tenerife (Ca	Flood	Riverine flood	Slide (land, mud, snow	--	79923	2002-0171
15/05/2010	26/05/2010	CZE	Opava, Bruntal, Novy Jicin	Flood	Riverine flood	Slide (land, mud, snow	--	190000	2010-0193
01/06/2013	07/06/2013	CZE	Chomutov, Most, Louny, L	Flood	Riverine flood	Slide (land, mud, snow	--	828552	2013-0205
24/10/1994	27/10/1994	GRC	(Dodekanisou district,	Flood	Riverine flood	Slide (land, mud, snow	--	437700	1994-0543
29/11/2001	29/11/2001	GRC	Samos Isl. (Samou district,	Flood	Riverine flood	Slide (land, mud, snow	--	0	2001-0642
02/02/2003	02/02/2003	GRC	Achaias, Ileias districts (D	Flood	Riverine flood	Slide (land, mud, snow	--	600000	2003-0097
21/10/2006	22/10/2006	GRC	districts (Peloponnisos	Flood	Riverine flood	Slide (land, mud, snow	--	0	2006-0568
09/07/1999	16/07/1999	HUN	Heves conty (Nord-Easterı	Flood	Riverine flood	Slide (land, mud, snow	--	128400	1999-0203
22/11/2002	03/12/2002	ITA	Trentino-alto Adige provir	Flood	Riverine flood	Slide (land, mud, snow	--	350000	2002-0740
25/01/2003	27/01/2003	ITA	Pescara, Chieti districts (A	Flood	Riverine flood	Slide (land, mud, snow	--	150000	2003-0043
29/05/2008	30/05/2008	ITA	Savigliano, Demonte towr	Flood	Riverine flood	Slide (land, mud, snow	--	0	2008-0216
01/10/2009	06/10/2009	ITA	Giampilieri, Taormina, Sca	Flood	Riverine flood	Slide (land, mud, snow	--	20000	2009-0428
31/01/2014	01/02/2014	ITA	Ponsacco, San Miniato to	Flood	Riverine flood	Slide (land, mud, snow	--	294000	2014-0045
08/01/2003	10/01/2003	MKD	Suto Orizarei, Centar distr	Flood	Riverine flood	Slide (land, mud, snow	--	0	2003-0033
/08/2006	/08/2006	MKD	Cento, Singelic villages (A	Flood	Riverine flood	Slide (land, mud, snow	--	0	2006-0460
24/08/1994	29/08/1994	MDA	Hancesti, Telenesti, Strase	Flood	Riverine flood	Slide (land, mud, snow	--	300000	1994-0180
26/01/2001	29/01/2001	PRT	Mesao Frio district (Vila R	Flood	Riverine flood	Slide (land, mud, snow	--	0	2001-0040
01/01/2003	08/01/2003	PRT	Agueda, Anadia, Mealhad	Flood	Riverine flood	Slide (land, mud, snow	--	0	2003-0001
22/10/2006	08/11/2006	PRT	Faro province	Flood	Riverine flood	Slide (land, mud, snow	--	0	2006-0617
18/02/2008	18/02/2008	PRT	Loures, Sacavem cities (Lo	Flood	Riverine flood	Slide (land, mud, snow	--	0	2008-0074
15/06/1998	30/06/1998	ROU	Bacau, Vaslui, Vrancea (N	Flood	Riverine flood	Slide (land, mud, snow	--	150000	1998-0193
28/07/2004	01/08/2004	ROU	Brasov, Buzau, Iasi, Bacau	Flood	Riverine flood	Slide (land, mud, snow	--	0	2004-0365
17/03/2005	25/03/2005	ROU	Mures province	Flood	Riverine flood	Slide (land, mud, snow	--	0	2005-0131
06/11/2009	07/11/2009	SRB	Nova Varos, Priboj, Sjenic	Flood	Riverine flood	Slide (land, mud, snow	--	0	2009-0530
16/04/2014	17/04/2014	SRB	Lucani municipality (Mora	Flood	Riverine flood	Slide (land, mud, snow	--	0	2014-0128
13/05/2014	20/05/2014	SRB	Ljig, Valjevo municipalitie	Flood	Riverine flood	Slide (land, mud, snow	--	2048262	2014-0164
04/04/2006	11/05/2006	SCG	Zabalj, Titel, Beocin, Novi	Flood	Riverine flood	Slide (land, mud, snow	--	0	2006-0156
27/07/2004	02/08/2004	SVK	Spisska Nova Ves, Gelnica	Flood	Riverine flood	Slide (land, mud, snow	--	0	2004-0369
13/09/2014	13/09/2014	SVN	Vransko municipality (Zale	Flood	Riverine flood	Slide (land, mud, snow	--	0	2014-0359
02/07/2005	06/07/2005	BGR	Popovo district (Targovitc	Flood	Riverine flood	Slide (land, mud, snow	Broken Dam/Bur	247000	2005-0338
09/05/2005	10/05/2005	RUS	Dagestan Rep., Chechnya	Flood	Riverine flood	Slide (land, mud, snow	Broken Dam/Bur	21168	2005-0276
29/08/2003	31/08/2003	ITA	Ugovizza village (Udine di	Flood	Riverine flood	Slide (land, mud, snow	Flood	655000	2003-0433
08/10/2006	12/10/2006	GRC	Thessalonikis, Chalkidikis (	Flood	Riverine flood	Slide (land, mud, snow	Rain	5659	2006-0541
20/02/2010	21/02/2010	PRT	Funchal district (Ilha Da M	Flood	Riverine flood	Slide (land, mud, snow	Rain	1350000	2010-0068
06/08/2016	07/08/2016	MKD	Chento, Indzikovo, Singeli	Flood	Flash flood	Slide (land, mud, snow	Storm	50000	2016-0282

Landslide:

Start date	End date	ISO Country	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Total damage ('000 US$)	Disaster No.
29/10/1997	02/11/1997	AZO	Ribeira Quente Village, Sa	Landslide	--	Flood	--	16300	1997-0272
01/05/1998	07/05/1998	ITA	Campania Region	Landslide	--	Slide (land, mud, snow	--	28700	1998-0119
10/03/1989	20/04/1989	SUN	Caucasus (Georgia)	Landslide	--	Flood	--	423000	1989-0435
14/11/2002	14/11/2002	CHE	Graubunden, Uri, Ticino, C	Landslide	Mudslide	Slide (land, mud, snow	--	180000	2002-0743

Technological Disasters:

Industrial accident:

Start date	End date	ISO	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Disaster No.
12/12/1999	12/12/1999	FRA	Near Penmarc'h (North-Wes	Industrial accident	Chemical spill	Oil spill	--	1999-0588
18/11/2005	21/11/2005	RUS	Khavarovsk region (Extrême	Industrial accident	Explosion	Chemical spill	--	2005-0644
04/06/1989	04/06/1989	SUN	Acha-Oufa, in Iglinsky Distri	Industrial accident	Explosion	Transport accident	--	1989-0022
17/11/2002	17/11/2002	ESP	Galicia	Industrial accident	Other	Oil spill	--	2002-0709
11/11/2007	11/11/2007	UKR	Kertch detroit (Ukraine)	Industrial accident	Chemical spill	Oil spill	--	2007-0678
19/10/2015	19/10/2015	UKR	Svatovo	Industrial accident	Fire	Explosion	--	2015-0586

Transport accident:

Start date	End date	ISO	Location	Disaster type	Disaster subtype	Associated disaster	Associated disaster2	Disaster No.
07/04/1989	07/04/1989	NOR	Near Bear Island (Barents Se	Transport accident	Water	Fire	--	1989-0488
18/07/2007	18/07/2007	UKR	Lviv region	Transport accident	Rail	Gaz leak	--	2007-0341

Terrorist attack:

Similarly, for terrorist attacks, the GTD database has been used to highlight the primary and secondary levels of disaster considering that some secondary levels (and in some cases tertiary) cannot include the intentionality (GTD).

eventid	provstate	city	location	summary	attacktype1_txt	attacktype2_txt	attacktype3_txt
201803230017	Occitanie	Trebes		03/23/2018: An assailant opened fire inside Super	Hostage Taking (Barri	Bombing/Explosion	Armed Assault
201008030008	Northern Ireland	Londonderry	The incident occurred a	08/03/2010: On Tuesday night around 0320, in De	Bombing/Explosion	Hijacking	Hostage Taking (Kidna
201506260005	Rhone-Alpes	Saint-Quentin-Fallavier		06/26/2015: An assailant attacked an Air Product	Hostage Taking (Barri	Bombing/Explosion	Unarmed Assault
199901050003	Northern Ireland	Belfast	Belfast (Capital City)	01/05/1999: Two men were shot in west Belfast, I	Armed Assault	Hostage Taking (Kidnapping)	
199901110002	Northern Ireland	Londonderry	Londonderry (County)	01/11/1999: An 18-year-old man was beaten in a	Armed Assault		
199901250003	Northern Ireland	Belfast	Belfast (Capital City)	01/25/1999: A 24-year-old man was approached b	Armed Assault		
199902200002	Lazio	Rome		02/20/1999: Kurdish supporters of the Kurdistan V	Armed Assault	Bombing/Explosion	
199903090001	Dublin	Dublin		03/09/1999: In Dublin, Ireland, the Irish Republica	Armed Assault		
199903120005	Northern Ireland	Belfast	Belfast (Capital City)	03/12/1999: A man was shot in both ankles by sus	Armed Assault		
199903130003	Northern Ireland	Londonderry	Londonderry (County)	03/13/1999: A man was shot in the foot in London	Armed Assault		
199903210002	Northern Ireland	Newtownards	Down (County)	03/21/1999: A thirteen-year-old boy was beaten v	Armed Assault		
199903260002	Northern Ireland	Londonderry	Londonderry (County)	03/26/1999: William Ward was shot six times in th	Armed Assault		
199904240004	Attica	Athens		04/24/1999: Two people riding on a bike, suspecte	Armed Assault		
199906100003	Northern Ireland	Londonderry	Londonderry (County)	06/10/1999: In a series of related incidents, arour	Armed Assault		
199906100007	Northern Ireland	Londonderry	Londonderry (County)	06/10/1999: In a series of related incidents, arour	Armed Assault		
199906100008	Northern Ireland	Londonderry	Londonderry (County)	06/10/1999: In a series of related incidents, arour	Armed Assault		
199906100009	Northern Ireland	Londonderry	Londonderry (County)	06/10/1999: In a series of related incidents, arour	Armed Assault		
199906120009	Northern Ireland	Ballymoney	County Antrim	06/12/1999: A 33-year old man was shot in both le	Armed Assault		
199906140004	Northern Ireland	Belfast	Belfast (Capital City)	06/14/1999: At approximately 8:00 pm local time	Armed Assault		
199906160007	England	Whitley Bay	Tyne and Wear (County	06/16/1999: An unidentified gunmen shot and wo	Armed Assault		
199906300002	Baden-Wurttemberg	Stuttgart		06/30/1999: Three unidentified men threw fire bc	Armed Assault		
199907070005	Northern Ireland	Londonderry	Londonderry (County)	07/07/1999: Six masked men forced their way intc	Armed Assault		
199907190010	Northern Ireland	Belfast	Belfast (Capital City)	07/19/1999: A 17-year-old youth was injured afte	Armed Assault		
199907250005	Northern Ireland	Belfast	Belfast (Capital City)	07/25/1999: The Irish Republican Army (IRA) was	Armed Assault		
199907290007	Northern Ireland	Belfast	Belfast (Capital City)	07/29/1999: Unknown youths armed with bricks, s	Armed Assault		
199908040003	Northern Ireland	Belfast	Belfast (Capital City)	08/04/1999: A 17-year-old was shot in the ankle ir	Armed Assault	Hostage Taking (Kidnapping)	
199908040004	Northern Ireland	Belfast	Belfast (Capital City)	08/04/1999: A 39-year-old man was stopped by tv	Armed Assault		
199908040005	Northern Ireland	Dundonald	Down (County)	08/04/1999: A Protestant teenage boy was injure	Armed Assault		
199908050005	Northern Ireland	Newtownabbey	Antrim (County)	08/05/1999: A 19-year-old man was walking along	Armed Assault		
199908140002	Unknown	Unknown		08/14/1999: Prince Charles was attacked in a rem	Armed Assault		
199909070001	Northern Ireland	Belfast	Belfast (Capital City)	09/07/1999: Unidentified assailants shot two men	Armed Assault		
199910020013	Basque Country	Bilbao		10/02/1999: A group of hooded individuals used p	Armed Assault	Facility/Infrastructure Attack	
199910020014	Basque Country	Bilbao		10/02/1999: A group of hooded individuals used p	Armed Assault	Facility/Infrastructure Attack	

3.2 Built Environment prone to SUODs

Today's BEs are the result, on the one hand, of deliberate and coordinated human effort and, on the other hand, of a spontaneous evolution, especially in references to those included in urban area. In fact, in such conditions, the coordination between the BEs (developed over time and spaces) is strictly combined to the overall system features. Hence, in such context, the shape of the BE and of the overall city structure, as well as of its components, have been studied from different points of view. In its pragmatic way, Lynch identifies six distinct aspects to define the BE form, especially in relation to those placed in urban areas: physical form, use/activities/movement, control, perception, continuity/change, movement or flow of materials and information (Lynch 1984). Michael Batty and his research group instead use a spatial analytical approach, considering the BEs of a urban area as a problem of organized complexity and they apply the concepts of emergence and evolution in moving toward solving that problem (Batty 2005).
The configurational approach tries to understand the spatial structure of such elements through a range of analytical methods. At the scale of settlements, the theoretical basis of the approach is the relationship between spatial structure and the generic function of movement (Hillier e Hanson 1984).
For the aims of this research, the most suitable approaches seem to be the typological and the historical-geographical one. The first is rooted principally in the work of Saverio Muratori and Gianfranco Caniggia. The approach they developed seeks to inform their architectural and urban proposals with an understanding of the built environment by examining its detailed structure and the historical process of its formation (Caniggia e Maffei 2001)
Their analysis of the BE proceeds from a scheme of subdivisions that forms a hierarchy: elements, structures of elements, systems of structures, and organisms of systems. This scheme is applied to towns, taking buildings as elements. The structure of elements is an association of buildings or an urban fabric, in general referred to as an aggregate. The system of structures is then a combination of tissues forming regions or districts, which taken together form the organism of the town.

As shown in Figure 12, in the first column, buildings and streets constitute the elements, which take the form of organized structures of elements moving towards the right of the image, until they become an organism, which is the BE.

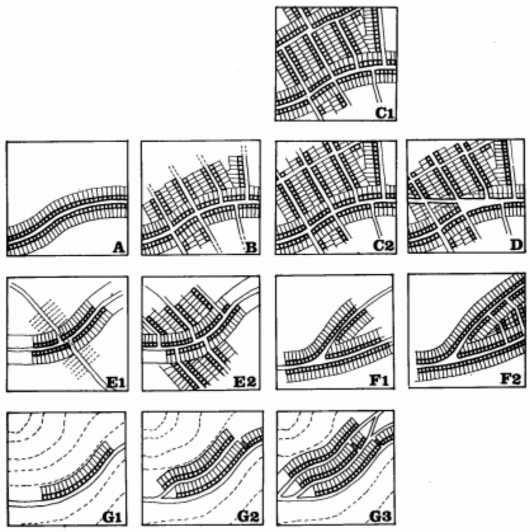


Figure 12: Transformation of urban tissue or aggregates in different generalized situation (elaborated from Caniggia and Maffei, 2001, p.130).

Caniggia and Maffei identify the following distinct aspects of urban form: physical form, function/use, the idea of the building or form, the act of construction/modification, the cultural process of derivation and/or development/change.
The historical-geographical approach to urban morphology is well summarized by the work of the geographer M. R. G. Conzen (Conzen 1960). The aim of Conzen's town-plan analysis is to explain the geographical structure and character of towns through a systematic analysis of their constituent elements and development through time. He distinguishes five general aspects: site, function, townscape, social and economic context, development. Within the townscape, he distinguishes three form complexes: town plan, land utilization pattern, building fabric. The town plan is itself subdivided into three complexes of plan-elements: street system, plot pattern, building pattern. The constituent element of the street-system is the street; the element of the plot pattern is the plot and the element of the building pattern is the block-plan of the building (Conzen 1960).
For Conzen, understanding the layering of these aspects and elements through history is the key to comprehending urban form. Although this approach is focused especially on the urban conformation, Conzen identifies the aspects that characterize the BE, i.e. the open spaces (squares and streets) and what surrounds them (i.e. buildings and blocks of buildings).

The link between these different approaches highlights that there are at least four broad types of aspect and eleven logically distinct general aspects in a BEs form, also in respect of their correlation with the overall urban area in which they are placed and which they characterize:

- spatial relations of physical features: natural physical form and built physical form
- interrelations between humans and physical features: social and economic context, use/function/activity, control intention, construction perception
- flows: natural, human
- change in formation/transformation/cyclical change

Previous studies clearly identify the components of a BE, allowing to recognize which aspects should be investigated primarily, since each BE is the sum of parts that coexist and that result from both a relational and functional points of view .
This also highlights how the BE is a complex system, whose functioning cannot be understood except by carefully evaluating what had influenced its current state. It is therefore necessary to develop a process that includes various scales and can be extended to numerous contexts. In this process, the fundamental element to "connect" and "interrelate" the BE components, its functions, and the hosted users (Mistretta et al. 2014) is surely represented by the Open Spaces in the Built Environment (Conzen 1960). Hence, the following sections use their classification in respect to the BE to characterize the BE itself according to the literature .

3.3 Open Spaces in the Built Environment classification

In the definition of a Built Environment as a common good, it is essential to subdivide the characterization from a macro-scale into smaller scales, which allow to understand the BE design, the relationship between buildings and spaces of use, as well as to interpret the signs that express the characters, the habits of the people and the quality of life, also in reference to the overall urban system (Mistretta et al. 2014).
If monuments, squares, buildings are recognized as common goods of general interest due to their historical value, it is more complex to recognize as a collective good a public space and its users, which constitute its

vital component. Therefore, the action of preserving an asset, which in this case is the community, passes through the protection of places in order to protect its users.
The subdivision of the spaces of the BE starts from the square, as a space that expresses the habitat of the city, a place of meeting, discussion and aggregation. From the urban point of view, the square can be defined as a free space, limited in whole or in part by buildings. The shape, the location, the function and the aesthetic expression of the square historically follow the urban evolution, with the main functions of place of passage, place of utility or place of the stay, functions that can also be combined or entirely grouped. The importance of the square further increases as urban space if it includes civil or religious buildings that are part of the monumental heritage.
Streets are often the most vital public spaces in cities. They are critical arteries for transporting goods and people, but they are also the places where we live, work, play and interact. They play a fundamental role in the public life of cities and communities (Forbes 1999).
Different types of roads have different levels of importance for public utility and safety. High-speed roads, inside or outside the city, as well as perimeter tree-lined avenues, support diverse uses, spaces and traffic streams, yet also produce large, complex intersections.
Neighborhood commercial streets, residential avenues and thoroughfares are magnets for neighborhood life and often medium-sized relative to other streets in the city. Over the course of the 20th Century, the roadways of many of these medium-sized streets in neighborhoods were widened to accommodate more auto traffic. Sidewalks were narrowed, trees removed, on-street parking restricted and signals coordinated to process more cars. Cities are now retrofitting these streets to support new development and to reinforce their neighborhood scale.
Very small streets are as much a part of a city’s street network as larger streets. While they may not carry heavy loads of through traffic, they provide access to properties and are often integral parts of the non-motorized street network. Many cities have made them pedestrian-only, removed curbs, or created shared spaces for people walking, driving and cycling. The pedestrian streets, which constitute the secondary network of the settlement fabric and participate in defining the way of life of the users, can be seen as micro-architectures, characterized by their own constructive elements, with direct effects both on the heritage that surrounds them and on the entire urban fabric.
Green spaces, such as parks and urban gardens, convey the dual message of landscape architecture and pleasure of visiting, often framing relaxing scenarios and architectural monuments, with avenues and fountains.

3.3.1 Morphological systems of BE open spaces

According to the classification elaborated from (Koren e Rus 2019) (

Types of Open Space	Subtypes of Open Space	References	The Sum of Documents	Disaster Management Actions [1]		Assessment Approach [1]		
				PRE-Disaster (%)	POST-Disaster (%)	Qualitative (%)	Quantitative (%)	Semi-Quantitative (%)
Green open spaces	parks	[2,14,15,25,30–33,37,39–66]	37	43	95	54	30	16
	gardens	[2,14,25,31,32,42,43,46,48–50, 52,54,56,59,67]	16	56	94	81	13	6
	water bodies	[14,15,30,33,35,37,41,43,48,56]	10	40	90	50	40	10
	wetlands	[14,30,35–37,50]	6	50	100	50	50	/
	forests	[43,48,50,63]	4	100	75	50	25	25
	hills	[14,30,33,35,41]	5	20	100	60	40	/
	playgrounds	[43,44,46,47,54,56,59,63]	8	88	88	25	38	38
	sport facilities	[33,35,50,63,64,68]	6	67	100	33	50	17
Built-up open spaces	streets	[2,14,15,25,30–33,35,37,39–46, 48–50,53–59,64,67,69–76]	38	42	95	55	34	11
	squares	[14,15,25,30–33,37,39–42,44–46, 48,49,53,55,58,59,69,70,77,78]	25	44	100	68	24	8
	car parks	[33,43,56,78]	4	75	75	25	50	25
	courtyards	[33,44,56]	3	67	100	/	67	33
Undeveloped spaces		[2,14,15,30–33,35,37,39,44,46, 48,50,52,53,55,67,70,71]	20	40	100	65	30	5
Not defined		[34,68,74,75,77,79–93]	12	83	50	50	17	33

[1] The results are displayed as a percentage of the total number of documents addressing the particular subtype of open space.

Figure *13*), this research focuses on built-up open spaces, by identifying, among these, two main morphological systems: the streets and the squares.

- <u>AREAL SPACES (Squares)</u>: open space or partially occupied by urban furniture or historical elements, enclosed partially or completely by constructions, with various urban functions, at the intersection of streets or along the route of a main road; it can have monumental character and to be indicated with a particular denomination.
- <u>LINEAR SPACES (Paths)</u>: space of public use, delimited and mostly equipped with roadbed and flooring, intended for the passage and transit of people and vehicles.

Types of Open Space	Subtypes of Open Space	References	The Sum of Documents	Disaster Management Actions [1]		Assessment Approach [1]		
				PRE-Disaster (%)	POST-Disaster (%)	Qualitative (%)	Quantitative (%)	Semi-Quantitative (%)
Green open spaces	parks	[2,14,15,25,30–33,37,39–66]	37	43	95	54	30	16
	gardens	[2,14,25,31,32,42,43,46,48–50, 52,54,56,59,67]	16	56	94	81	13	6
	water bodies	[14,15,30,33,35,37,41,43,48,56]	10	40	90	50	40	10
	wetlands	[14,30,35–37,50]	6	50	100	50	50	/
	forests	[43,48,50,63]	4	100	75	50	25	25
	hills	[14,30,33,35,41]	5	20	100	60	40	/
	playgrounds	[43,44,46,47,54,56,59,63]	8	88	88	25	38	38
	sport facilities	[33,35,50,63,64,68]	6	67	100	33	50	17
Built-up open spaces	streets	[2,14,15,25,30–33,35,37,39–46, 48–50,53–59,64,67,69–76]	38	42	95	55	34	11
	squares	[14,15,25,30–33,37,39–42,44–46, 48,49,53,55,58,59,69,70,77,78]	25	44	100	68	24	8
	car parks	[33,43,56,78]	4	75	75	25	50	25
	courtyards	[33,44,56]	3	67	100	/	67	33
Undeveloped spaces		[2,14,15,30–33,35,37,39,44,46, 48,50,52,53,55,67,70,71]	20	40	100	65	30	5
Not defined		[34,68,74,75,77,79–93]	12	83	50	50	17	33

[1] The results are displayed as a percentage of the total number of documents addressing the particular subtype of open space.

Figure 13: Seismic resilience actions (pre- and post-disaster) and the assessment approach (qualitative, quantitative and semi-quantitative) of different sub-types of open space (Koren e Rus 2019).

One of the simplest **square** definitions is "a void surrounded by buildings where certain activities take place".It is therefore intended a public place inside an urban fabric, defined by a prevalent function. The square becomes the place where the connective space of the street plot expands and becomes an urban element: no more space for the flow of the road network, but place of arrival, due to the convergence of the flows of mobility (Figure 14).

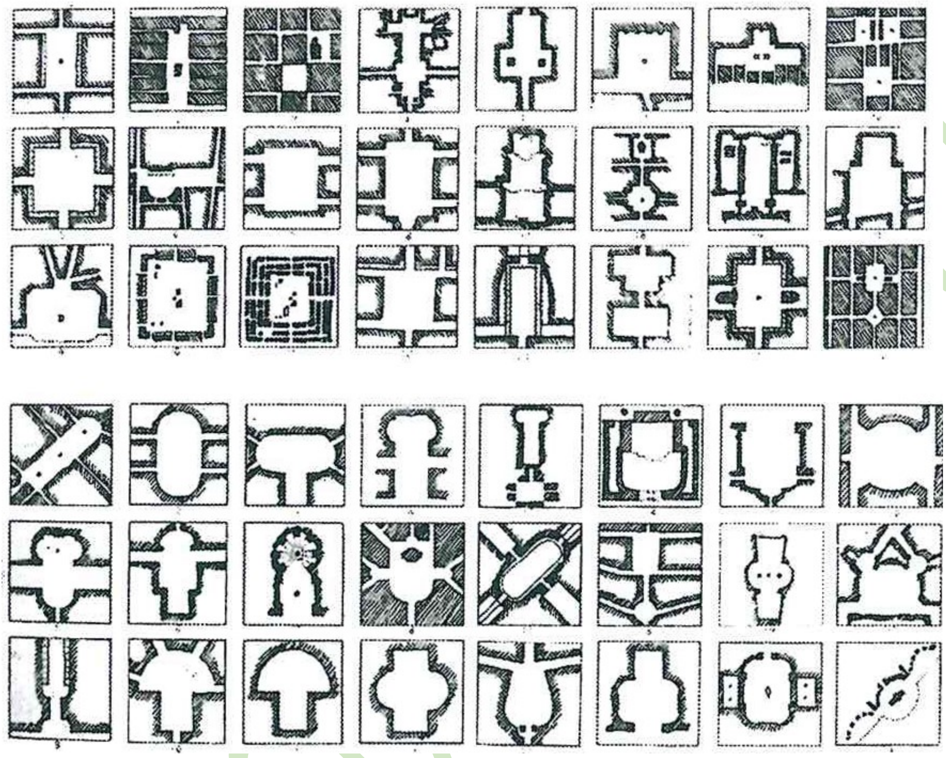


Figure 14: Types of squares (Ronzani e Boschi 2001).

According to the analysis of public spaces in the historical BEs, the close connection between the square and the city, makes it possible to read the evolution of the urban fabric and of the society that determined it. In this sense, the reference archetypes of the square, in all its historical evolution, are those of the classical Greek or Roman city: forum and agora, on the one hand, and acropolis, on the other, due to the fundamental categorization of open square or closed square (Ronzani e Boschi 2001). The typology therefore depends on the shape that the empty space assumes following the arrangement of the buildings facing the central place. The design of the squares over time has drawn on these two archetypes and their various combinations. In closed squares, the space is organized by the layout of the facades of the buildings that surround them. In the open squares, the buildings are volumes placed within the space with a strong value of visual polarization. Only in the 19th and 20th centuries, the use of public and private transport forced to upset the rules of the classical square. There is no longer an aggregating function of urban life, but a junction of ever faster lines of movement.

Nowadays, the meaning of square has lost its uniqueness. It remains as one of the possible articulations of the public space in which social life can be understood as a place of exchange and commerce. Thus, the most recent model of the square is the covered square, or gallery, that is the fundamental junction of large commercial or directional structures that stands as an alternative to the outdoor square.

The significative research about square typological analysis conducted by Enrico Mandolesi e Alessandra Ferrero is one of the main references regarding the *areal spaces* (Enrico Mandolesi e Alessandra Ferrero 2001) (Figure 15). In this research, they analyzed all the squares of the Italian area of Piceno, reaching a typological classification of these (Figure 16). The work represents a deductive approach to the classification that is a base of this part of the present research, which indeed would operate with an inductive approach.

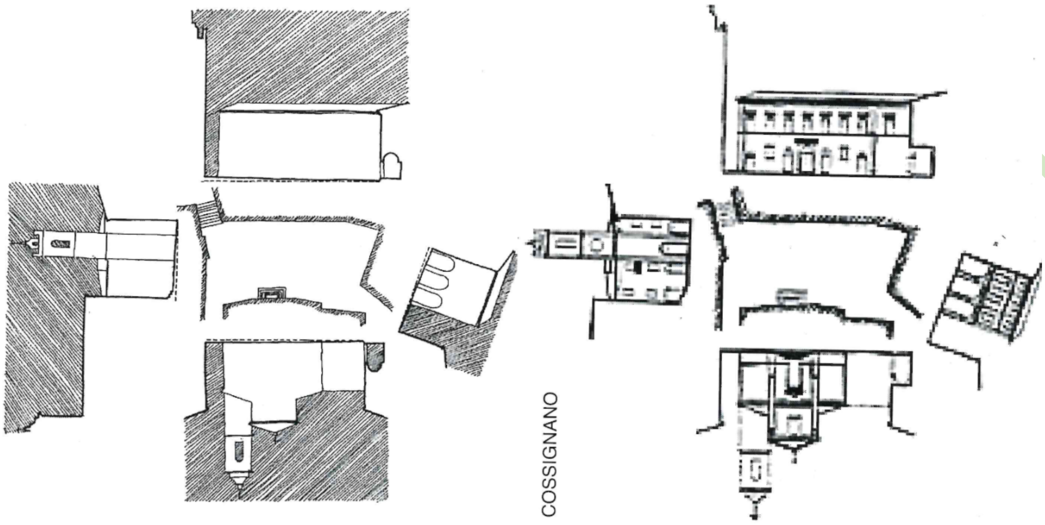


Figure 15: Cossignano's square. Morfological analyses of the square and survey of built facades (Enrico Mandolesi e Alessandra Ferrero 2001).

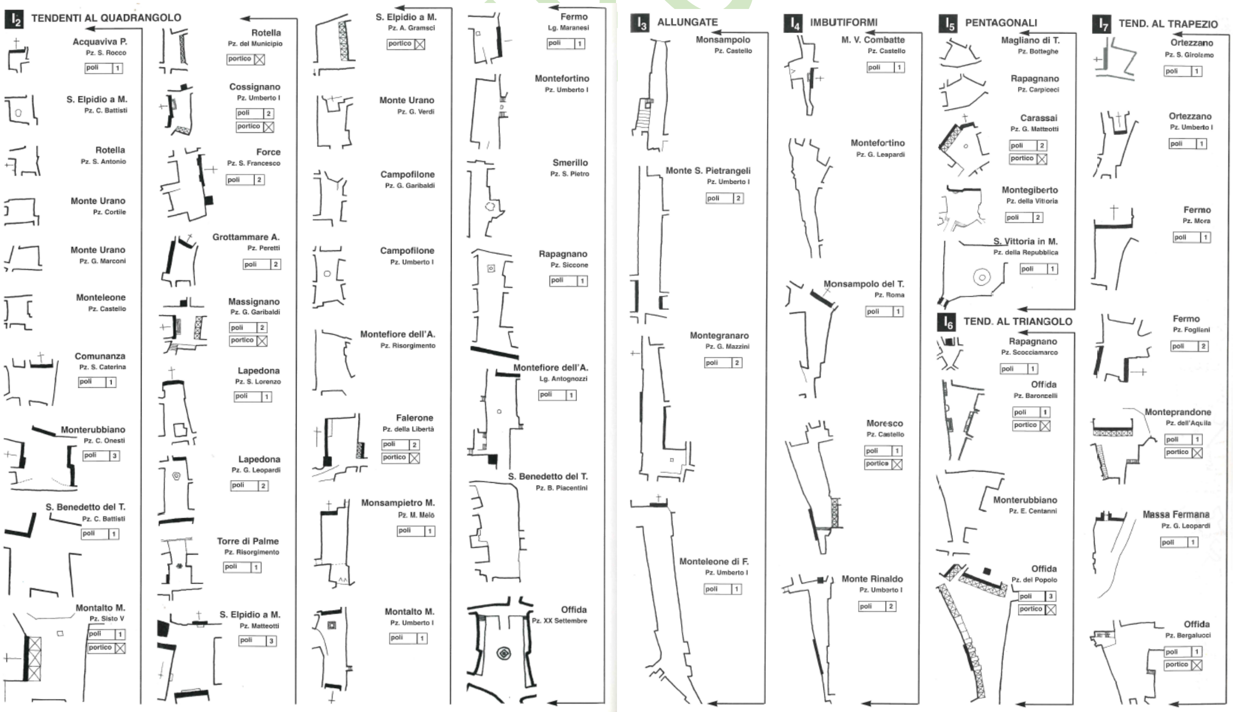


Figure 16: Typo-morphological analysis of Piceno's square (Enrico Mandolesi e Alessandra Ferrero 2001).

The **street** is one of the fundamental elements of any BEs, mainly while considering those in urban areas. In its technical, formal and symbolic variants, it appears as one of the most multiform urban elements (Ronzani e Boschi 2001) (Figure 17)

The network designed by the set of streets is a fundamental part of the settlement model itself, also since the street is one of the most durable signs of the urban fabric. Over the centuries, the concept of the street has undergone several variations, in parallel with the urban history and industrialization. In the medieval city, the road is curved and generates ever-changing perspectives, where buildings become reference points. The interrupted building curtain, the repeated characteristics of the buildings, the absence of interrupting elements between the roadside and the buildings, the functional contiguity between the activities inside the buildings and the public space denote a physical continuity between building and open space. The road section is generally narrow, and it adapts to the topography, with slopes and tiers.

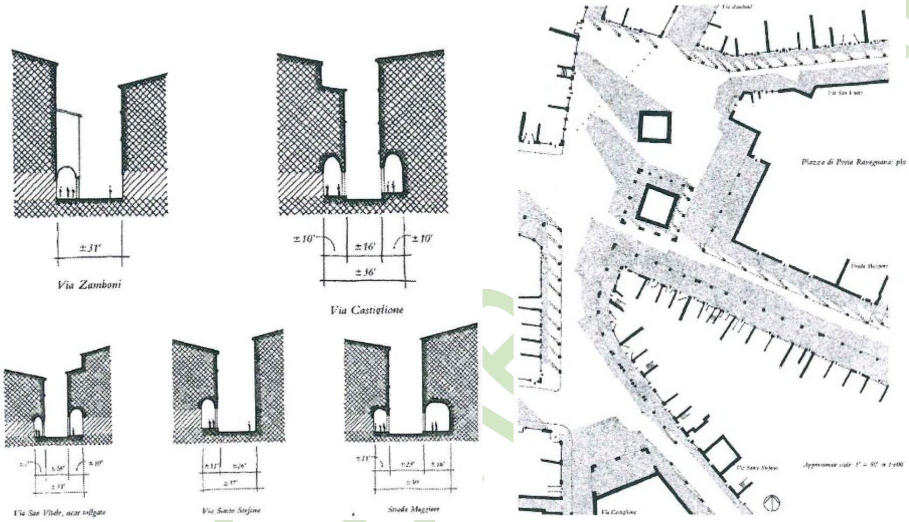


Figure 17: Road sections in the urban centre of Bologna (Ronzani, Boschi, 2001).

In the post-modern city, the concept of road is instead based on high mobility and widespread use of the motor vehicle. It is no longer the pedestrian that regulates its dimensions and forms in relation to places, but the street becomes the common thread that holds the places together.

In the definition of a street as a path, multiple components are involved, able to construct clear mental maps of reference for people. The identifiability of the road can therefore refer to the concentration of special uses or activities along it, or to characteristic spatial qualities, able to reinforce the image of particular paths, or to the particular treatment of the facades of buildings, or to the surfaces of pavements, or in the presence of vegetation.

Various classifications of paths and street are available in scientific literature. Moughtin (Moughtin 1991) analyse the paths in European context, from Vitruvio to contemporary urbanism, describing some parameters to face in the classification. Forbes (Forbes 1999) faces different types of international classification, mainly based on the functional aspects (The Traditional Functional Classification System (Figure 18), Region of Hamilton-Wentworth Classification System, Metro Portland's Street Classification System, Province of Ontario Classification System, AIA Street Classification System).

Classification	Location	Characteristics
Principal Arterial	Rural	Trip lengths for statewide or interstate travel. Integrated movement generally without stub connections. Accommodates movement between (virtually) all urban areas with pop. 50,000. Two design types: freeways and other principal arterials.
	Urban	Serves major centers of activity with the highest traffic volumes and longest trip lengths. Integrated internally and between major rural connections. Service to abutting lands is subordinate to travel service to major traffic movements. Design types are interstate, other freeways and other principal arterials.
Minor Arterial	Rural	Links cities, large towns and other traffic generators attracting traffic over long distances. Integrated interstate and intercounty service. Designs should be expected to provide for relatively high speeds and minimum interference to through movements.
	Urban	Trips of moderate length at a lower level of mobility than principal arterials. Some emphasis on land access. May carry local bus routes and provide intracommunity continuity but does not penetrate neighbourhoods.
Collector	Rural	Serve intracounty travel with travel distances shorter than on arterial system. More moderate speeds. Divided into major and minor system.
	Urban	Provides both land access and traffic circulation within all areas. Penetrates neighbourhoods and communities collecting and distributing traffic between neighbourhoods and the arterial streets.
Local	Rural	Local roads primarily provide access to adjacent land and the collector network. Travel is over short distances.
	Urban	Primarily permits direct land access and connections to the higher order streets. Lowest level of mobility. Through traffic is usually deliberately discouraged.

Figure 18: The Traditional Functional Classification System (Forbes 1999).

The form of the street can be analysed in terms of a number of main characters such as straight or curved, long or short, wide or narrow, enclosed or open, formal or informal. Street form can also be analysed in terms of scale, proportion, contrast, rhythm or connections to other streets and squares. Between the various classifications, the one proposed by Region of Hamilton-Wentworth Classification System (Figure 19) appears to be the more suitable to the European urban context of historical cities.

Classification	Primary Uses	Road Users	Speed (Vehicular)	Flow Characteristics	Adjacent Land Uses	Typical Elements
Passage	Walking Socializing Gathering Shopping	Pedestrians Cyclists	N/A	Pedestrian Priority	High density residential, retail/commercial, mixed use	Sidewalk and pedestrian amenities
Traditional Street	Walking, Cycling, Socializing, Access to properties, Parking and loading	Pedestrians Cyclists Buses Cars (local) Trucks (deliveries only)	< 30 km/h	Pedestrian flow is the primary consideration. Vehicle flow is interrupted.	High density residential, retail/commercial, office, mixed use	Sidewalks on both sides of the street, 2 lanes of travel, parking lanes
Main Street	Walking, Cycling Access to properties, Socializing, Parking and loading, Circulation	Pedestrians Cyclists Buses Cars (local) Trucks (deliveries only)	30 to 40 km/h	Traffic calmed	High density residential, office, retail, mixed use, civic space	Two wide sidewalks, 2 lanes of travel (maximum), parking lanes
Gateway	Access to properties Socializing Parking and loading, Walking Cycling Circulation	Pedestrians, cyclists Buses Cars (local) Trucks (deliveries)	30 to 50 km/h	Traffic calmed. Pedestrians and vehicles are given roughly equal consideration.	Mixed use Civic space	Two wide sidewalks with many pedestrian amenities, provisions for cyclists, 2 to 4 lanes of travel, boulevards and/or a landscaped median, parking lanes, transit amenities.
Mobility Street	Walking Cycling Freight movement Travel circulation	Pedestrians, cyclists Buses Cars (through) Trucks (through)	50 to 60 km/h	Uninterrupted vehicular flow. Pedestrian flow is interrupted at points of conflict. Transit may be given priority.	Commercial, office	One or two sidewalks with boulevards, provisions for cyclists, 4 to 6 lanes of travel, possibly exclusive transit lanes.

Figure 19: Region of Hamilton-Wentworth Classification System (Forbes 1999).

Recent researches faced on the vulnerability of streets and paths, enlarging the consolidated field of building scale (Cherubini e Reluis 2009; Zheng et al. 2009; Ranjbar et al. 2017). Some of them focused on the neural approach, considering the paths as links between polarities (Asprone et al. 2014), others faced the typological and morphological aspects of the built environment (Oliveri (a cura di) 2004). Olivieri and his group focuses on the case study of Nocera Umbra, a historical town in Italian Region of Umbria, to deepening the studies on Minimum Urban Structure (SUM). SUM is a holistic approach to the seismic vulnerability of urban organism. In this study, they structured a vulnerability assessment of both buildings in aggregates and paths inside the historical tissues. The assessment is typological based and presented qualitative parameters, the values are expressed in different weights (Figure 20;

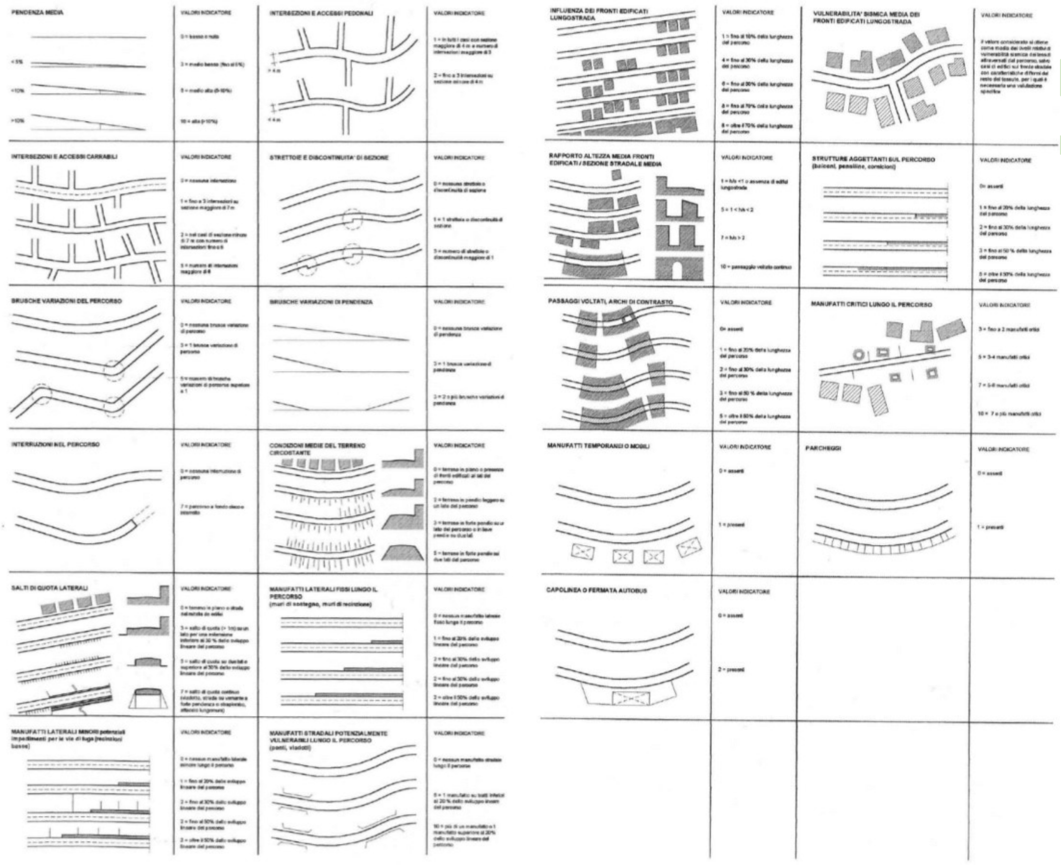


Figure 21).

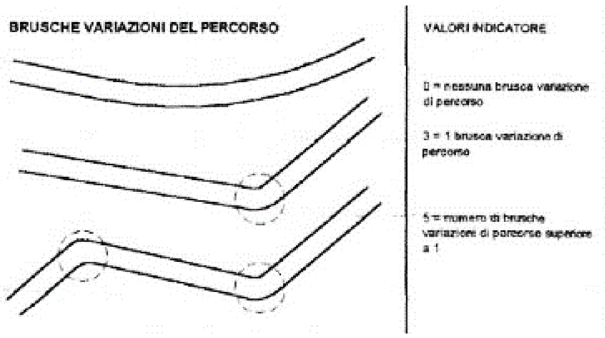


Figure 20: Example of parameters for the of path vulnerability assessment (Oliveri (a cura di) 2004).

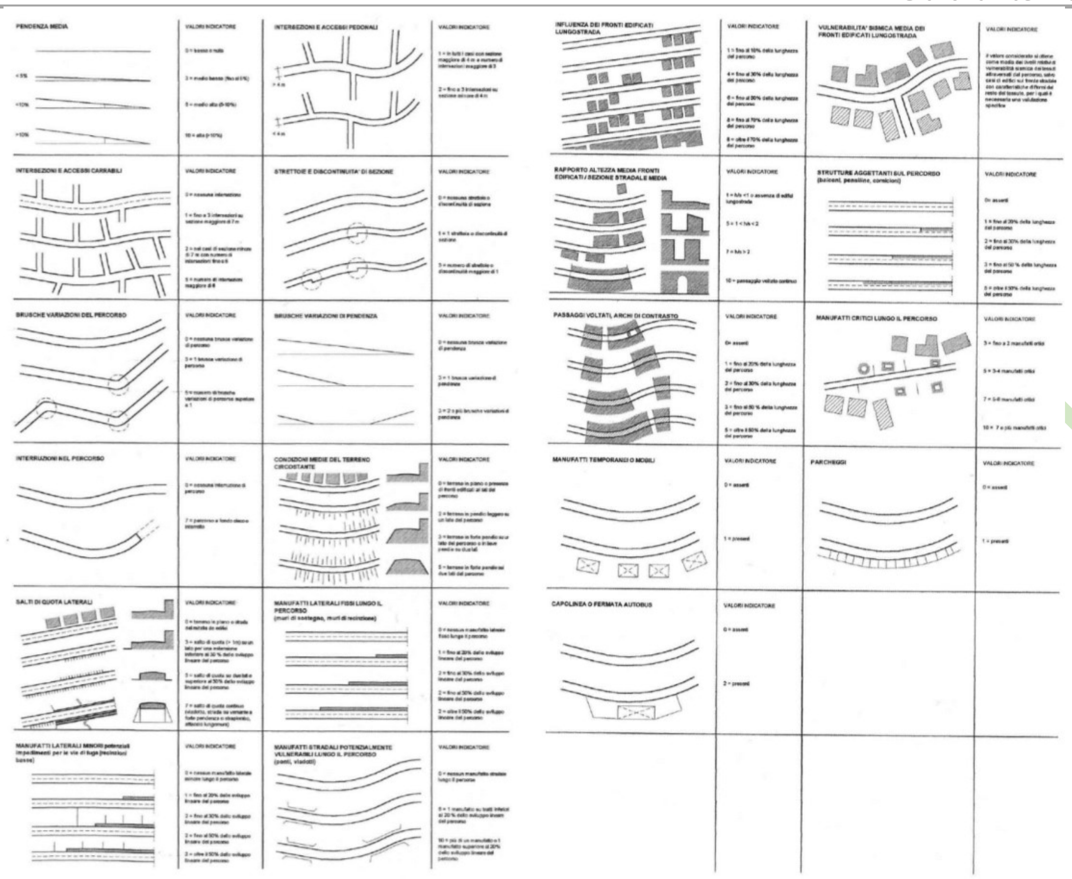


Figure 21: Parameters for the of path vulnerability assessment (Oliveri (a cura di) 2004).

3.3.2 Criteria for BE Classification according to Building-related typological and SUOD features

In the view of above, the investigation of the Criteria for BE classification concerns the features of the historical urban centres (Table 5).

Table 5: Criteria for BE classification.

Classification of Criteria	Sub-system of geometric objects	Parameter	Reference
Typology	Main Morphological systems of BE open spaces Dimensional parameters	· Areal spaces · Linear spaces · Width · Length · H fronts / width	(Caniggia e Maffei 2001; Mandolesi e Ferrero 2001) (Italian technical commission for seismic micro-zoning 2014)
Geometric-Space characters	Frontier	· Continuous built front · Sights · Special building · Town Walls · Porches · Water · Topography (height difference or depth / containment wall)	(Mandolesi e Ferrero 2001; Oliveri (a cura di) 2004)

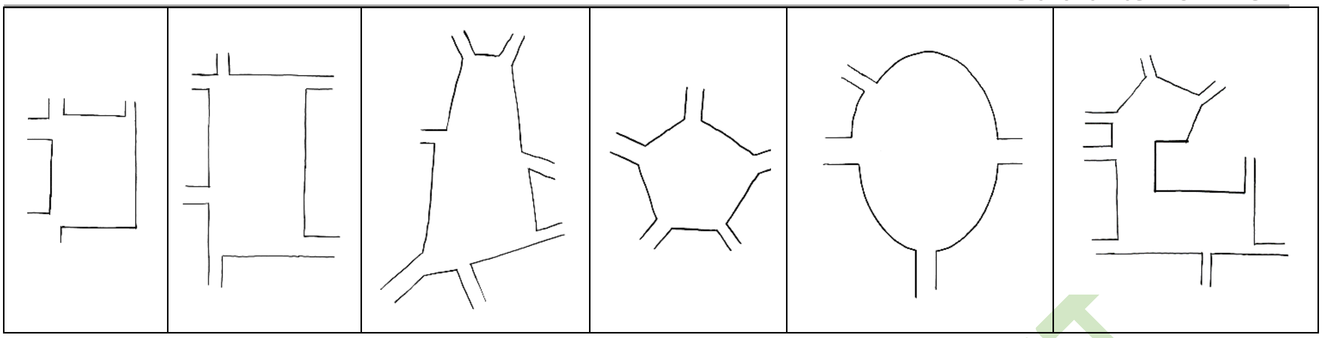
	Content	· Green area · Accesses · Sights · Covers · Fountains · Monumental elements (obelisks) · Slopes and height/depth changes · Green area	
Constructive characteristics	Frontier	· Age of the built environment · Construction techniques	(Mochi e Predari 2016; Bernardini 2017; D'Amico e Currà 2018)
	Content	· Materials and finishes · Urban furniture	(Dan et al. 2017)
Characteristics of use		· Time · Crowding · Strategic buildings · Public uses · Accessible to pedestrian / vehicle · Controlled accesses · Presence of vulnerable population · Sensitive goals	(Mäntyniemi 2012; Prati et al. 2012; Bernardini et al. 2014, 2018)
Environmental Characteristics		· Climate · Road networks · Infrastructure networks · Underground cavities · Specific hazard assessment	(Indirli 2009; AA.VV. 2013; Italian technical commission for seismic micro-zoning 2014)

AREAL BE (SQUARES)

According to the classifications present in the literature (also in reference to case studies), numerous morphological configurations of the open space emerged. For the purposes of the relationship with SUODs, these configurations can be traced back to some main types. 6 main categories (of which one is a composite one) can be identified as reported in Table 6 by setting up the spatial classification proposed by Mandolesi (Mandolesi e Ferrero 2001) and the historical-procedural one proposed by Caniggia Maffei (Caniggia e Maffei 2001), and comparing them with the criteria for expeditious evaluation of urban vulnerability (Oliveri (a cura di) 2004) and the emergency limit condition (CLE) (Italian technical commission for seismic micro-zoning 2014).

Table 6: Proposed main morphological configuration of Areal BE.

MAIN TYPES					
Tending to quadrangle	Elongated with parallel sides	Tending to triangular and funnel-shaped	Trapezoidal and polygonal	Tending to circular, ovoid and ellipsoid	Composite



The following definitions can be provided according to Table 6:

- Tending to quadrangle: absence of a prevalent dimension in the planimetric development. Ratio between dimensions less than or equal to 2/3.
- Elongated with parallel sides: presence of a prevalent dimension in the planimetric development and sides that can be considered parallel. Ratio between dimensions greater than 2/3.
- Tending to triangular and funnel-shaped: presence of an obtuse angle or shape similar to triangular geometry.
- Trapezoidal and polygonal: polygonal shapes with trapezoidal geometry, or with a number of regular borders greater than 4.
- Tending to circular, ovoid and ellipsoid: circular, ellipsoidal or ovoid geometry that differ from the polygonal ones.
- Composite: complex structures that are configured as a composition of the previous types.

For each one of the main Morphological systems of BE open spaces, Table 7 includes the additional characterization conditions. For instance, multiple spatial conditions can appear and because of Geometrical data (compare Table 5): height of the fronts; width; length, diameter, angles.

Table 7: Additional characterization of Aerial BE.

CHARACTERISTICS OF GEOMETRY AND SPACE	(parameters)	(sub-parameters)
frontier	Continuous built front	(absence of Special building)
	Sights	
	Town walls	
	Porches	
	Water	
	High or depth difference / containment wall	
	Green area	
	Access	
content	Sights	
	Canopy	
	Fontaine	
	Monuments (obelisk)	
	Slope / High or depth difference	
	Green area	

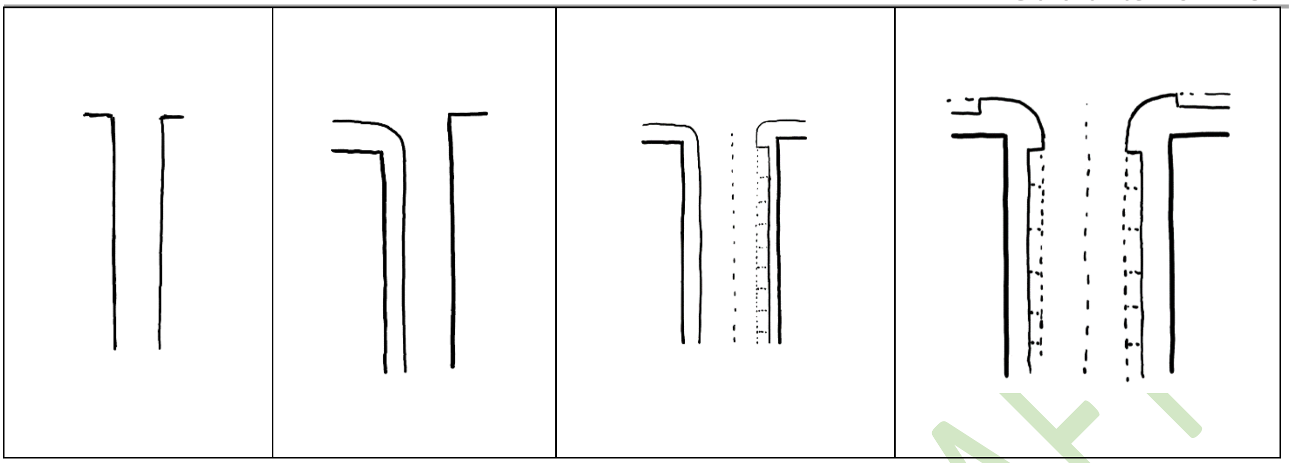
CONSTRUCTIVE CHARACTERISTICS	(parameters)	(sub-parameters)
frontier	Age of built environment	heterogeneity
	Construction techniques	Construction techniques
content	Materials and finishing	Slickness, compactness, …
	Urban forniture	Presence of obstacles
CHARACTERISTICS OF USE	(parameters)	(sub-parameters)
	Time	Daily schedule
	Crowding	Crowding index
	Strategic building	
	Public use	Concerts / theater / festivals / parking / sights
	Accessible to vehicle or pedestrian	
	Controlled access	Access to public infrastructures or strategic buildings
	Vulnerable users	Tourists, aged people, children
	Sensitive targets	Terroristic attack (e.g. strategic buildings or significative people for political, economic or religious reasons)
ENVIRONMENTAL CHARACTERISTICS	(parameters)	(sub-parameters)
	Climate	Climate condition
	Road network	
	Infrastructural network	Water, sewage, electricity
	Underground cavities	
	Hazard assessment	(e.g. seismic hazard, hydrogeological hazard)

LINEAR BE (PATHS)

The main types of linear BE are elaborated starting from the Region of Hamilton-Wentworth Classification System analysed by Forbes (Forbes 1999). In this classification the types reported are 5: Passage, Traditional Street, Main Street, Gateway, Mobility Street. This classification system is the initial part of a wider transportation study to develop a transportation plan that would be supportive of desired land uses and economic initiatives. The importance of this study is related to a new recognition that the street is a public space performing many functions and serving many users. Starting from their study, the classification proposed in this report consider 4 main types, specifically related to the BE of historical towns, where "gateways" and "mobility street" can be joint in a single type, excluding street section with more then 4 lanes of travel, for the aim of the proposed research.

Table 8: Proposal of classification by morphology of Linear BE.

MAIN TYPES			
Passage	Traditional Street	Main Street	Gateway / Mobility Street



As for the Areal BE, Linear BE can be distinguished according to morphological aspects as follows (The main types of linear BE are elaborated starting from the Region of Hamilton-Wentworth Classification System analysed by Forbes (Forbes 1999). In this classification the types reported are 5: Passage, Traditional Street, Main Street, Gateway, Mobility Street. This classification system is the initial part of a wider transportation study to develop a transportation plan that would be supportive of desired land uses and economic initiatives. The importance of this study is related to a new recognition that the street is a public space performing many functions and serving many users. Starting from their study, the classification proposed in this report consider 4 main types, specifically related to the BE of historical towns, where "gateways" and "mobility street" can be joint in a single type, excluding street section with more then 4 lanes of travel, for the aim of the proposed research.

Table 8):

- Passage: no vehicular traffic, sidewalk and pedestrian amenities, paths of connection between main roads in the historical town.
- Traditional Street: possible presence of sidewalks on one or both sides of the street, 1 or 2 lanes of travel, possible presence of parking lanes
- Main Street: Two wide sidewalks, 2 lanes of travel (maximum), parking lanes.
- Gateway / Mobility Street: Two wide sidewalks with many pedestrian amenities, provisions for cyclists, 2 to 4 lanes of travel, boulevards and/or a landscaped median, parking lanes, transit amenities.

For each one of the main Morphological systems of BE open spaces, multiple spatial conditions can exist, as shown by Table 9. For instance, Geometrical data can affect Morpho-typological aspects, because of one of the following sub-conditions:

- straight or curved;
- long or short;
- wide or narrow;
- enclosed or open.

Table 9: Additional characterization of Aerial BE.

CHARACTERISTICS OF GEOMETRY AND SPACE	(parameters)	(sub-parameters)
frontier	Continuous built front	(absence of Special building)
	Sights	

	Town walls	
	Porches	
	Water	
	High difference / containment wall	
	Green area	
	Access	
content	Sights	
	Canopy	
	Fontaine	
	Monuments (obelisk)	
	Slope / High or depth difference	
	Green area	
CONSTRUCTIVE CHARACTERISTICS	(parameters)	(sub-parameters)
frontier	Age of built environment	heterogeneity
	Construction techniques	Construction techniques
content	Materials and finishing	Slickness, compactness, …
	Urban forniture	Presence of obstacles
CHARACTERISTICS OF USE	(parameters)	(sub-parameters)
	Time	Daily schedule
	Crowding	Crowding index
	Strategic buildings	
	Public uses	Concerts / theater / festivals / parking / sights
	Accessible to vehicle or pedestrian	
	Controlled accesses	Access to public infrastructures or strategic buildings
	Vulnerable users	Tourists, aged people, children
	Sensitive targets	Terroristic attack (e.g. strategic buildings or significative people for political, economic or religious reasons)
ENVIRONMENTAL CHARACTERISTICS	(parameters)	(sub-parameters)
	Climate	Climate condition
	Road network	
	Infrastructural network	Water, sewage, electricity
	Underground cavities	
	Hazard assessment	(e.g. seismic hazard, hydrogeological hazard)

4. Conclusions

Nowadays, the response of Built Environments (BEs) to catastrophic events is closely related to the concept of resilience which describes the ability of this system to withstand shocks and to preserve the essential asset that ensure strategic services and functions to the hosted users. The resilience of BEs depends on both

structural features of the Bes themselves and social aspects. In fact, while the flexibility, redundancy and modularity of BE guarantee the organization of the strategic function, the preparedness of the social agents increases the ability to absorb shocks.
Therefore, the effect of disasters is affected by users' presence combined to the particular features of the BE, especially while referring to BEs placed in urban areas, which is characterized by complexity issues on BEs correlation, overall layout, users' (i.e. population's) densities and so on. In this context, historical BEs represent critical elements, because of these built-up areas shows conditions of inner vulnerability.
To increase the safety and security in the built environment and then reduce disaster risk and improve BEs resilience (and, as a consequence, the one of the urban areas that they can constitute), this deliverable identifies the main issues related to the features of BE prone to disaster conditions. To this aim, according to a literature review-based approach, the deliverable firstly classifies the types of disasters affecting the BE, and then investigates the BEs characteristics, by mainly focusing on those related to SUODs. As a key element, results underline how the architectural features of open space in the Built Environment affect the performance of the overall system in respect to the SUODs-related conditions, also in reference of the human behavior during an emergency situation. Hence, the identification of morphological systems of open spaces in the BEs (Section 3.3.1) and the definition of Criteria for BE Classification according to Building-related typological and SUOD features (Section 3.3.2) are offered in this report.
The investigation of the criteria for the BE classification encompasses historical-geographical approach, morphology and social-economic factors, such as social, economic, administrative, cultural, etc. (mainly related to the uses of the public space in the BE, and also combining data with the urban-scale standpoint, since BEs generally are not isolated systems). Areal and linear BEs are so evidenced and characterized. In this context, results underline how areal BEs (e.g. public squares) are one of the most relevant elements in reference to the aesthetic expression of the BEs, i.e. of historical BEs and related transformation over time (specially, while referring to urban ones). In fact, they generally collect the most important civil or religious buildings in such kind of BEs. Moreover, according to the discussion of each specific elements of these categories, it can be evidenced hot the outlined common characteristics are common to National and European contexts, mainly those related to BEs in urban and historical areas, which are worthy of investigation since are affected by risk-increasing exposure and vulnerability conditions.
Next research steps will take advantages of these results in the characterization of significant real SUOD-affected BE, by involving case studies and moving towards the definition of BE-Typologies prone to SUOD.

5. Abbreviations

BE - Built Environment

CRED - Centre for Research on the Epidemiology of Disasters

GTD - Global Terrorism Database

SLOD - Slow-onset disaster

START - National Consortium for the Study of Terrorism and Responses to Terrorism

SUOD - Sudden-onset disasters

UNDRR - UN Office for Disaster Risk Reduction (formerly known as UNISDR)

UNISDR - United Nations International Strategy for Disaster Reduction

WHO - World Health Organization

6. References

AA.VV. (2013) Rischio sismico urbano. Indicazioni di metodo e sperimentazioni per l'analisi della Condizione limite per emergenza e la Struttura urbana minima. Rapporto finale di ricerca

Arup, RPA, Siemens (2014) Making cities strong by investing in resilience - Toolkit for resilient cities

Asprone D, Cavallaro M, Latora V, et al (2014) Assessment of urban ecosystem resilience using the efficiency of hybrid social-physical complex networks

Batty M (2005) Cities and Complexity. Underst Cities with Cell Autom AgentBased Model Fractals 14:124–125

Bernardini G (2017) Fire Safety of Historical Buildings. Traditional Versus Innovative "Behavioural Design" Solutions by Using Wayfinding Systems, 1° edn. Springer International Publishing

Bernardini G, D'Orazio M, Quagliarini E, Spalazzi L (2014) An agent-based model for earthquake pedestrians' evacuation simulation in Urban scenarios. In: Transportation Research Procedia

Bernardini G, Quagliarini E, D'Orazio M (2018) Strumenti per la gestione dell'emergenza nei centri storici. EdicomEdizioni

Bosher L (2014) Built-in resilience through disaster risk reduction: operational issues. Build Res Inf 42:240–254. https://doi.org/10.1080/09613218.2014.858203

Butt TE, Camilleri M, Paul P, Jones KG (2015) Obsolescence types and the built environment - Definitions and implications. Int J Environ Sustain Dev 14:20–39. https://doi.org/10.1504/IJESD.2015.066896

Caniggia G, Maffei GL (2001) Architectural composition and building typology : interpreting basic building. Alinea

Centre for Research on the Epidemiology of Disasters (CRED) (2019) Disasters 2018: Year in Review. CRED Crunch April 2019:2

Cerè G, Rezgui Y, Zhao W (2017) Critical review of existing built environment resilience frameworks: Directions for future research. Int J Disaster Risk Reduct 25:173–189. https://doi.org/10.1016/j.ijdrr.2017.09.018

Cherubini A, Reluis P (2009) Rischio sismico di Sistemi Urbani utilizzando l' analogia delle reti neuronali. ANIDIS2009BOLOGNA

Coaffee J, O'Hare P, Hawkesworth M (2009a) The visibility of (in) security: The aesthetics of planning urban defences against terrorism. Secur Dialogue 40:489–511

Coaffee J, Wood DM, Rogers P (2009b) The everyday resilience of the city. Basingstoke Palgrave Macmillan doi 10:9780230583337

Combs CC, Slann MW (2009) Encyclopedia of terrorism. Infobase Publishing

Conzen MRG (1960) Alnwick, Northumberland: A Study in Town-Plan Analysis. Trans Pap (Institute Br Geogr. https://doi.org/10.2307/621094

CRED (2018) Natural Disasters 2018

D'Amico A (2016) Resilienza Urbana ai Disastri. Il ruolo del patrimonio costruito. - Urban Disaster Resilience.

The role of the built heritage

D'Amico A, Currà E (2018) Urban resilience in the historical centres of Italian cities and towns. Strategies of preventative planning. TECHNE 15:. https://doi.org/10.13128/Techne-22162

D'Amico A, Currà E (2014) The Role of Urban Built Heritage in Qualify and Quantify Resilience. Specific Issues in Mediterranean City. Procedia Econ Financ. https://doi.org/10.1016/S2212-5671(14)00929-0

Dan HC, He LH, Xu B (2017) Experimental investigation on skid resistance of asphalt pavement under various slippery conditions. Int J Pavement Eng 18:485–499. https://doi.org/10.1080/10298436.2015.1095901

Department of Humanitarian Affairs/United Nations Disaster Relief Office (1992) An Overview of Disaster Management. United Nations Development Programme

Desouza KC, Flanery TH (2013) Designing, planning, and managing resilient cities: A conceptual framework. https://doi.org/10.1016/j.cities.2013.06.003

Dickson E, Baker JL, Hoornweg D, Asmita T (2012) Urban Risk Assessments

EM-DAT General Classification

Enrico Mandolesi, Alessandra Ferrero (2001) Piazze del Piceno. Gangemi Editore spa

Fatiguso F, De Fino M, Cantatore E, Caponio V (2017) Resilience of Historic Built Environments: Inherent Qualities and Potential Strategies. Procedia Eng 180:1024–1033. https://doi.org/10.1016/j.proeng.2017.04.262

FEMA (2013) HAZUS - Multi Hazard Eathquake Model

Forbes G (1999) Urban Roadway Classification. Urban Str Symp Dallas, Texas

Freytag A, Krüger JJ, Meierrieks D (2011) The origins of terrorism: Cross-country estimates of socio-economic determinants of terrorism. Eur J Polit Econ 27:S5–S16. https://doi.org/10.1016/J.EJPOLECO.2011.06.009

GTD Access the GTD

Haigh R, Amaratunga D (2010) An integrative review of the built environment discipline's role in the development of society's resilience to disasters. Int J Disaster Resil Built Environ 1:11–24. https://doi.org/10.1108/17595901011026454

Hillier B, Hanson J (1984) The Social Logic of Space. Cambridge University Press

Holling CS (1973) Resilience and Stability of Ecological Systems. Source Annu Rev Ecol Syst 4:1–23

Holling CS (1996) Engineering resilience versus ecological resilience. Found Ecol Resil 51–66

Indirli M (2009) Organization of a geographic information system (GIS) database on natural hazards and structural vulnerability for the historic center of San Giuliano di Puglia (Italy) and the city of Valparaiso (Chile). Int J Archit Herit 3:276–315. https://doi.org/10.1080/15583050902803780

Italian technical commission for seismic micro-zoning (2014) Manuale per l'analisi della CONDIZIONE LIMITE PER L'EMERGENZA (CLE) dell'insediamento urbano

Jabareen Y (2013) Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. Cities 31:220–229. https://doi.org/10.1016/j.cities.2012.05.004

Jha AK, Miner TW, Stanton-Geddes Z (2013) Building Urban Resilience: Principles, Tools, and Practice. World Bank Publications

John Twigg; Humanitarian Practice Network (2015) Disaster Risk Reduction- Good Practice Review 9. Humanit Policy Netw 44:

Kappes MS, Keiler M, von Elverfeldt K, Glade T (2012) Challenges of analyzing multi-hazard risk: A review. Nat. Hazards 64:1925–1958

Kelman I (2010) Natural Disasters Do Not Exist (Natural Hazards Do Not Exist Either). London

Kim Y, Newman G (2019) Climate Change Preparedness: Comparing Future Urban Growth and Flood Risk in Amsterdam and Houston. Sustainability 11:1048. https://doi.org/10.3390/su11041048

Koren D, Rus K (2019) The potential of open space for enhancing urban seismic resilience: A literature review. Sustain 11:. https://doi.org/10.3390/su11215942

Kurrild-Klitgaard P, Justesen MK, Klemmensen R (2006) The political economy of freedom, democracy and transnational terrorism. Public Choice 128:289–315. https://doi.org/10.1007/s11127-006-9055-7

Lewis D, Branch R, Headquarters U-H, Dan N (2014) URBAN RESILIENCE INDEXING PROGRAMME

Lynch K (1984) Good city form. City

Mandolesi E, Ferrero A (2001) Piazze del Piceno. Gangemi

Mäntyniemi P (2012) An analysis of seismic risk from a tourism point of view. Disasters 36:465–476. https://doi.org/10.1111/j.1467-7717.2011.01266.x

Miller W (2015) What does built environment research have to do with risk mitigation, resilience and disaster recovery? Sustain Cities Soc 19:91–97. https://doi.org/10.1016/j.scs.2015.07.004

Mistretta P, Garau C, Pintus S (2014) Beni Comuni dello Spazio Urbano

Mochi G, Predari G (2016) La vulnerabilità sismica degli aggregati edilizi : una proposta per il costruito storico. Edicom

Moore T (2008) BIP 2034:2008 - Disaster and Emergency Management Systems. British Standards Institution, London, UK

Moughtin C (1991) The European city street, part 1: paths and places. Town Plan Rev 62:51–77. https://doi.org/10.3828/tpr.62.1.j0v4j745161766r6

MunichRE NatCatSERVICE

National Consortium for the Study of Terrorism and Responses to Terrorism (START) (2019) Global Terrorism Database Codebook: Inclusion Criteria and Variables

O'Keefe P, Westgate K, Wisner B (1976) Taking the naturalness out of natural disasters. Nature 260:566–567. https://doi.org/10.1038/260566a0

Oliveri (a cura di) M (2004) Regione Umbria. Vulnerabilità urbana e prevenzione urbanistica degli effetti del sisma, il caso di Nocera Umbra. Urban Quad

Online Etymology Dictionary disaster | Origin and meaning of disaster

Piazza JA (2008) Incubators of terror: Do failed and failing states promote transnational terrorism? Int Stud Q 52:469–488. https://doi.org/10.1111/j.1468-2478.2008.00511.x

Prati G, Catufi V, Associate LP (2012) Emotional and behavioural reactions to tremors of the Umbria – Marche earthquake. Disasters 36:439–451. https://doi.org/10.1111/j.1467-7717.2011.01264.x

PreventionWeb - UNDRR https://www.preventionweb.net/terminology#D

Ranjbar HR, Dehghani H, Ardalan ARA, Saradjian MR (2017) A GIS-based approach for earthquake loss estimation based on the immediate extraction of damaged buildings. Geomatics, Nat Hazards Risk 8:772–791. https://doi.org/10.1080/19475705.2016.1265013

Ranke U (2016) Natural disaster risk management: Geosciences and social responsibility

Ronzani G, Boschi F (2001) Contributi di metodo per la lettura degli spazi urbani. CLUEB

Santamouris M, Cartalis C, Synnefa A (2015) Local urban warming, possible impacts and a resilience plan to climate change for the historical center of Athens, Greece. Sustain Cities Soc 19:281–291. https://doi.org/10.1016/j.scs.2015.02.001

Spence R (2004) Risk and regulation: can improved government action reduce the impacts of natural disasters? Build Res Inf 32:391–402. https://doi.org/10.1080/0961321042000221043

UNDRR UNDRR

UNDRR (2019) Global Assessment Report on Disaster Risk Reduction (GAR)

UNDRR Disaster Definitions - Global Disaster Loss Collection Initiative

UNISDR (2015) Sendai framework for disaster risk reduction 2015-2030

United Nations Office for Disaster Risk Reduction (UNISDR) (2009) https://www.preventionweb.net/files/7817_UNISDRTerminologyEnglish.pdf. In: 2009 UNISDR Terminol. Disaster Risk Reduct.

University of Oxford Our World in Data

Valdés HM, Amaratunga D, Haigh R (2013) Making Cities Resilient: from awareness to implementation. Int J Disaster Resil Built Environ 4:5–8. https://doi.org/10.1108/17595901311299035

WHO (2014) Definitions: emergencies

Woo G (2015) Understanding the Principles of Terrorism Risk Modeling from Charlie Hebdo Attack in Paris. Def Against Terror Rev 7:

Zheng X, Zhong T, Liu M (2009) Modeling crowd evacuation of a building based on seven methodological approaches. Build Environ 44:437–445. https://doi.org/10.1016/j.buildenv.2008.04.002