HLF (Heritage Lottery Fund, UK) (2015) Values and benefits of heritage. Accessible online at: https://www.hlf.org.uk/values-and-benefits-heritage

ICCROM, ICOMOS-ICORP (2015) Overview report of the Nepal Cultural Emergency Crowdmap Initiative. Accessible online at: https://www.icomos.org/images/DOCUMENTS/Secretariat/2015/Nepal/Nepal_Cultural_Emergency_Crowdmap_Initiative_Overview_ReportFinal.pdf

IFRC (2014) World Disasters Report 2014: Focus on Culture and Risk

Johnnides, C. (2010) Disaster Preparedness for Cultural Heritage. EAP DRM Knowledge Notes; No. 14. World Bank, Washington, DC. Accessible online at https://openknowledge.worldbank.org/handle/10986/10125

Loulanski, T. (2006). Cultural heritage in socio-economic development: local and global perspectives. Environments, 34(2), 51.

Medina, N. (2009) Cultural Heritage and Identity in the Wake of the L'Aquila Earthquake. Accessible online at: http://www.cyark.org/news/cultural-heritage-and-identity-in-the-wake-of-the-laquila-earthquake

Russo, A. P., & Van Der Borg, J. (2002). Planning considerations for cultural tourism: a case study of four European cities. Tourism management, 23(6), 631-637.

Tweed, C., & Sutherland, M. (2007) Built cultural heritage and sustainable urban development. Landscape and urban planning, 83(1), 62-69.

UNESCO (2010) Managing disaster risks for world heritage. Accessible online at: http://www.preventionweb.net/files/14614_188562e1.pdf

UNESCO (n.d.) UNESCO's response to protect culture in crises. Unite 4 Heritage Initiative. Accessible online at: http://unesdoc.unesco.org/images/0024/002449/244984e.pdf

Wijeratne, P. Post-Tsunami Redevelopment and the Cultural Sites of the Maritime Provinces of Sri Lanka. In Meier, H.R., Petzet, M. and Will, T. (eds) (2008) Cultural Heritage and Natural Disasters. Risk Preparedness and the Limits of Prevention. ICOMOS, Tud Press. Accessible online at: https://www.icomos.org/images/Cultural_Heritage_and_Natural_Disasters.pdf

Jha, A.K., Barenstein, J. D., Phelps, P. M., Pittet, D., Sena, S. (2010) Safer homes, stronger communities: A handbook for reconstructing after natural disasters, Chapter 11: "Planning reconstruction - Cultural heritage conservation", World Bank pbl, pp.173-179. Accessible online at: https://www.gfdrr.org/sites/gfdrr.org/files/Chapter_11_Cultural_Heritage_Conservation.pdf

Jigyasu, R., Murthy, M., Boccardi, G., Marrion, C., Douglas, D., King, J., ... & Osihn, M. (2013). Heritage and Resilience: Issues and opportunities for reducing disaster risks

SECTION 2: CITIES AND DISASTER RISK REDUCTION

1. Cities: places of complexity

Cities are complex three-dimensional spaces in which social, political and economic organisations interact in different ways and at multiple levels with buildings, infrastructures, production and service facilities, open areas. These interactions reflect the cultural features and the degree of technological development of cities and their inhabitants.

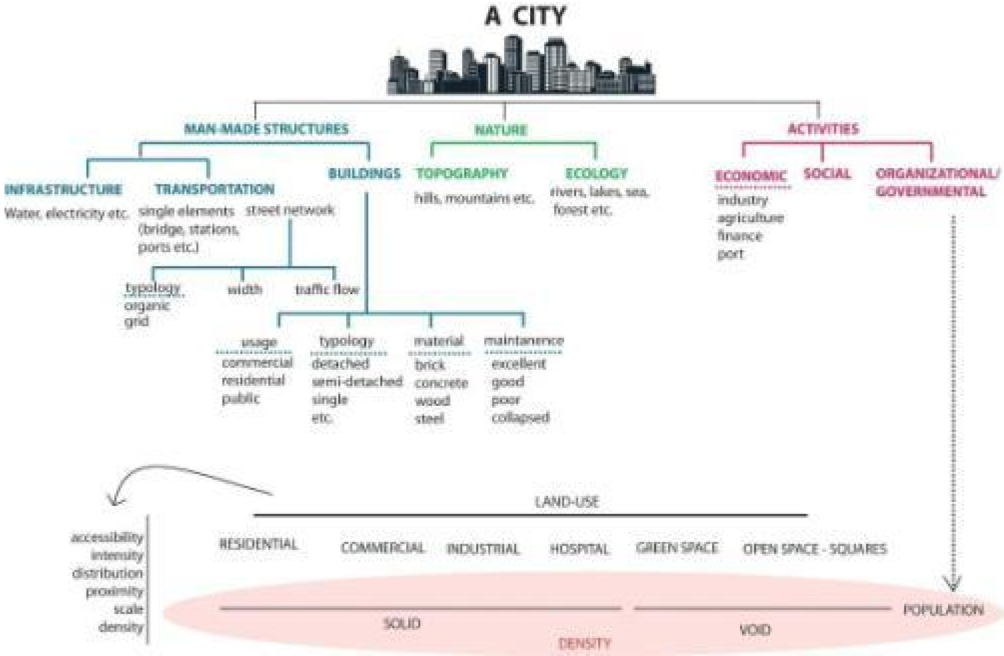


Figure15.: Cities at the cross-connection between the built and the natural environments, the social and economic systems

Cities share with complex systems virtually all features that characterize them as such. The first feature is the non linearity between systems and components with the consequent impossibility to predetermine how the latter will interact with each other in the future or under changed conditions. A second feature derives from the "path dependency" of decisions that are made, particularly those regarding locational issues and the establishment of new urban functions in a previously not urbanized area. Third the difficulty to forecast the response to external forcing such as that imposed by natural hazards or man made severe accidents. Other important aspects that need to be considered are: the fast evolution of the "urban" particularly in the more recent decades, implying differential development dynamics; the pressure to become more resilient, able to adapt to internal and external pressures and shocks; the multilayered governance of cities, resulting from a deeply transformed geography in which urban fringes tend to blur into rural areas making it very hard to define a clear cut border between what is "city" and what is not. An additional element of complexity derives from a simple quantitative datum: more than 54% of the world population lives today in cities, 75% in Europe, reversing any prior historic trend and requiring therefore highly skilled managers to keep cities function and able to respond to multiple stresses including natural disasters and man made incidents. A cultural innovation is required from city managers and planners to overcome traditional perspectives and understanding of what cities are that were still relevant and viable only half a century ago.

The implications for DRR have been depicted very smartly in the Flood Risk Management Plan, strategic document prepared by the largest River Basin Authority in Italy, the Po RBA. In the scheme presented in the Plan (Figure 16), the need to integrate the objectives of the Water Framework and the Floods Directives is highlighted, showing that both are acting at the conjunction of social, environmental and economic systems. This apparently trivial representation actually introduces significant novelties in the way engineers and planners have conceived insofar disaster risk protection and prevention. It suggests in fact that environmental sustainability needs to be coupled with risk prevention, meaning that at the city level the two cannot be kept separated anymore and that actually they should include also climate change adaptation. Fragmentation of programs and initiatives is not a viable option: because of the complexity of implied systems and their mutual interrelationships, a much more cooperative effort is required from the different branches of cities' *and regions' offices in charge of individual policies and programs having effects on each system and systems' components.*

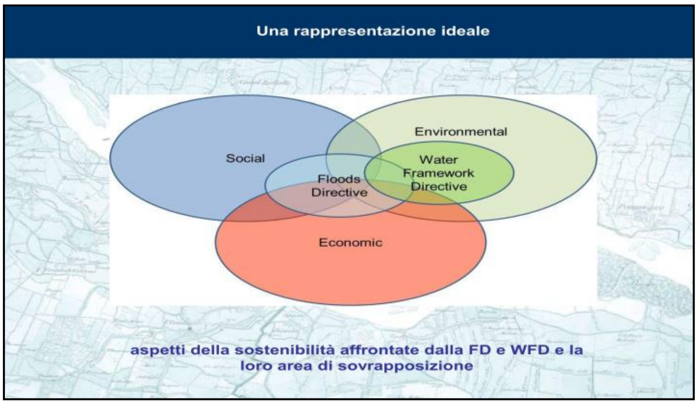


Figure 16.: Interaction of systems to be considered for the integrated implementation of the Floods and the Water Framework Directives

As it can be seen in practice in the case studies of the Umbria Region, Italy and Lorca, Spain, flood risk management plans are inherently multi-scale. At the riverbasin scale it is possible to identify the most critical process and rivers' sections. At this scale the effectiveness of both structural an social, political and economic organisations non structural risk mitigation must be assessed, whilst at the city level individual projects aimed at reducing the risk locally must be implemented.

After the Industrial Revolution the relationship between the natural and the man-made environments of cities has been progressively overlooked, but it is rather evident that nature has always constrained and still does urban morphology. In the more recent years, there has been a rediscovery of the "natural" in the "urban". Open spaces in cities have been devoted to urban agriculture, intercepting the still existing agricultural land and practices in the peri-urban; innovative projects have brought "nature based solutions" to reduce hazards such as floods and heat waves right in the core of cities. Those cannot be considered as fit for all solutions, but they clearly highlight different attitude towards natural spaces in cities. Yet in general terms it can be said that cities where the link between natural and man-made environments has been addressed in a sustainable manner are also less exposed and vulnerable to natural hazards, while cities where such link has been neglected display unsustainable patterns of development that make them also more prone to damage and disruption when stressed by natural extremes.

2.1. The relevance of spatial scales to cities

Contemporary cities need to be comprehended as nodes acting at multiple scales in space and time. Spatial scales that matter for a given city depend on its connections with other cities and regions that are part of their surrounding but also geographically remote.

In fact, we cannot limit the consideration to "local" aspects, because nowadays local, regional, national and global levels are interconnected, though in different ways for metropolitan and central areas on the one hand, for small-medium towns and marginal and non-central areas on the other. Actually the situation is much more diversified and complex than the dichotomy between central and peripheral may hint at: cities may be central in a global perspective, but they can also be central to a nation or to a region, given the services and the type of functions they offer to other cities gravitating on them. This was certainly the case of l'Aquila, where all services located in the historic centre had to be relocated in the Coppito Schools of the Financial Police. Cities that are the margin of global networks can be still central to a region. The different scales are in tension with each other, and this tension owes a lot to the type of existing networks (both physical and nonphysical, hard and soft).

The number of central areas has increased as they represent a reference for different regions that differ as far as their amplitude and their concentration in terms of population, assets and richness is considered. Peripheral and semi-central cities are to different degrees dependent on metropolitan areas but at the same time are also detached from the most rapid and increasing networks.

Without understanding those complex interrelationships and interlinkages it will be extremely difficult to understand also the systemic social and economic and ripple effects a disastrous event may have. A disaster nowadays is seldom only local: immigrants from South East Asia have become a supportive communities for the countries hit by the tsunami in 2004; the 2011 earthquake affected some economic sectors in the USA depending on specific products that were produced in Japan. The fact that distances count differently in a globalized world means that regions and cities are closer or farther depending on their position and centrality in the various transport routes. This has implications also for the way in which aid and support can be provided once a disaster has hit in a region. Often aid arrives quicker to the airport of a capital city or to the regional central district than it takes from there to be moved to the areas that have been most affected, if the latter are located in detached, sparse and remote locations.

Mobility has changed forever the spatial dimension of cities, selecting those that are easier to reach with respect to those that are peripheral to high speed means of transportation. So cities like Istanbul are central nodes globally, while it takes the same time requiring to fly to Istanbul to reach by road or railway relatively isolated cities in the Umbria Region in Italy. Research produced some years ago on the differences in time needed to reach each area in Europe has produced a rather interesting geography of remote and central zones.

This has clearly fundamental implications for disaster management, in terms of capacity of external forces to reach places that have been hit. Inner, mountain areas in Europe require longer times to be reached, and accessibility may be hampered by multiple hazards, such as landslides, and by the lack of redundancy in networks. Multi-risk events are more likely in those areas. An example is provided by the recent sequence of earthquakes in Central Italy 2016: localities that are very close to the capital city could not be reached for days because of roads obstructed by collapsing bridges, falling landslides and buildings debris. The concurrent severe snowstorm in January 2017 provoked in some localities a two weeks blackout, with electrical companies unable to bring generators to the more remote areas and to act fast in small congested cities close to the coastline and in sparse settlements isolated due to the closure of the single narrow and covered by meters of snow roads.

Scales that are relevant for cities may therefore vary from very local to global, depending on the relative position of such cities, on their role as a service provider and as an economic actor in regional, national and international contexts. This does not necessarily imply that only core central cities must be protected, but rather that differential risk mitigation policies are needed to acknowledge for the diversity and the degree of relevance with respect to differential spatial scales.

Nowadays cities do not exist in isolation (they never had) but now less than ever. They are part of networks that varies according to the relevance, size, distance from which they attract visitors and investments. There may be large metropolitan cities at the key nodes of networks working at the global scale, medium cities, gravitating around a main centre, positioning themselves within local, regional, national economic and political boundaries.

Cities' culture, resulting from past trends and present choices, shape the way in which cities position themselves locally and globally, also through designed strategies. For example becoming the European Capital of Culture for a given year, becoming a university centre, offering congress facilities, opening museums, boosting technological innovation.

The role a city play regionally, nationally and internationally has important implications for DRR.

At the impact and emergency disaster managers, civil protection authorities have to understand that damage is never only a local issue, unless for physical direct destruction of artefacts. Particularly in *the case of indirect damage and for long term damage, scale matters a lot. Damage due to business and services interruption may be suffered miles away from the epicenter of the disaster; the network of cities to which the affected area pertain may feel the repercussions of the event in terms of unavailability of goods, lost customers (at least for some time), lost gateways for their products.*

Strategic choices will have to be made in order to restart those activities that are crucial for the city's position in the network they pertain to, guaranteeing that it will not loose its role. However the issue must be looked at also at other scales and from other perspectives. What one city can loose may be gained by another, that is already well positioned before the impact of the event. How to account for those shifts is a matter that needs to be considered by national governments. Methods and tools to measure indirect impacts are still in their infancy and there is still much to be unveiled and explained in order to make pertinent analyses at different scales. In the meantime it would be important for city managers, for the association of mayors, for different governance and governmental bodies with responsibilities in both economic development and disaster management to ask questions regarding what may happen if a disaster strikes in a city they consider vital, or what strategies and priorities they would give to protect this or that city or after an extreme event occurs.

2.1. Cities' specialization as they position themselves at different spatial scales

Cities were initially mainly a market place, but have become in the modern times a place of production, and more recently a place of services ranging from basic to high level, such as educational and innovation centers. In today's context, some cities have become very specialized, such as trade cities, port cities, finance cities, political and administrative nodes, religious destinations, etc. Every type of specialization entails a different city culture, with important consequences as to how cities interact with each other and in the way they interact with "nature".

Also specialization entails prevalence of certain types of patterns, both in the two and three dimensional spaces, reliance on predominant types of infrastructures and services.

Figure 17: Volos

The major economic function of a city shapes its structural pattern and physical artefacts. Considering the ex-industrial role of Volos in Greece helps us to understand the huge fabric blocks in the city and the city's functional grid pattern.

The city's specialization should orient decisions on what to protect most and first, on what are viable means of protection, on how they can be implemented without constraining the activities and operations that are mostly needed for the specialized city. In recovery and reconstruction the most critical assets that guarantee the possibility to keep the specialized role and function will guide priorities of reopening areas and functions and of compensating and restoring damage.

Modern cities' culture orient choices towards specializations that can be permanent overtime or confirm the capacity to host for a certain period important events, exhibitions, games. In this respect, mega-events such as Olympic games, Expo exhibitions, universal fairs have become the object of both policies aiming at competing at global level and of controversies depicting such events as disruptive of citizens' everyday life and well-being. The capacity to host such events, though, is important nowadays as it may boost local economy and generate new networks and exchanges.

2.2. Mega-events, cities and organizational cultures

Guaranteeing the safety and security of such events has become a critical point, especially after September 11, but also prior to it.

Mega-events are marketing tools for cities to make them globally significant and attract national and international interest from all over the world. Mega-events are also engines for the structural development of cities, as economic resources gained by mega-events are used to activate urban development. If the mega-events are handled well politically, organizationally and structurally, they provide great advantages for social, structural and economic challenges. A well-organized mega-event is helpful for the formation of human capital in the field of the design, implementation and management of the event. If the social inclusion strategy is adapted during the implementation phase, the labour market can be adapted and allow access to those from a lower social status. Mega-events also trigger tourism in the medium and long term; the numbers both from London and Milan prove this statement. The main reasons are improved conditions, increased visibility, and increased supply conditions.

Mega-events include the notion of culture in terms of two perspectives; organizational culture and culture in hard infrastructure. The former is about the cooperation of several national and international organizations to achieve a successful mega-event. The latter is about improving the structural condition of a city, as to obtain a mega-event, a well-maintained infrastructure system is a must.

Having good quality infrastructure is not sufficient for being a part of this worldwide competition and hosting a mega-event. Providing resilience against disruption to infrastructure and services is also imperative to ensure the competitive advantage of cities, as well as the safety and security of infrastructures. Hosting a mega-event brings a major challenge to meet resilience targets, meaning, the increased exposure of the population, including both inhabitants of the city and tourists/visitors coming to the event. That tremendous increase of exposed population from different cultures does not necessarily add new risks, but concentrates the current risks in the city in one place. Therefore, disaster risk reduction (DRR) that considers these cultural diversities must be a part of the investment to increase the resilience of the infrastructure systems. There are also other issues, such as the new risk landscape, including terrorism, traffic jams and changing hazard conditions that increase the vulnerability of cities, and the multiple interaction patterns of infrastructure systems. The latter occurs between the three layers existing in the territory: spatial, organizational (public institutions or private, depending on the owner of the infrastructure system) and social (the users of the system).

2.3. The complex mix of hard and soft infrastructures in guaranteeing cities functioning

Disasters are responsible for the occurrence of serious damages on structures and infrastructures, particularly in urban areas. All the lifelines (hard infrastructures) are impacted by extreme events, and their functionality limited as a consequence of both physical damages and changes in the operational conditions. Lifelines are vulnerable elements, but also crucial assets to guarantee safety and well-being. Disasters cause complex short- and long-term effects on social structures as well, which are difficult to understand and define (soft infrastructures). A strong connection exists: the reliability of physical infrastructures during the emergency management contributes to mobilize the social capital. Similarly, the existing soft infrastructures may condition the level of service provided by the hard infrastructures.

Community organizations and community-based networks play a key role in disaster preparedness and recovery. Local knowledge, understandings, perceptions, resources, and cooperative strategies are crucial in determining system survival and, particularly, to properly drive recovery conditions.

The role of hard infrastructures (e.g. water supply infrastructures) at urban level supports the efforts of local communities during the emergency phase, revealing as a key asset to cope with the disaster.

Lifelines provide a very clear example of assets that work and function at multiple scales due to the internal hierarchy among individual components (typically plants and networks and networks of differential capacity), to the mutual interdependency among infrastructures (the power system is vital for all the others, to pump water and to guarantee communication survival), and to the interconnectedness between lifelines and any other urban function and asset. Such high level of interdependency cannot be understood only locally, as lifelines are organized regionally, nationally and across borders (let's think to the large gas and oil pipes connecting Africa to Europe and Eastern to Western Europe). In order to guarantee the resilience of hard infrastructures, policies have been set at the European level, however their success depend strongly on how local, regional, national service and networks providers are able to prevent, manage the damage due to natural disaster forcing and to recover and to what extent they are interacting with emergency managers.

Figure 18.Hard infrastructures in L'Aquila (Italy)

L'Aquila city has a long history of disastrous earthquakes (1461, 1703, 1915, 2009). The earthquake in 2009 struck L'Aquila province at 3.32 a.m. on 6 April 2009. As a consequence 308 people died and 1500 resulted injured. Although the magnitude was moderate, the impacts were high, mainly due to the high urban vulnerability.

3. Urban patterns result from and shape the relationship among systems and systems' components.

3.1. Introduction

Cities' complex interdependences between elements and systems occur in the three dimensional space. An urban pattern is the combination of buildings' density, the prevailing typology of the road network, i.e. ring, grid or linear, and the width of the streets in comparison with the height of the buildings and, finally, the features of the natural environment, that constraints and in the meantime provides opportunities for cities' development.

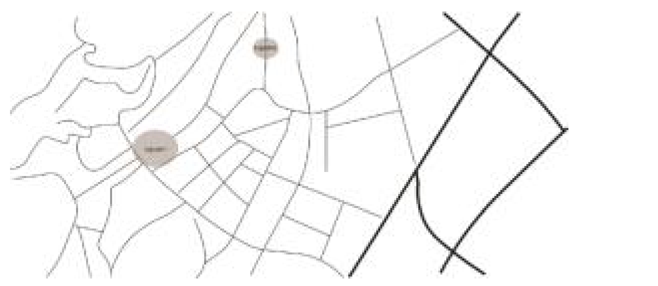
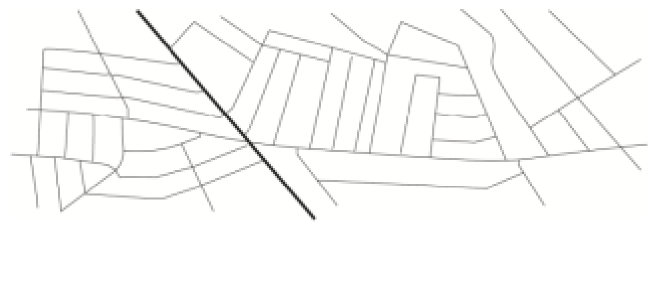
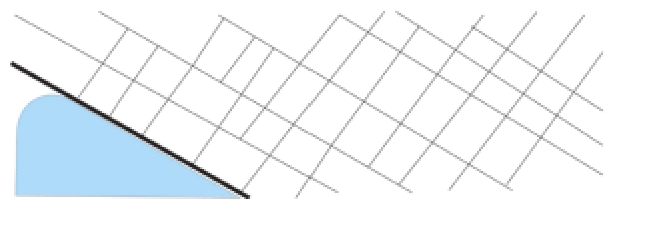
The type of urban pattern has decisive implications for emergency management, and in particular for all activities related to evacuation, positioning of roadblocks, selection of areas devoted to locate civil protection and rescuers tracks and devices. A regular grid, such as that characterizing the original roman-style settlement can be easily found in colonial cities, in modern expansion areas such as in Volos in Greece and sometimes also in ancient towns such as Tourin in Italy. Such regular grid guarantees redundancy in access ways to almost all point shaped element in cities and fastest in and out travels. Furthermore, the regular grid permits to better define areas pertaining to predetermined emergency centres and to distribute rationally services such as hospitals, fire brigade stations, etc.

Circular, round grids are more complicated to manage: redundancy is still guaranteed but not to all locations, avoiding central nodes is virtually impossible, congestion is more likely in ordinary times and to be expected and therefore carefully managed in emergencies.

Linear cities are those that develop along the coast or important infrastructures such as roads and railways; they are characterized by the general absence of significant alternatives in case of transportation routes failures and by the fact they are easily cut in more parts disconnected from each other that will need to respond a crisis independently from each other. This was certainly the case in Kobe a rather emblematic example of linear city, hit by the earthquake in 1995.

Whilst cities generally present a predominant pattern, there may be also coexistent patterns, particularly in large metropolitan areas that result from the aggregation of pre-existing settlements once autonomous and of newly added development zones.

Different city patterns require city and disaster managers to adopt different strategies in deciding the location of critical infrastructures, in defining self reliant zones and in preparing themselves, other agencies and citizens for contingencies.

	Figure 19.: The street pattern in Lorca Lorca contains both organic and linear patterns in its street morphology. The city was organized on a human scale, and highly walkable. It provides a low speed of travel within the narrow streets and a high speed of travel in the recently built linear pattern.
	Figure 20.: The street pattern in Istanbul The pattern is taken from a residential section of Istanbul. The area includes a mono-functional housing development that does not provide functional feasibility. However, the distribution of the streets provides accessibility.
	Figure 21.: The street pattern in Volos Volos has a grid street pattern that provides a rapid connection between distant parts. Highly accessible. Urban blocks are mixed-use, combining residential, touristic and commercial activities.

However consideration cannot be limited to the plan layout: buildings, transportation networks, services, work activities occur in three-dimensional space. The relation between the latter needs to be considered also vertically. In the XVIII century scholars and architects were already aware of the fact that the reciprocal ratio between buildings height and streets' width has important implications in case of earthquakes for example, determining the possibility or not of buildings standing at the opposite sides of a street battering against each other; they were also concerned about the amount of debris that could layer on the road, provoking its closure and the difficulty to open it rapidly for search and rescue. We may certainly say that such relationships are relevant also for other risks, such as floods, in determining for example the time needed to dry up first floors after inundation.

The urban pattern in the third dimension has relevant implications also during emergencies, as it implies the easiness of carrying and using cranes if necessary, of maneuvering firemen tracks, etc. In modern times different interventions can be thought of, provided that such relationships are recognized and related to a variety of indicators of health, sustainability and safety as for the built *environment, whilst considering appropriate dimensions of emergency cars and devices to be used in constrained environment.*

Figure22.: The streets of Orvieto a historical town in Umbria Region (the photo credit: Claudia Moreschi) versus a main street in Istanbul Metropolitan City.

3.2. Cultural habits drive people in using buildings and spaces

How people use places and buildings depend on their culture, there is the indigenous culture of the inhabitants of cities but also the newer inhabitants bring their own ways of using spaces (for example public spaces). Uses may be or become incompatible with the original layout of buildings requiring changes in internal configuration of spaces that may lead to unpredictable yet dramatic outcomes in terms of structural resistance to earthquake. For example the opening of large shop windows at the first level of buildings, or the elimination of structural components to create parking spaces or laboratories may change the original performance of buildings against horizontal accelerations.

The use of basement as residential units or offices clearly puts at risk the life of people and valuable goods in flood prone areas. City managers need to be aware of the fact that not only hard components of cities determine structural features, but also the soft way spaces and artefacts are exploited and change to conform them better to new uses.

4. Soft and hard infrastructure: A resilience based approach for urban DRR

4.1. Introduction

Disasters cause serious damage on structures and infrastructures, particularly in urban areas. All the lifelines (‘hard infrastructures’, e.g. water supply, transport, power supply, telecommunication) are impacted by extreme events, and their functionality is limited as a consequence of both physical damages and changes in the operating conditions. Lifelines are vulnerable elements, but also crucial assets to guarantee the safety and well-being of the impacted population. The role of hard infrastructures at urban level supports the efforts of local communities during the EM, being a key asset to cope with the disaster. As a matter of fact, society and local economy benefit from the operation of hard infrastructural systems.

Disasters cause complex short- and long-term effects on social structures as well, which are often difficult to understand and define (soft infrastructures). Community organizations and community-based networks play a key role in disaster preparedness and recovery. Local knowledge, understandings, perceptions, resources, and cooperative strategies are crucial to determine system survival and, particularly, to properly drive recovery conditions.

A strong connection exists between the two infrastructures: the reliability of physical infrastructures during the emergency management contributes to mobilize the social capital. Similarly, the existing soft infrastructures may condition the performances and the level of service provided by the hard infrastructures. More specifically, infrastructural systems play a fundamental role in keeping alive the social networks within a community in case of disasters by continuing to provide key services. The process of recovery after extreme events, is also generally supported by the availability of critical services, which significantly contribute to increase the resilience of the whole community.

4.2. Resilience based approach for DRR

Resilient systems have a reduced probability of failure, lower consequences from failures and a reduced time for recovery. At urban scale, resilience is related to the capacity of cities to cope with and recover from external shocks. Infrastructural systems of a city are linked with social and institutional systems, but also with the economic and environmental ones, and thus their resilience is necessarily connected to several intertwined dimensions.

Enhancing resilience means improving the capacity of the whole system to anticipate threats, reduce vulnerability and allow a complete recovery from impacts. Several factors contribute to increase the resilience, related to the 'physical' and 'non-physical' characteristics of the system. All these features are found to be highly influential in all phases of a disaster.

Read more: resilience of hard and soft infrastructure

The concept of resilience tends to be strictly related to both static and dynamic components of disasters across pre and post event context. A static model of resilience identifies and organizes critical variables, whereas a dynamic model represents how and why such variables change across time and space. Resilient systems have a reduced probability of failure, lower consequences from failures and a reduced time for recovery. Referring specifically to urban environments, resilience is related to the capacity of cities to cope with and recover from external shocks. An urban system can be considered resilient if it is sustainable even during the hazard occurrence phase, the most critical period, in which the city suffers the impacts of an extreme event and tries to reconfigure both its physical and social aspects towards a new equilibrium.

The infrastructural system of a city has to be conceived as linked with social and institutional systems, but also with the economic and environmental ones that are all embedded within the urban context and dynamically interacting. **Physical (hard) infrastructure** involves amendments to the physical surroundings and landscape to serve a given purpose (e.g. transportation, power supply, water supply, management, and treatment). **Social (soft) infrastructures** refers to the networks and interactions among individuals, groups, and institutions within and outside the community. The link between them is crucial, since the resilience of a system is described by its level of functionality and assuming that it directly represents the level of satisfaction of citizen.

Enhancing resilience means improving the capacity of the whole system to anticipate threats, reduce vulnerability and allow a complete recovery from impacts. Several factors contribute to increase the resilience, which might not necessarily be related to the 'physical' characteristics of the system. They may depend on individual conditions (e.g. well-being and survival skills) and on community characteristics (community connectedness, community infrastructure, participation in disaster response and recovery, engagement in decision making). All these features are found to be highly influential before a disaster strikes, as well as in the event of a disaster and during recovery.

Several extreme events suggested that infrastructural systems play a fundamental role in keeping alive the social networks within a community in case of disasters by continuing to provide key services. The process of recovery after extreme events, is generally supported by the availability of critical services, which significantly contributes to increase the resilience of the whole community.

The Case Study of L'Aquila supported drawing a few key conclusions:

- Physical infrastructure provides a vital support to communities during emergency and recovery phases after a disaster. The uninterrupted availability of critical services is a requirement to guarantee the safety and the well-being of a population when a disaster occurs and speeds up the recovery: in this direction, the technical performances of the whole infrastructural system are a key asset to deal effectively with emergencies and contribute to community resilience. On the other hand, the resilience of a community affects the level of service provided by the hard infrastructural system as well: the behaviors of the users (e.g. good practices, flexibility, …), their level of knowledge along with the skills of the authorities managing the emergency and driving decision-making – in a word, their culture - have a direct influence on the response of the hard infrastructural system.
- Infrastructural systems must directly match the needs of a community, and thus should firstly reflect the spatial distribution of the served population. Secondly, the performances of infrastructural systems should be flexible enough to evolve with time, in the aftermath of a disaster and in the recovery phase, since the needs of the whole system change according to the specific path of recovery determined by the specific strategies implemented.

Describing resilience: the resilience triangle

Referring to a wide scientific literature, the shift from risk management towards ‘resilience management’ paradigm is crucial. Resilience approach addresses the complexities of large integrated systems and the uncertainty of future threats, overcoming the main drawbacks associated to risk management: a) it allows modeling the interactions between different risks; b) it helps analyzing the gradual worsening of environmental conditions; c) it overcomes the limits associated to the use of historical/past data, focusing on the ‘unexpected’; d) it considers the new perspective on extreme events which are now becoming ‘routine’ events; e) it fosters better information to communities. The resilience approach emphasizes the system’s ability to anticipate and absorb potential disruptions, develop adaptive means to accommodate changes, and establish response behaviors aimed at either building the capacity to withstand the disruption or recover as quickly as possible after an impact. The key difference (Cimellaro 2016) is that Risk analysis is used to prioritize the mitigation strategies; Resilience analysis is used to prioritize the restoration strategies.

In its more general definition, resilience could be viewed as the ‘intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its non-essential attributes and rebuilding itself’. It is a multidimensional, sociotechnical issue that addresses how people, as individuals or groups, manage **uncertainty**. In infrastrucures and engineering field, it can be defined as the ability of systems to absorb the shocks of extreme events such as natural disasters. Resilience can be achieved by enhancing the ability of an infrastructure to perform during and after a hazard, as well as through emergency response and strategies that effectively cope with and contain losses and recovery strategies.

In order to propose a quantitative way of analyzing resilience, Bruneau et al. (2003) and Tierney and Bruneau et al (2007) suggested the use of a **‘resilience triangle’** (Figure 29) to describe resilience, representing both the loss of functionality from damage and disruption, and the pattern of restoration and recovery over time. It is defined graphically as the normalized area underneath the performance function of a system (Cimellaro 2016). It is used to measure the functionality of a system after a disaster, and also the time it takes for a system to return to pre-disaster levels of performance (or, according to specific conditions, to reach higher or lower performance conditions). The area within the resilience triangle relates directly to the resiliency with small er areas indicating greater resilience. Actions, behaviors, and properties of social units, organizations and networks all contribute to reducing the area of the resilience triangle.Resilience-enhancing measures aim at reducing the size of the resilience triangle. Such strategies may act upon the multiple dimensions associated to resilience, which are normally included in the **R4 Framework**: a) **robustness**, the ability to withstand external actions without significant degradation or loss of performance; b) **redundancy**, the extent to which systems and elements are substitutable; c) **resourcefulness**, the ability to diagnose and prioritize problems and to initiate solutions by identifying and mobilizing resources; d) **rapidity**, the capacity to restore functionality in a timely way.

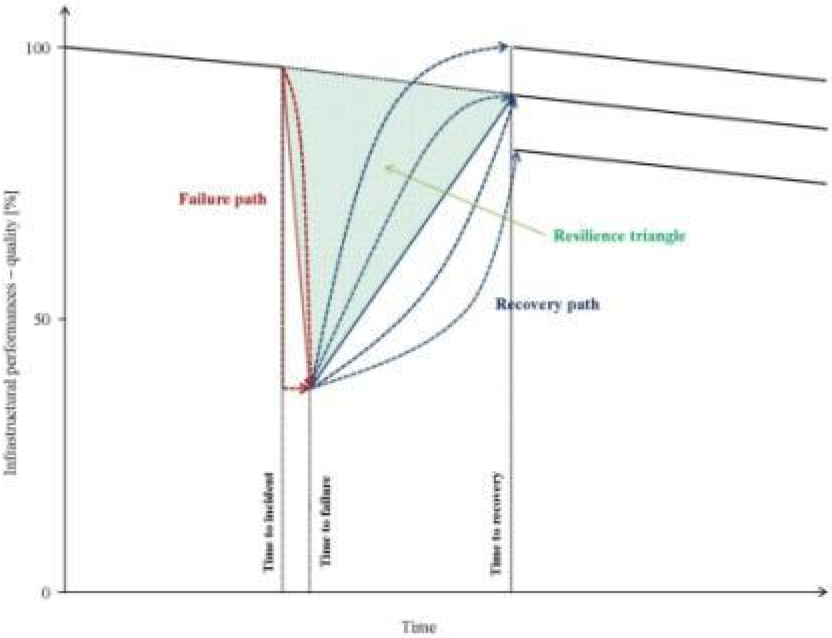


Figure 23. Graphical representation of the 'resilience triangle'.

Resilience-enhancing measures aim at reducing the size of the resilience triangle through strategies that improve the infrastructure's functionality and performance (the vertical axis in the figure) and that decrease the time to full recovery (the horizontal axis). For example, mitigation measures can improve both infrastructure performance and time to recovery. The time to recovery can be shortened by improving measures to restore and replace damaged infrastructure.

Clearly, identifying the features of organizations and other social units that make them resilient is difficult. The objectives of Disaster Resilience are to minimize loss of life, injuries, disruption of important services, and economic losses. Specifically, disaster resilience is characterized by (Cimellaro 2016):

- **Reduced failure probabilities**– i.e., the reduced likelihood of damage and failures to critical infrastructure, systems and components;
- **Reduced consequences from failures**– in terms of injuries, lives lost, damage and negative economic and social impacts;
- **Reduced time to recovery**– the time required to restore a specific system or set of systems to normal or pre-disaster level of functionality.

Modeling resilience: TOSE approach

Going further into details in LS resilience, one of the the most consolidated and interesting approaches is based on the conceptualization of its four inter-related dimensions: Technical, Organizational, Social and Economic (TOSE approach). The Technical dimension of resilience refers to the ability of interconnected physical systems to perform to acceptable/desired levels. Organizational resilience is related to the organizations and institutions that manage the physical components of the systems, and is thus significantly affected by 'culture': it encompasses measures of capacity, planning, training, leadership, experience, and information management that may improve (or hamper) disaster-related organizational performances and problem solving. Among the influential parameters, the ability to incorporate lessons learned from past disasters, the training and the experience of personnel should be considered. The Social dimension includes population and community characteristics that render social groups either more vulnerable or more adaptable to hazards and disasters, and is strictly connected to ‘cultural’ issues as well: social indicators include for example, poverty, education, linguistic isolation, a lack of access to resources for protective action, such as evacuation. Finally, Economic resilience has been analyzed in terms of the inherent properties of local economies and in terms of their capacity for post-disaster improvisation, innovation, and resource substitution.

Resilience assessment was performed with specific reference to L’Aquila Case Study, implementing the TOSE approach on drinking water supply through SDM (see Methodological approaches: SDM & Graph Theory – System Dynamics Modeling). It is worth considering that L’Aquila case study was used to collect and structure the knowledge needed for model building and validation. Nevertheless the model and, more in general, the methodological approach, is broad enough to be implemented with minor changes and adaptations in different cases, conditions, and even on various infrastructural systems.

The global model of resilience is plotted in the following Fig. 1 (full details are in Pagano et al. 2017) and in the **Case Study Manual**. The dimensions of resilience were defined adapting the general TOSE framework to the case of drinking water supply systems. The model was built in order to deal separately with the four basic dimensions of resilience, and then the reciprocal influences among variables were identified. For instance, some capabilities reflecting organizational culture (e.g. the availability of human resources, the availability of a good knowledge concerning the infrastructure and the environment) which may have a direct influence on system resilience (i.e. they support a quick and effective response to technical issues) are explicitly included. The role of the social dimension contributing to resilience, particularly focuses on the characterization of how behaviors, attitudes and awareness of the served population may either help or hamper resilience. The model mainly aims at providing information on the water deficit during emergency and in the immediate aftermath, performing a comparison between water inflow and water demand.

Specific sub-models are identified by purple boxes and defined in order to deal with key issues contributing to resilience according to the TOSE conceptualization. Most of the sub-models are mutually interconnected, and can be run and analyzed independently. Each of the sub-models considered provides a quantitative insight into the main dynamics of the specific dimensions of the TOSE approach.

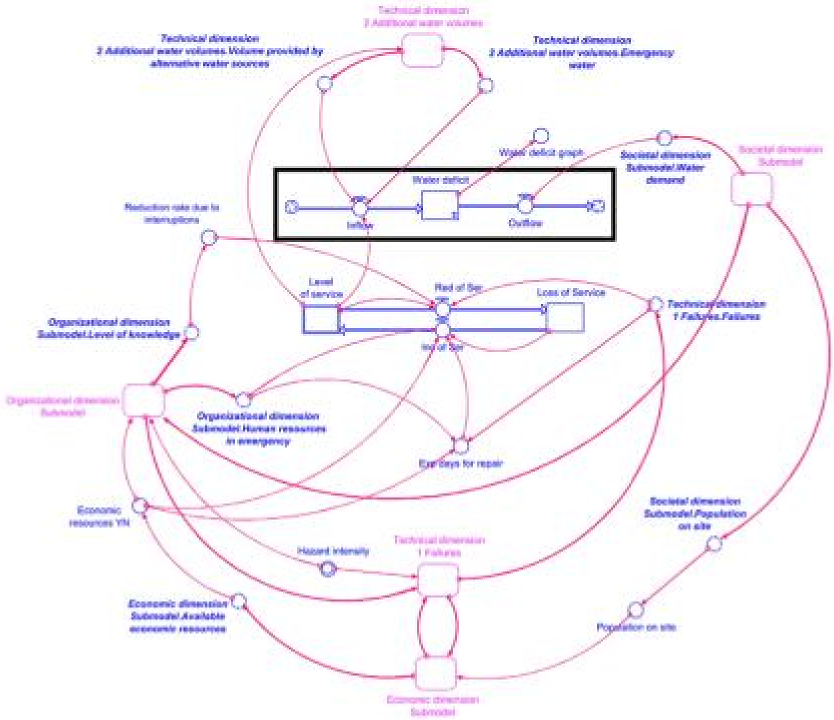


Fig. 24. SD based resilience assessment model

The model can be also used in order to perform a scenario analysis: this may support decision-makers to understand the impact of different strategies, conditions, assumptions on the response of the system. The key outcome of modeling is the analysis of the evolution of water deficit with time, as in Fig. 2, which is a way of interpreting and representing the resilience triangle. The comparative analysis of multiple scenarios helps describing the impact of different states of specific variables on the model outcomes. Starting from the Scenario 0, which reconstructs the 'real' evolution of the events after the earthquake, the others are built for the purpose of comparison as follows: 'Scenario 1' shows how a decrease in organizational skills may have a dramatic influence on system response; 'Scenario 2' simulates a decrease of 'infrastructure physical vulnerability' which, although expensive has a definitely positive impact; 'Scenario 3' describes instead an integrated strategy where infrastructural improvement actions are supported by also by a better 'knowledge of critical points', 'training level' of the personnel and enhancement of 'community awareness'.

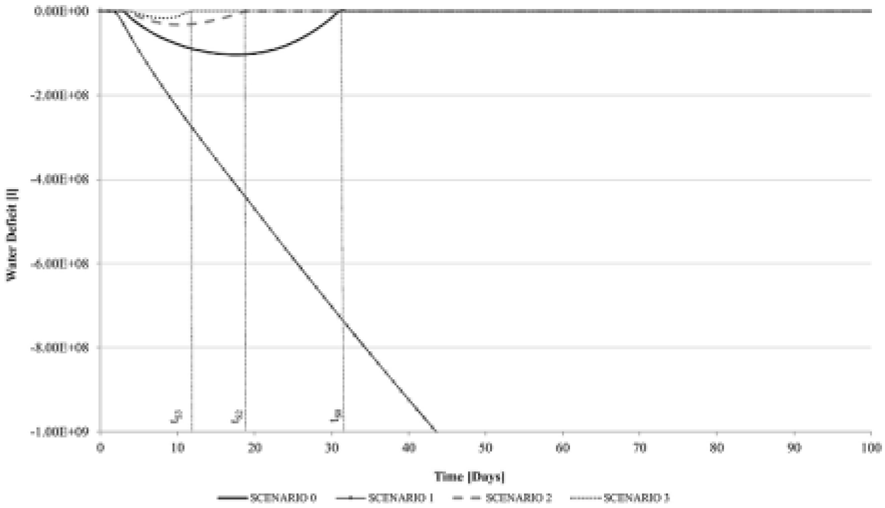


Fig. 25. Results of the resilience assessment in terms of 'Water deficit' for the modeled scenarios.

The results were discussed in details with the experts, and clearly underlined that the role of 'non-structural' measures on soft infrastructural system might be important as well as structural ones to increase resilience. Particularly, acting on several 'cultural' issues related to both individual (e.g. people awareness) and organizational features (e.g. cooperation, training level, knowledge) may have a benefit comparable with the one associated to the implementation of structural measures.

4.3. System Dynamics Modeling

System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems, which are characterized by interdependence, mutual interaction, information feedback, and circular causality (Richardson 1999).

Starting from the seminal work by Forrester on Industrial Dynamics (1961), the span of applications grew from corporate and industrial problems to include the management of research and development, urban stagnation and decay, commodity cycles, and the dynamics of growth in a finite world. SD is now applied in economics, public policy, environmental studies, engineering, defense, theory-building in social science, and other areas, as well as its home field, management.

- The system dynamics approach involves:
- Defining problems dynamically, in terms of graphs over time.

- Focusing on the characteristics of a system that themselves generate or exacerbate the perceived problem.
- Thinking of all concepts as continuous quantities interconnected in loops of information feedback and circular causality.
- Identifying independent stocks or accumulations (levels) in the system and their inflows and outflows (rates).
- Formulating a model capable of reproducing the dynamic problem of concern.
- Deriving understandings and applicable policy insights, and implementing changes.

SDM consists of qualitative/conceptual and quantitative/numerical modelling methods. Qualitative modelling, e.g. based on causal loop diagrams, improves our conceptual system understanding. Quantitative modelling, e.g. stock-and-flow models, allows to investigate and visualize the effects of different strategies through simulation.

Causal loop diagrams and then, stock and flow diagrams, model relationships among variables which have the potential to change over time. Such models distinguish between different types of variables: there are stocks (or level or accumulation) and flows (or rate). A stock is a measurable accumulation of physical or non-physical resources, whereas a flow is the movement of something from one stock to another. Generally, stocks are graphically expressed as boxes, whereas flows are represented by arrows (Figure 32). It is interesting to consider that almost every business process, and its related components, can be expressed in terms of stocks and flows.

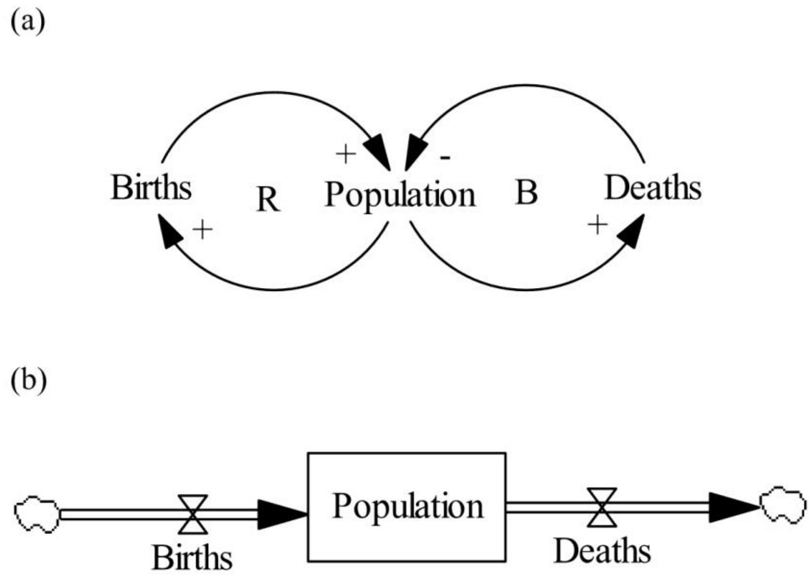


Fig. 26. Graphical representation of stock and flow notation, with the classical example of population change.

One of the key elements in SD is the presence of loops, either reinforcing or balancing. A **reinforcing loop** is one in which an action produces a result which influences more of the same action thus resulting in growth or decline. A **balancing loop** attempts to move some current state to a desired state though some action. A balancing loop is representative of any situation where there is a goal or an objective and action is taken to achieve that goal or objective.

SDM is a particularly effective modeling solution if the system is complex and an analytical solution could be excessively time consuming or simply impossible. It shows significant capabilities for modeling decision-making processes and human behaviors, thus being particularly useful for analyzing organizational evolution. Such approach may reveal really useful in describing the way policies, delays, and structures are related, and how they influence the stability of the system. The strength of SDM also lies in its ability to account for nonlinearity in dynamics, feedbacks, and time delays.

The use of a SD model supported us in identifying and analyzing the main elements fostering or hampering resilience. The model has been used to evaluate the impact of actions and strategies for resilience improvement on the dynamic evolution of the system. Finally, it has been used to identify critical feedbacks, and to evaluate their influence on the implementation of policies aiming to enhance LS resilience, assessing their evolution with time.

An SDM project typically consists of the following phases:

- **problem definition**
- **system conceptualization**: Define the purpose of the model; define the model boundary and identify key variables; describe the behavior or draw the reference modes of the key variables; diagram the basic mechanisms and the feedback loops of the system
- **model formulation**: Convert feedback diagrams to level and rate equations; Estimate and select parameter values.
- **model evaluation/testing**: Simulate the model and test the dynamic hypothesis; test the model's assumptions; test model behavior and sensitivity to perturbations
- **policy analysis and implementation**: test the model's response to different policies; Translate study insights to an accessible form.

The development of SD models is helpful for an improved system understanding, and the development of a tool to analyze and evaluate strategies and policies, and the testing of theories.

Suggestions for further reading:

Forrester, J.W. 1961. Industrial Dynamics. Cambridge, MA: The MIT Press. Reprinted by Pegasus Communications, Waltham, MA.

Sterman, J.D. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston: Irwin McGraw-Hill.

Vennix, J. A. M. 1996. Group Model Building: Facilitating Team Learning Using System Dynamics. Chichester: Wiley.

4.4. Graph Theory

In mathematics, graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects. A graph in this context is made up of vertices, nodes, or points which are connected by edges, arcs, or lines. A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge, or its edges may be directed from one vertex to another. A graph structure can be extended by assigning a weight to each edge of the graph. Graphs with weights, or weighted graphs, are used to represent structures in which pairwise connections have some numerical values. Formally, a graph is a pair of sets (V, E), where V is the set of vertices and E is the set of edges, formed by pairs of vertices.

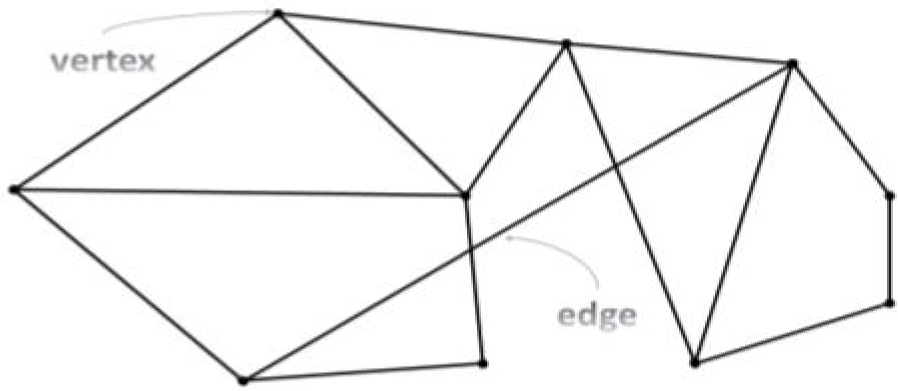


Figure 27.

Graphs can be used to model many types of relations and processes in physical, biological, social and information systems. Many practical problems can be represented by graphs. Emphasizing their application to real-world systems, the term network is sometimes defined to mean a graph in which attributes are associated with the nodes and/or edges. Graphs are used to represent networks of communication, problems in social media, sociology, biology, and many other fields. Graph theory is also used to study molecules in chemistry and physics, in computational neuroscience , in engineering studies (e.g. to represent the micro-scale channels of porous media).

Graph Network Theory has been widely used for the analysis of engineering systems, such as infrastructures, particularly in the field of transportation or water supply (e.g. Yazdani et al. 2011, Torres et al. 2016).

The topology of critical infrastructures, such as water distribution systems, can be easily described through the definition of a network of nodes connected by links. The structure of the network itself reflects the characteristics of the underlying network of users of the service, both in terms of spatial pattern and in terms of service requirements and expected performances (e.g. the nodes reflect the water demand). The topology and the functionality are thus two strictly intertwined aspects of the operation of the whole system. This underlying pattern of users, and their specific needs, evolves with time during the whole emergency, and thus the network should be flexible enough to provide a sufficient level of service, although somehow limited, even in case of dramatic changes in some conditions (e.g. extensive damages in the network).

Such a network is typically governed by complex structures and dynamical processes, due to the large number of interconnected and interacting components. A quite simple way to model such networks is to represent the structure of the system through a mathematical graph, collecting nodes to represent specific elements and links to represent the pipes between nodes.

The study of complex networks by using graph theory helps with the classification of different networks and with the analysis of the influence of their shape and connectedness on the vulnerability, robustness and tolerance. Structural measurements may quantify the connectivity patterns among the network components. These metrics become trivial in WDNs which exhibit low redundancy and sparseness at transmission or subsystem level. The structural network measurements can be classified in several ways, but mainly in statistical and spectral forms. All the topological metrics can be used to assess the reliability of complex networks, describing the influence of the underlying structure and connectivity constrains on network behavior. The selection of a set of indicators/metrics allows identifying the key elements to support proper network operation, to prioritize actions to deal with emergency and to check whether a sub-network of users (e.g. the “critical” ones, such as the system of hospitals, shelter camps, …) can be supplied by the hard infrastructural system in variable operating scenarios.

Following the available literature, the key measures to be considered in infrastructural modeling, are summarized in the following:

- Link density q (Network density) is the most basic indicator of the linkedness or sparseness of the structure of a network.
- Average node degree k is a basic measure of node connectivity. It reflects the overall topological similarity of the network to perfect grids or lattice-like structures.
- Network diameter d: captures the maximum eccentricity of nodes in the network.
- Average path-length lT: estimates the average number of links that need to be traversed in order to reach from one point to another, representing network reachability and efficiency.
- Clustering coefficient Cc, is used to measure the redundancy by quantifying the density of triangular loops and the degree to which junctions in a graph tend to be linked.
- Meshed-ness coefficient Rm provides an estimation of topological redundancy by finding the number of independent loops as a percentage of the maximum possible loops.
- Central-point dominance CB measures the concentration of the network topology around a central location. It quantifies network vulnerability against failures.
- Density of articulation points Dap estimates the percentage of the nodes/junctions whose failure may potentially disrupt water delivery by isolating a part of the network.
- Density of bridges Dbr estimates the percentage of the links/pipes whose failure may potentially disrupt water delivery by isolating a part of the.
- Spectral gap Δλ is computed as the difference between the first and second eigenvalues of the adjacency matrix. Small spectral gap would probably indicate the presence of articulation points or bridges.
- Algebraic connectivity λ2: higher values suggest better network's structural robustness and fault tolerance.
- Critical ratio of defragmentation fc provides a theoretical value for the critical fraction of the nodes which need to be removed for a network to lose its large scale connectivity.

The results of the implementation of Graph Theory in L'Aquila CS, with specific reference to the drinking water supply system, are described in: Hard/soft infrastructural systems in L'Aquila: water supply

4.5. L'Aquila earthquake (2009)

L'Aquila city had experienced multiple major earthquakes in the past. A disastrous earthquake occurred in 1461, with an estimated magnitude of 6.5 and approximately 150 victims. Another relevant earthquake occurred in 1703 (it was a part of a significant earthquake sequence), killing approximately 6000 people in the city and its surroundings. Referring to the recent history, an event in January 1915 killed 32500 people, including almost the whole population of Avezzano, 50 km south of L'Aquila (Alexander 2014).

The case study refers to the disastrous Magnitude 6.3 earthquake which struck L'Aquila city and its province at 3.32 a.m. on 6 April 2009. As a consequence of the event, 308 people died and 1500 were injured (see Fig. Main features of the L'Aquila earthquake in 2009). Although the physical event was relatively moderate (moment magnitude 6.3), its impacts were particularly high mainly due to the very high vulnerability of lives, livelihoods, building stock and institutions in the Apennine Mountains. The physical vulnerability level of its masonry buildings (poorly maintained and not strengthened), mainly located in the historical city center, led to enormous damages. Reinforced concrete structures were affected as well. Surprisingly, more casualties were due to the collapse of reinforced concrete buildings than of the masonry ones, due to their higher vulnerability (Contreras et al. 2014).

The role of hard infrastructure (e.g. water supply infrastructures) at urban level supported efforts of local communities during the emergency phase, proving to be a key asset to cope with the disaster.

More in general, the earthquake led also to a series of scandals and controversies that lasted for years and are still ongoing, revealing the vulnerability of the 'institutional' framework. In the aftermath of the disaster, one of the most controversial developments was indeed related to the behavior of institutions and scientists, and their information sharing with the community (Alexander 2014).

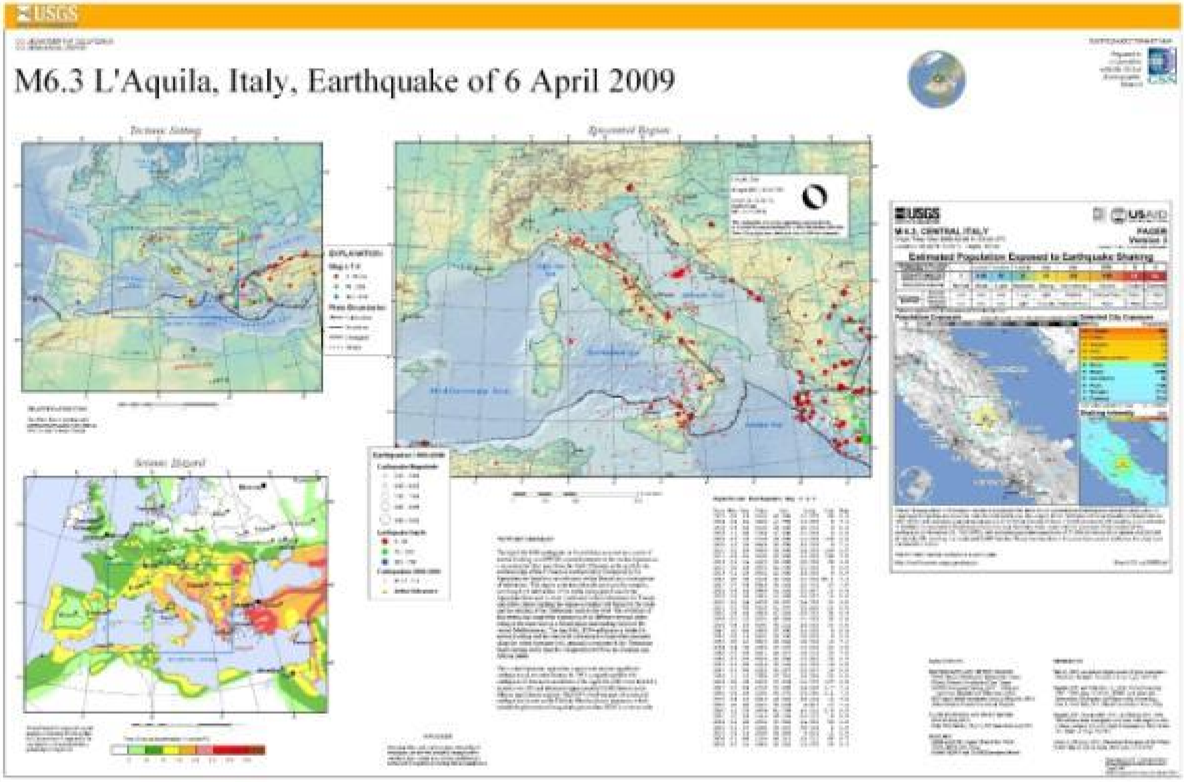


Figure 28. Further details on the main features of the earthquake are available at https://gemecd.org/event/4

https://www.google.com/maps/d/u/0/viewer?hl=en&oe=UTF8&msa=0&z=13&source=embed&ie=UTF8&mid=1EJlHUhyUkh6mH4rxiLi56enVWtM&ll=42.348030261916854%2C13.398127439697305

Fig. 29. a,b) Damage in the city center. c) Damage to the water supply systems

One of the most controversial issues was the trial and prosecution of seven functionaries of the Italian National Department of Civil Protection (DPC), mainly due to the kind of information ("incomplete, imprecise and contradictory on the nature, causes, dangers and future development of seismic activity in the area in question" - Il Centro 2012) shared with the community. Some citizens had acted on that information and as a consequence had lost their lives.

This had a strongly negative impact on the trust level of local community toward the emergency managers, with consequences on the acceptability of the following emergency management and recovery measures. After the earthquake, the local community was forced to abandon the city center. New towns were developed in safer places, disaggregating the original socio-cultural networks. New networks emerged after the disasters, showing different cultural aspects.

Further details on L'Aquila trial can be found at: https://eagris2014.com/

Suggestions for further reading:

Alexander, D. E. (2014). *Communicating earthquake risk to the public: The trial of the L'Aquila Seven*. Natural Hazards, 72, 1159–1173.

Contreras D., Blaschke T., Kienberger S., Zeil P. (2014). *Myths and realities about the recovery of L'Aquila after the earthquake*, International Journal of Disaster Risk Reduction, 8:125–142.

Forino G. (2015) *Disaster recovery: narrating the resilience process in the reconstruction of L'Aquila (Italy)*, Geografisk Tidsskrift-Danish Journal of Geography, 115:1, 1-13, DOI: 10.1080/00167223.2014.973056

Kongar I., Esposito S., Giovinazzi S. (2015). *Post-earthquake assessment and management for infrastructure systems: learning from the Canterbury (New Zealand) and L'Aquila (Italy) earthquakes*, Bull Earthquake Eng DOI 10.1007/s10518-015-9761-y

Rossetto T., Peiris N., Alarcon J.E., So E., Sargeant S., Free M., Sword-Daniels V., Del Re D., Libberton C., Verrucci E., Sammonds P., Walker J.F. (2011) *Field observations from the Aquila, Italy earthquake of April 6, 2009*, Bulletin of Earthquake Engineering 9, 11–37, doi: 10.1007/s10518-010-9221-7

4.6. Hard/soft infrastructural systems in L'Aquila: water supply

After a disaster strikes, a prompt return to the status quo is needed. Nevertheless, simply rebuilding communities to pre-disaster standards would recreate the vulnerabilities that existed earlier and expose them to future disasters. Reconstruction is generally an opportunity to build back better. It is the restoration and improvement of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.

This "build back better" approach advocates for the restoration of communities and assets in a manner that makes them less vulnerable to disasters and strengthens their resilience. Disaster risk reduction measures should be included into post-disaster recovery and rehabilitation processes. Resilient recovery and reconstruction are widely recognized as imperative for sustainable development.

Recovery thus represents much more than a return to the pre-event state. Recovery actions can also promote both physical and economic resilience, and prompt or facilitate investment in infrastructure upgrades and urban revitalization. Resilient recovery and reconstruction can be realized through a variety of strategies: enhancing preparedness; relocating critical facilities to safer areas; integrating disaster risk reduction measures into infrastructure improvements; strengthening governance structures, including the development of institutional mandates for disaster risk management; using the reconstruction process to address urban planning challenges; and establishing predictable contingent financing mechanisms, including disaster risk financing.

The issue of 'Building back better' emerges after major disaster, like the L'Aquila earthquake in 2009. As a consequence of the earthquake and of its impacts on the built environment, L'Aquila is still undergoing a complex process of reconstruction. Particularly, on the one hand the extent of damages in the whole urban area limited the functionality of infrastructures and the accessibility for community (see e.g. Fig. 1); on the other hand, the changes in the population localization due to both temporary sheltering strategies and to the evolution of new permanent areas, forced a radical change of the performances required to the infrastructures. Particularly for the purposes of EDUCEN project, the water supply system represented the key infrastructural system to analyze.

The experience and the knowledge developed during the earthquake and in the aftermath of the disaster, provided crucial information to support the reconstruction phase. Learning from past errors and from the key criticalities encountered was a fundamental step for an innovative, sustainable, effective, safe, 'resilient' design. Just to provide an example, the high uncertainty of the available information and the poor accessibility of some infrastructures often limited the possibility to operate promptly during the emergency; similarly, the need to adapt the whole network to both changes in the urban pattern and specific local needs (e.g. the need to provide some buildings with water using a network with a huge number of breaks) during the reconstruction phase, caused significant stress levels for the system. The urban critical infrastructural systems were thus deeply rethought, and redesigned according to the new needs of the city, and to the experience.

Figure 30. One of the main damages in 2009: Gran Sasso Aqueduct

The design of the 'SMART TUNNEL' reflects a basic principle: electricity, gas, water and communication systems are key services supporting daily activities and the well-being of a community (http://www.sottoserviziaq.it/it/home.html). The basic idea behind the smart tunnel is simply to collect and integrate all the critical services in an 'invisible' shell, i.e. an underground concrete gallery, in order to protect them from external threats and make them easily accessible and repairable, both in case of disasters and in ordinary operation.

Providing safe drinking water to a community in case of disasters is one of the main commitments of emergency managers and local authorities. Particularly, the urban water distribution network of L'Aquila city, is being currently rebuilt according to innovative criteria, such as the distrectualization. The basic idea is to split the whole network into a number of subsystems characterized by spatial and functionality homogeneity in order to facilitate maintenance and management procedures. Distrectualization allows: a) controlling leakages and water losses; b) isolating single subsections of the whole network; c) implementing more effective measurements of hydraulic parameters. The distrectualization supports flexibility and adaptation capability to the evolution of the urban pattern, and thus is strongly connected to the evolution of the whole city.

The L'Aquila case study is unique and relevant also because it allows the comparative analysis of two different networks operating within the same urban pattern. The urban water distribution system was completely redesigned after the disaster and is currently being built. The same methodology was implemented to assess both infrastructural configurations, and selected metrics used to compare systems. In the following Fig. 2 the two systems are depicted ('OLD' and 'NEW' networks), along with their representation according to Graph Theory formalization (Fig. 3).

See the section (Methodological approaches: SDM e Graph Theory – Graph theory) for further details.

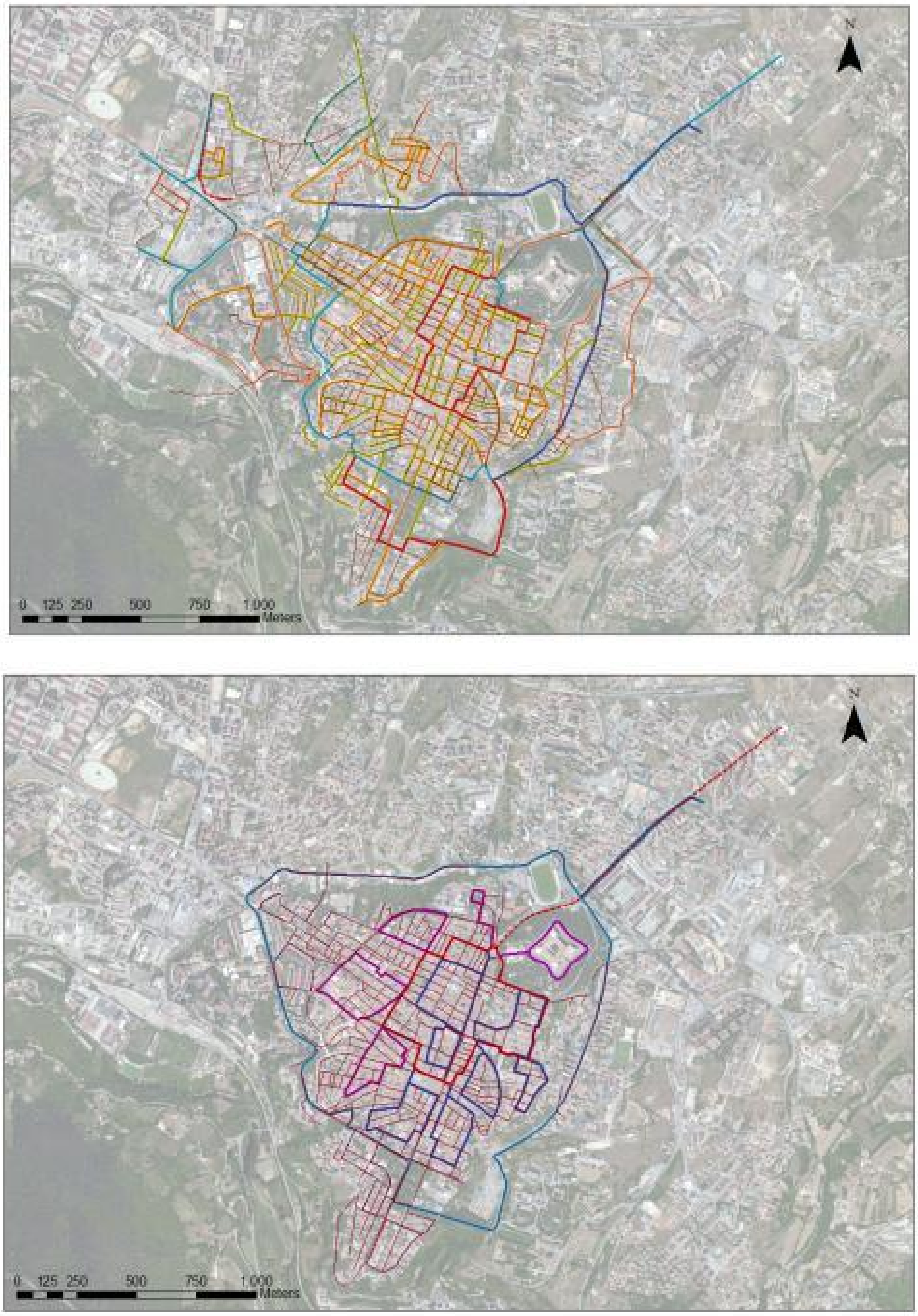


Fig.30 and 31. Representation of the urban water distribution network: OLD and NEW networks.

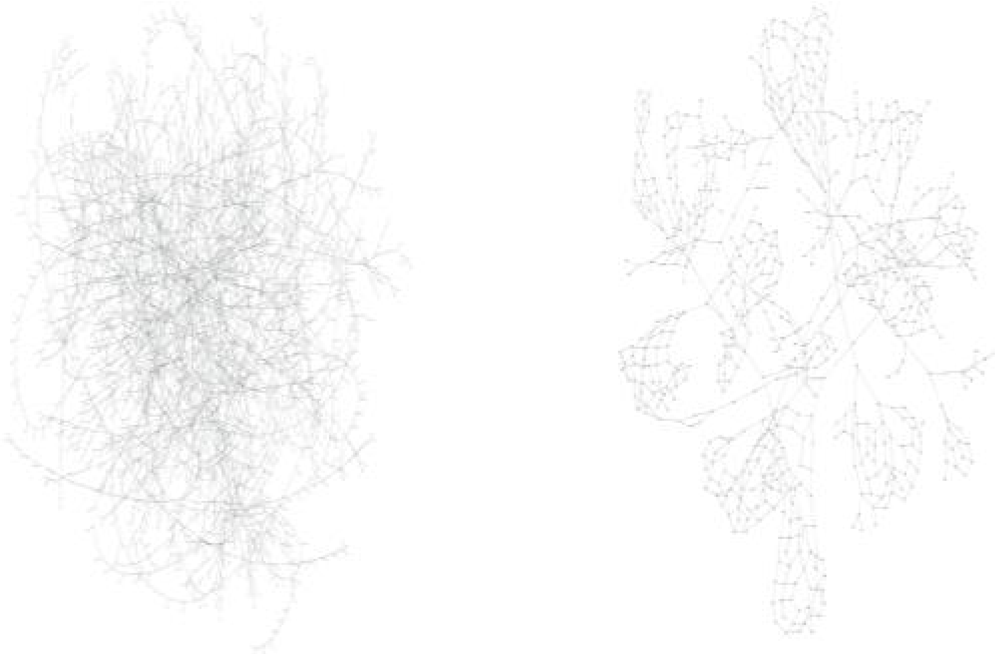


Fig. 32. Representation of the urban water distribution network according to graph theory: OLD and NEW networks.

The selected measures, according to graph theory computed in an undirected and unweighted version, are summarized in the following Table 1. Full details on the selected measures are available in the section ‘Methodological approaches: SDM & Graph Theory – Graph theory’. It is worth mentioning that the ‘NEW’ network is made of two independent subnetworks (‘CS’ – Centro Storico and ‘ZM’ – Zona Media), and thus the metrics are computed independently. The results generally contribute to suggest a better resilience of the new network, particularly in terms of flexibility, robustness and redundancy. Nevertheless, a comprehensive analysis should also be coupled with hydraulic models and with suitable performance indices.

Table 2. Overview of the results of Graph theory analysis

NETWORK	q	k	d	l_T	C_c	R_m	C_B	D_{ap}	D_{br}	λ_2	$\Delta\lambda$	f_c
NEW – CS	0.006	3.00	26	13.43	0.041	0.252	0.412	0.1	0.11	0.0027	0.3869	0.500
NEW – ZM	0.013	2.63	23	10.74	0.02	0.162	0.584	0.285	0.51	0.004	0.3798	0.387
OLD	0.0006	2.15	97	32.76	0.004	037	0.455	0.391		0.00041	1.1247	0.127

References

Alexander D. E. (2014). Communicating earthquake risk to the public: The trial of the L’Aquila Seven. Natural Hazards, 72, 1159–1173.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O’Rourke, T. D., Reinhorn, A. M., et al. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra, 19(4), 733–752.

Cimellaro G.P. (2016). Urban Resilience for Emergency Response and Recovery. Fundamental Concepts and Applications. Springer International Publishing Switzerland. ISSN 1573-6059

Contreras D., Blaschke T., Kienberger S., Zeil P. (2014). Myths and realities about the recovery of L'Aquila after the earthquake. International Journal of Disaster Risk Reduction, 8, 125-142.

Jacob M. Torres, Leonardo Duenas-Osorio, Qilin Li, and Alireza Yazdani. “Exploring Topological Effects on Water Distribution System Performance Using Graph Theory and Statistical Models,” January 1, 2017. doi:10.1061/(ASCE)WR.1943-5452.0000709.

Pagano A., Pluchinotta I., Giordano R., Vurro M. (2017). Drinking water supply in resilient cities: Notes from L’Aquila earthquake case study. Sustainable Cities and Society 28: 435–449

Richardson G.P, System Dynamics. In Encyclopedia of Operations Research and Management Science, Saul Gass and Carl Harris, eds., Kluwer Academic Publishers, 1999/2011

Tierney, K., & Bruneau, M. (2007). Conceptualizing and measuring resilience: A key to disaster loss Reduction.TR NEWS 250. pp. 14–18

Yazdani, A., R. Appiah Otoo, and P. Jeffrey. “Resilience Enhancing Expansion Strategies for Water Distribution Systems: A Network Theory Approach.” Environmental Modelling & Software 26, no. 12 (December 2011): 1574–82. doi:10.1016/j.envsoft.2011.07.016.

5. Cities at the crucible of multiple historic and present dynamics

In the past cities used to take decades to build new areas, to transform a city centre, to introduce new infrastructures. In contemporary cities many forces drive change, including, recently, digital and communication technologies. Mobility has grown dramatically the possibility to expand cities much beyond their “natural” borders. Today cities may face much more rapid changes in terms of the pace of construction, creation of new networks and shift from one developmental model, such as industrial, to another, more service oriented.

Nevertheless, city vulnerability is not only the result of recent changes, even when they occur very rapidly; but also of past decisions, of trends that started long ago. Vulnerabilities in a city have accumulated over the course of time. If this is true for the past, it will be even more so in the future. Future vulnerabilities will be the result of today’s decisions mixed with changes in the natural, social, political and economic environments.

Different temporal dynamics unfold in cities: some are the result of long duration processes that accumulate over decades and centuries. They are the result of micro level decisions or lack of decisions, of actions that are prescribed in cities regulations or embedded in the non material culture of inhabitants.

Other dynamics reflect abrupt changes, due to the interruption of ordinary life, after a war, a disaster, a dramatic change such as the one that occurred with the industrial revolution, when old schemes were wiped off, destroying centennial walls to allocate more space for factories and urbanized peasants. Such deliberate changes include modifications in the city layout, patterns, with the introduction of new infrastructures, large palaces, new economic attractive centres.

Whilst planners have become familiar with the different dynamics in cities’ landscape of the past they are far less aware of the potential of a catastrophic event to change dramatically the conditions and the image of a city, in a way that may make it not recognizable, with the loss of those key referential places and buildings.

Whilst the recognition of past dynamics is important to reconstruct the decisions and events that have led to the current situation in terms of vulnerability and resilience, planners and city managers encounter difficulties in imagining future scenarios. Planners are not trained to foresee how the *environment they are used to and in which they have prepared to be operational in case of disaster may change suddenly and abruptly. They are not used to recognize in an apparently stable landscape and in the natural features that are part of it the potential for abrupt changes in the future. How cities change and evolve during a crisis has still to be fully understood and investigated; however it is evident that developing an understanding of this type is crucial both in the prevention stage, to avoid the most hazardous locations and to increase unduly exposure and vulnerability. For preparing to an emergency it is important to make civil protection and first interveners aware that references that they have placed on their maps that are part of the emergency plan may have changed or have been destroyed.*

Vulnerability patterns produced by rapid urbanization: the case of Istanbul

The structural development history of Istanbul is given here to better understand the effects of rapid urbanization on inherited vulnerabilities of cities. Changing national economic policies has had a distinctive effect on Istanbul's economic, spatial and social structures. In the last period, the increase in the vulnerability is defined due to large industrial areas in hazard prone areas, increased density of people and buildings and low quality dwellings. After the 80s, the percentage of Istanbul's population in Turkey's total population increased immensely. The number of buildings grew accordingly. Istanbul was a second level earthquake zone until 1996, then it became a first level earthquake zone. All the buildings constructed before 1997 were built according to the previous building code. As a result of these trends, the city has become more vulnerable to hazards.

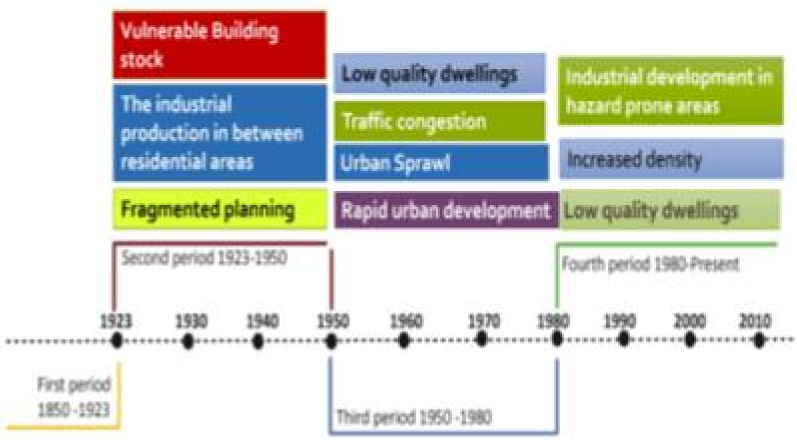


Figure 34.

5.1. Past lessons learnt embedded in today's cities landscape

Cities, their identity and building techniques are partly influenced by their environment and the threat of hazards. People adapt the built environment to adjust to living with risks in places where they are frequently exposed to hazards. These patterns become embedded in cultures over time (Moore 1964 in WDR 2014: 124). This accommodation is reflected in the design of buildings and the materials and construction techniques. Important to note however is that these architectures are the result of a whole range of socio-cultural factors, not just the threat of hazards.

This heritage serves a role in preserving local identity and personality, but also local knowledge; preserving heritage has educational purposes in awareness raising, as the layout of a city (plazas, avenues), the construction of buildings (Dordrecht's 'floating cellars') and infrastructure (multiple escape routes) may reveal a logic that is often more in tune with urban exposure to natural hazards than today's urban development.

In areas of the world where earthquakes present a frequent threat to people's lives and assets, similar anti-seismic construction methods have evolved. Bankoff identified at least three zones of identifiable earthquake resistant architecture: the Alpine-Himalayan belt, the Eastern Mediterreanean, Southern Europe and the Himalayan arc. People living in these regions are culturally distinct but share a similar risk from earthquakes and their responses to the threat are similar.

Such seismic construction subcultures often use local materials, skills and resources. Traditional buildings are usually of configurations and have a small number of storeys. A look at such cultures may help in vulnerability reduction and disaster mitigation. Examples that may be relevant for the EDUCEN project include, the göz dolmas and muskali dolmas technique in Turkey, the casa baraccata technique in Italy, the pontelarisma technique in Greece and the Pombalina structures in Portugal. The latter, Pombalina structures, originate from after the Lisbon Earthquake in 1755. Notable features of such structures include reinforcement by the gaiola, an internal wooden cage.

Figure 35. from left to right: The göz dolmas and muskali dolmas technique in Turkey, the gaiola in Lisbon, and the pontelarisma technique in Lefkada (Greece).

5.2.What is selected from the past to become preserved heritage

As Kevin Lynch, a XIX worldwide known urban planner author to the famous "The image of the city", used to say, cities are not only physical places, but embed symbolic and cultural meanings that are inscribed in the way they have been designed and in the way places and spaces have been designed and built. The richer in terms of cultural meaning a city is, the larger potential for people living and visiting it to develop a geography of the place, made of points of reference and milestones representing guiding elements within the built environment.

The historic built environment often provides a city with character, quality and spirit, containing 'deep-seated associations' of the local population. Heritage is also increasingly recognized as both engine and catalyst of socio-economic development.

It has been noted that an increasing number of European cities selected tourism as a strategic sector for local development. By investing in cultural attractions and infrastructure, cities seek to secure a niche position on the international tourism map. Thus city branding. Tourism also represents an important source of financial resources for the preservation and restoration of the heritage.

Managing and protecting the physical city inevitably involves dealing with cultural heritage in both its material and nonmaterial form.

UNESCO defines cultural heritage as ''the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations'' (www.unesco.org).

What has been and will be selected of the past depends on the culture of the city of today, of its inhabitants, of their relationship with memory. The city is a multilayered superimposition of infrastructures, buildings, spaces, and uses of the latter that have undergone a process of selection that can be more or less conscious, more or less deliberate. Yet the current pattern of vulnerabilities depends on such superimposition and it is virtually impossible to intervene to mitigate and reduce vulnerabilities in a way that will be accepted socially without considering such historic unfolding.

Disasters shutter the built environment and in it immovable tangible cultural heritage. Individual buildings, groups of buildings, whole neighbourhoods and settlements of historic or vernacular (traditional) character, under preservation status or not, are damaged at various degrees or collapse. It then becomes a major issue to decide what to keep from what existed before the disaster and at what price in terms of resources, money and time.

Decisions regarding what should be preserved, reconstructed, retrofitted, must be made also in the light of the destruction that has occurred and the vulnerabilities that have been made manifest.

Difficult trade-offs present themselves in a time when pressures to the response mechanism are severe and often overwhelming. Should all buildings deemed as dangerous be demolished as soon as possible and what procedures should be followed? Should owners of dangerous historic buildings be allowed to proceed with engineering interventions for removing dangerous elements or even for the demolition of the dangerous building? In case of listed historic buildings that are deemed damaged beyond repair, should protection of heritage be considered prevail over protection of lives? Apart from historic buildings and monuments, what should be done with damaged (in some cases damaged beyond repair) traditional buildings and neighbourhoods that are not listed as monuments to be preserved? How long should recovery be delayed in order to protect tangible cultural heritage either already listed or not? Who and how should deal with such trade-offs and make decisions?

Especially in some types of disasters such as earthquake disasters, damaged buildings can be dangerous for people, especially in aftershocks. Even more, people feel threaten by buildings; old buildings are often seen as dangerous without exception. In these conditions, preservation of existing buildings and neighbourhoods appears to be a luxury at the best and an unnecessary present threat and future risk. In the mist of emergencies and urgent needs, it takes a long term outlook to see the significance of heritage for future quality of life and sustainable development.

Such decisions are dependent very strongly on the culture of the country, of its inhabitants, on their tendency to keep strong links with the past and its tradition that translates into quest for returning to the pre-event environment or instead favour innovation and substitution of the destroyed stock.

In societies and areas with disaster experience, the knowledge that the disaster is not the end but a phase, assists in maintaining a long term view. In such cases, the city and the society realise more that there will have a future and the foundations of this future lay in post-disaster decisions. If there is no local disaster experience, consultancy and know-how by trusted knowledgeable external agencies can be very helpful. What counts more though is the existing attitude of the devastated society towards culture and cultural heritage, history and continuity.

6. How cities are managed matters

6.1. city management and disasters

There are various styles and approaches to city management: participatory, centralized, delegating to local neighborhoods. City management is influenced by laws, policies, rules and norms that are defined at different scales (from municipal to metropolitan to global).

As the trend towards urbanization has been growing fast in the last decade, international organisations such as the World Bank, the OECD, United Nations have devoted large attention to cities, to how they have been changing and evolving and to defining guidelines to support the difficult task of planning and managing cities of the present age.

City mangers are confronted with an ever rising pile of demands raised by citizens who are asking for better services, faster communications, greener spaces, and by new obligations set by policies including environmental sustainability, climate change adaptation and disaster risk reduction.

Creating a bridge between the latter three is a necessity before being an opportunity favouring knowledge exchange. The same managers are in fact pressured to deal and implement all those policies, for which no additional financial or human resources are expected to be invested by governments shrinking their role and interventional capacity. Clearly though some cities are better equipped than others in facing contemporary challenges that are not only associated to the natural environment but also to social, political and economic issues. This has to be brought in mind as disaster risk prevention must be accommodated within a much larger set of objectives, that compete for limited resources to be accomplished.

There are however some issues that link the type of administrative culture of a city with the challenges it faces in dealing with DRR. One important aspect relates to the existence or absence of vertical and horizontal integration between offices and officers in charge of different aspects of city's management.

Fragmentation and separation of competences is often the prevailing style of government, that undermines the benefit of investments and initiatives as the latter risk to remain piecemeal and ineffective if not properly coordinated. In many analyses of initiatives taken for climate change adaptation even in countries with very good tradition in public administration, separation among offices and personnel, lack of communication among the latter has produced partial and unsatisfactory results. The same can be said for risk prevention, scattered among a large number of ministries, agencies, and even at the local scale uncoordinated among the bureaus that could instead largely benefit from collaboration and integration of practices and procedures.

The field of disasters is even more complex, as it is not restricted to the traditional arena of city managers and planners, but must necessarily include those actors that intervene during an emergency, such as the army, fire brigades, police, medical doctors that do not have generally a strong role in cities' governance. They are asked to play a role only limitedly to disaster impact and recovery.

In order to better complement and integrate policies, however, it would be recommended to involve such actors more broadly, taking into account their perspective also when deciding about critical infrastructures location, about development zones, about preservation projects of historic centres.

A new type of collaboration should be looked for also between actors in the public and the private sectors as well as with civic associations and groups. In the field of disaster risk prevention there is an increasing recognition of the mutual interest of public and private organisations to work together, exchange data, information and define common strategies to avoid cities' functional disruption during and after an extreme event's impact.

In this respect insurers are already collaborating in some countries such as Norway and France to provide their data deprived from sensitive elements in order to inform about past and future potential risks at the city and even at the asset level.

Critical infrastructures providers are increasingly burdened by responsibilities they are charged of by public authority and citizens' association. Such challenges may induce them toward a more open sharing of their data and their understanding of how a disaster may impact on key lifelines and services and define jointly with emergency managers and city planners improved responses and better risk mitigation measures.

6.2. Strategies and intervention across the "disaster cycle"

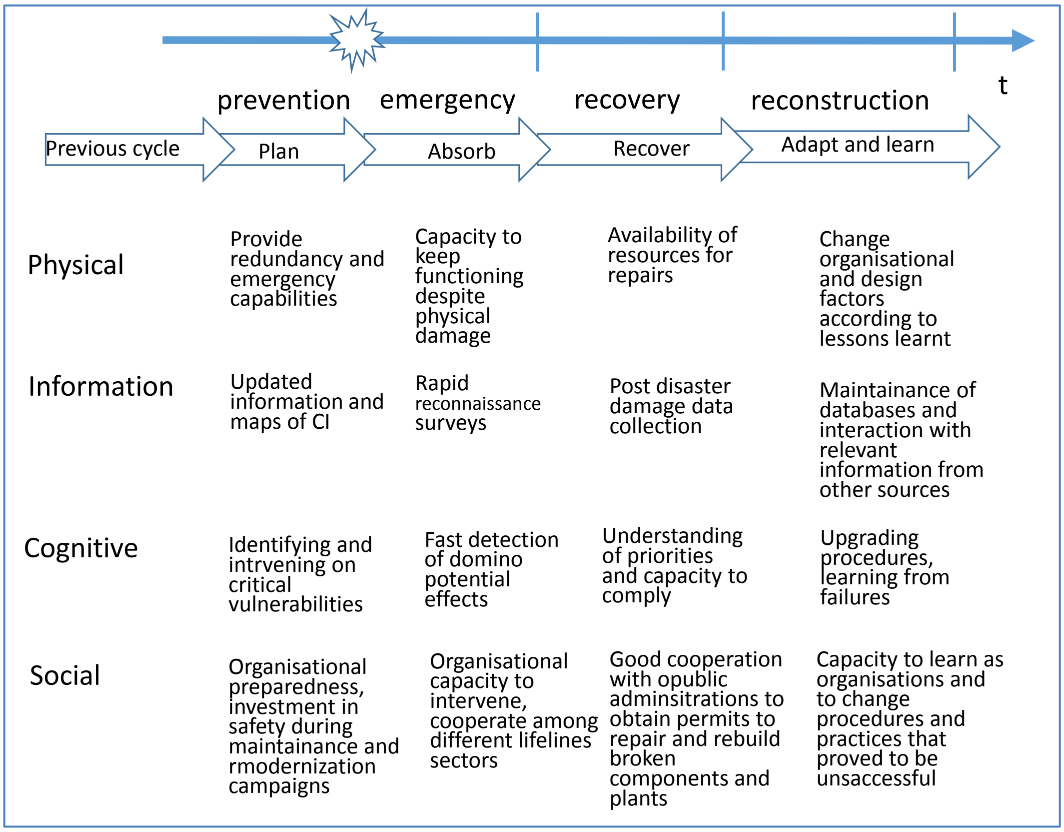
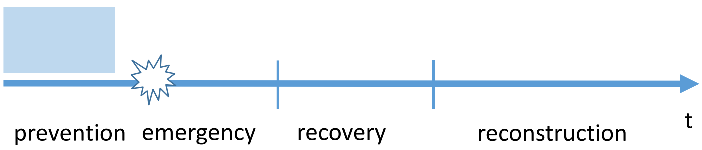


Figure 36.: aspects that need to be considered to make critical infrastructures more resilient to disasters (after Linkov et al., 2013)

Highlights the types of capacities that need to be put in place in particular to make critical infrastructures such as lifelines resilient to disasters. In the 'x' axe the different phases are representing in which different behaviours are required: before the event it is necessary to plan adequately, during the emergency it is necessary to absorb the stress and respond, during recovery fast return to normalcy is required even putting in place temporary repair measures. In the reconstruction it is necessary to learn from the event in order to revise procedures and design that proved to be unsuccessful or unsatisfactory.

The capacities that are necessary are distinguished between: physical, necessary to make infrastructures more redundant, better equipped with safe-fail mechanisms; informational, related to the best use of data and information to support decision making at each phase; cognitive, related to the understanding and the early detection of critical domino effects potential; and social, mainly related to the organizational capacity to coordinate and intervene in case of need. As it can be easily seen the capacities are both "hard" and "soft".

Figure 37.In the prevention phase



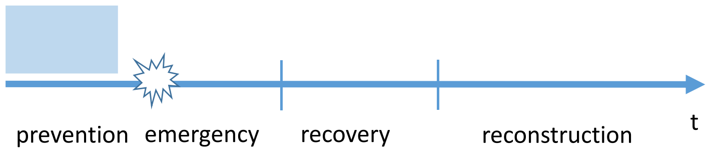
At the global scale, the Resilient Cities Campaign carried out by UNISDR has been certainly the most eminent example of large scale initiatives aiming directly at the city level; similar stance has been taken by the Rockefeller Foundation with the 100 Resilient City project. At present the Sendai Framework for Disaster Risk Reduction is addressing all spatial levels, specifying for each what are the main targets to be achieved in the next fifteen years, starting from March 2015 when it was approved in the World Conference held in Japan.

The main issue with all those initiatives is their very general approach that needs then to be interpreted and applied at the city level, ranging from metropolitan areas, where real intervention has to be carried out going down to the single neighborhoods or districts' level, to medium small cities. In both cases it is key to have on the one hand a strategy that combines typical demands of services and functions raised by social and economic agents with environmental and safety concerns and on the other to leverage the latter into ordinary plans and programs. This is perhaps the most difficult to achieve as until now risk mitigation measures and adaptation to climate change have been pursued separately from the other ordinary policies to manage cities.

In the prevention phase a number of decisions can be made to avoid exposure in the most hazardous zones, reduction of physical and systemic vulnerabilities to the multiple stresses that may affect the city, and finally structural measures to reduce the hazards' intensity and/or frequency. A mix of measures is generally more likely to be effective, depending on the specific characteristics of the context and the risks at stake.

Pre-disaster awareness as regards the significance of cultural heritage pays off during the pressing emergency phase and also, having in place a strategy for the preservation of cultural heritage including institutions and legislation, as well as inventories and documentation of historic buildings and their contents. Furthermore, it would be greatly advantageous to already have in place a disaster governance structure that integrates also the cultural heritage community.

Figure 38. In the emergency phase



As mentioned above, in the emergency phase, depending on the level of destruction, the environment in which city managers and civil protection forces will have to intervene may be significantly disrupted and changed, posing many challenges in order to respond to immediate needs. This is a phase where mostly search and rescue activities and temporary sheltering has to be carried out, creating a rupture in everyday life and normal functioning of cities. Cities are also places where the probability of enchained events, including na-techs, that is technological accidents triggered by a natural disaster, are more likely, given the interaction and the complexity of different systems including critical infrastructures and industrial areas.

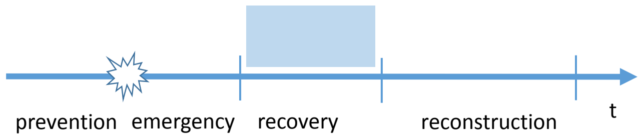
The management of emergencies will be carried more or less smoothly depending on the prior preparedness, on the existence and good quality of emergency plans and on the prior integration of the latter with urban and land use plans, for example for accommodating temporary camps and areas for the gathering of emergency means.

During the emergency phase there are some important priorities to be of concern for city and emergency managers, that can be summarized in the following: taking care of victims and guaranteeing that critical infrastructures keep function despite some level of damage. Even though immediate needs for life and health get the highest priority, people do care also about the preservation of those values and assets that represent their self-identity and in the meantime may constitute a reason for hope and "raising from ashes" again.

In this respect, for example, intervening on cultural heritage to save what has survived complete destruction may be vital for the community. Activities for saving historic and vernacular buildings, groups of buildings, neighbourhoods and settlements cannot be postponed for long, beyond the emergency phase or some elements to be preserved will be ruined or even demolished in the chaos and fear typical of post-disaster situation.

Emergency intervention measures of technical and non-technical character should be taken promptly. Technical measures include for example shoring structures to safeguard their resistance capacity in case of earthquakes, and moving to safer places movable objects such as ancient books, paintings and sculptures. L'Aquila in Italy was probably one of the cities that has experimented the larger shoring intervention ever after the earthquake in 2009. The failure to do so after the last year earthquake in Central Italy has meant dramatic failure of heritage that had been already weakened by prior shakes in the long sequence that has characterized that event. Moving valuable objects is possible if prior safe locations for their storage have been identified in emergency plans, as was the case for the Spoleto repository prepared in Umbria after the 1997 earthquake and used in the recent 2016 one. Non-technical measures refer to emergency planning concerning cultural heritage salvation, the deployment of special emergency response teams with clear roles and responsibilities for each member and equipped with safety equipment and appropriate material resources.

Figure 39. In the recovery phase

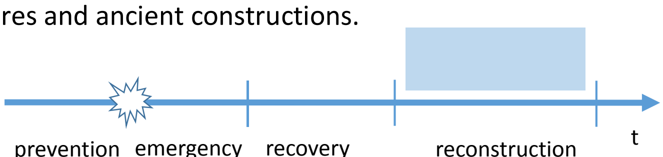


The recovery phase is perhaps the most critical for the destiny of a city after a disaster. It is the time when critical decisions are made regarding reconstruction, about strategies for the future, that may diverge from traditional paths even in a dramatic way. Also it is the time for collecting and analyzing damage data in order not only to estimate the needs in terms of finance and resources for rebuilding and restoring, but also for learning lessons and decide about intervention modalities that will reduce pre-event vulnerabilities, making cities more resilient.

Post-disaster damage assessment has gained much more attention recently than ever before, making it clear that d good level of understanding of what has been damaged and why is essential to support better decisions about priorities and modality of intervention. The experience carried out in the Umbria Region after the two floods in 2012 and 2013 provide an example of damage assessment that regards all sectors relevant in urban life and matches it with the description of the physical phenomena that has triggered the damage, that is attentive to the spatial and the temporal scales at which damage unfolds.

In the case of cultural heritage, specific damage assessments, documentation of the building and its condition (photos, drawings, reports etc.) need to be conducted, considering the differences between ordinary buildings and structures and ancient constructions.

Figure 40.In the reconstruction



Many point at the reconstruction as the phase offering the largest window of opportunities for improving the pre-event situation, as after a disaster some restrictions in the use of land and more stringent building codes may be accepted more easily. It is a time when also relocation of some assets and lifelines can be decided to make future cities more resilient. However such window closes fast, certainly faster than the time needed for the overall reconstruction, and ineffective decision making and implementation may not exploit the opportunities offered by the event.

Reconstruction should be certainly considered as the phase where all risk mitigation and climate change adaptation measures can be considered, as they will work for the future, as most natural disasters tend to repeat, even though there are large uncertainties regarding when, and some hazards may be worsened by climate change.

Reconstruction of cultural heritage require very strong competences of the building sector with specialized personnel and knowledge regarding ancient techniques and materials.

References

Atun, F., Kundak, S. (2013). Before And After HFA Retrospective View of Progress in Disaster Risk Reduction System in Turkey. Input Paper Prepared for the Global Assessment Report on Disaster Risk Reduction 2015. Retrieved from: http://www.preventionweb.net/english/hyogo/gar/2015/en/bgdocs/inputs/Atun%20and%20Kundak,%202014.%20Before%20and%20After%20HFA%20%20Retrospective%20View%20of%20Progress%20in%20Disaster%20Risk%20Reduction%20System%20in%20Turkey.pdf

Burton, I., Kates, R.W., White, G.F., (1993). The Environment as Hazard. New York and London: Guilford Press.

De Steffani, A. (2011). A la carte urban policies. Mega-events: from exceptionality to construction of ordinary planning practices. A look at Italy: case study of the 2006 Winter Olympic Games in Turin. Science Future of Lithuania, 3(3), 23–29. ISSN 2029-2341 print, ISSN 2029-2252 online, doi:10.3846/mla.2011.047

Geddes, P. (1915). Cities in evolution: an introduction to the town planning movement and to the study of civics. William and Norgate Publisher.

Gehl, J. (1987). Life between buildings: Using Public Space. Washington, Covelo, London: Island Press. ISBN: 9781597268271.

Gehl J. (2010). Cities for People. Washington, Covelo, London: Island Press, ISBN: 9781597265737.

Gregory, F. (2012). Chapter 11 - The European Union and the promotion of major event security within the EU area. Routledge Online Studies on the Olympic and Paralympic Games.

HABITAT III New Urban Agenda, October 2016, Quito, Ecuador. Retrieved from:

https://www2.habitat3.org/bitcache/97ced11dcecef85d41f74043195e5472836f6291?vid=588897&disposition=inline&op=view

House of Commons Committee of Public Accounts (2007). The Ninth Report of Session 2006-2007. Preparations for the Olympic and Paralympic games – risk assessment and management.

Hewitt, K. (1997). Regions of Risk: A Geographical Introduction to Disasters. Essex: Longman.

Know4DRR, “Enabling knowledge for disaster risk reduction in integration to climate change adaptation” Project, available at: http://www.know4drr.polimi.it

Linkov, I et al. (2013). Measurable resilience fo actionable policy, ACS publications.

Lynch, K. (1960). The image of the city. The Technology Press and Harvard University Press, Cambridge.

Menoni, S., Molinari, D., Parker, D., Ballio, F., Tapsell, S. (2012). Assessing multifaceted vulnerability and resilience in order to design risk mitigation strategies. Natural hazards, 64(3), 2057–2082.

Paris Agreement on Climate Change, October 2016, Paris, France. Retrieved from:

http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

Sendai Framework for Disaster Risk Reduction, March 18, 2015, Sendai, Japan. Retrieved from: http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

Sustainable development goals, September 2015 in New York, USA. Retrieved from:

https://sustainabledevelopment.un.org/sdgs

The prefecture of Milan, (2015). La prefettura al centro operative misto, 184 Giorni Viaggio dentro EXPO, a cura della Funzione Communicazione del COM, in Italian

TUIK (2011). Turkey's statistical yearbook. Turkish Statistical Institute

Vale, L.J., Campanella, T.J. (2015). The Resilient City. How Modern Cities Recover from Disaster. New York: Oxford University Press.

Wisner, B., Blaikie, P., Cannon, T., Davis, I. (1994). At Risk: Natural Hazards, people's vulnerability and disasters. London: Routledge.

Wamsler, C., Brink, E., Rivera, C. (2013). Planning for Climate Change in Urban Areas: From Theory to Practice. Journal of Cleaner Production, 50 (July 1), 68–81.

World Disaster Report: Focus on culture and risk. (2014). IFRC. Retrieved from: http://www.ifrc.org/Global/Documents/Secretariat/201410/WDR%202014.pdf

SECTION 3: INCLUSION IN DISASTER RISK REDUCTION: ENGAGING WITH DISASTER AFFECTED GROUPS

1. What is community?

Author: Robert Coates

Community-based approaches are now a fundamental pillar of disaster risk reduction and response. This was made explicit in the Hyogo Framework (2005-15), which directed global policies and initiatives with the by-line: Building the Resilience of Nations and Communities to Disasters. Vulnerability and resilience work is now increasingly measured and perceived according to more or less-cohesive communities and social support networks.

Yet it is not so clear what a 'community' really means. Are communities the close, cohesive units they are imagined to be, and does this even matter for disaster professionals? Rather than to assume that the community in question presents the same characteristics and motivations across its members, the cities section of this handbook advised us to unpack 'the social mechanisms that actually create resilience in a community'. This is a key point in what follows.

- The first half of this chapter briefly looks at the idea of community,
- The second half considers what community aware behaviour can add to disaster risk reduction work. Above all, here we think through what an improved understanding of community does to deliver better risk reduction and response.

Figure 41. What is community?

1.1. Questioning community

Like 'culture' itself, the word community is slippery – it means different things to different people in different places. Communities are indeed often perceived from outside rather than from within: migrant communities in European cities can easily be thought of as individual units, with common languages, identities, or customs. This may contain a grain of truth but it may also be an easy generalisation that papers over numerous cracks. The differences among each groups' members may