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Some key elements for vulnerabilities assessment with respect to complex hazardous events

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Table of contents

1 Key elements for vulnerabilities assessment with respect to complex hazardous events

The topic of vulnerabilities to complex hazardous events and mainly to technological hazards triggered by natural ones (na-techs) has been explored in this deliverable leading to a better understanding of the challenges that such phenomena lay down for hazard and vulnerability analyses. First of all, it has been underlined that in case of complex events an effective vulnerability assessment requires a clear understanding of the threats/hazards which elements and systems are exposed to and of their evolution over time and space. As clearly shown by the Katrina case study, the underestimation of the potential chains of hazards may drive towards the implementation of ineffective structural preventative measures which, in turn, induce a false sense of safety, opening the floor to an increase of exposure and vulnerabilities. Therefore, the overcoming of current approaches to hazard analysis is required.

Up to now, many authors have stressed the fact that, namely in urban areas, hazards are changing, shifting from individual hazards towards "an interactive mix of natural, technological and social events" (Mitchell, 1999). Such "hybrid" or "complex" hazardous events are generally characterized by low probability of occurrence - even though this probability is becoming higher and higher in case of na-tech due to the increased complexity both of hazards and territories – but also by heavy consequences in terms of damages. To deal with such events, the still widespread reductionist approach - that has for long driven to analyze separately the different hazards - has to give way to a holistic approach, aimed at exploring potential sequences and chains among the multiple hazards which potentially threaten a given territory.

Therefore, according to the main outcomes rising from the provided case studies on complex events, in order to face the challenge stemming from such events, some key points have to be taken into account for renewing the current approach to both hazard and vulnerability assessment.

As concerns **hazard analysis**, two main points can be listed:

- ***Holistic approach to hazard analyses***

  The focus of hazard analysis has to be shifted from individual, separate hazards to the interactive mix of natural, technological, social hazardous phenomena; the rising relevance of complex hazardous event, mainly in case of na-tech, is due to the interactions of the tightly coupled natural-human-technological systems which have prompt and major impacts on each other.

- ***Dynamic hazard scenarios***

  Hazard analysis has to focus, even though only qualitatively, on the different hazards at stake, on their temporal and spatial evolution paths, including the potential sequences or chains of events. Different hazard scenarios, from the most-likely case to the least likely one (worst case), have to be taken into account.

As concerns **vulnerability assessment** some key points can be singled out:

- ***Complex framework of vulnerabilities***

  The growing complexity of territories, according to some scholars, increases both exposure and vulnerability, producing as effect more frequent and severe disaster. In case of complex events, vulnerabilities depend on intrinsic features of the phenomena themselves, on the consequences of the interactions between hazards and the affected areas and, in many cases, on the lack of an adequate preparedness to such events. The latter induces ineffective interventions that, in turn, may increase vulnerabilities and damages, involving targets not affected by the hazards themselves. Therefore, in these cases, vulnerability assessment has to take into account not only the heterogeneous vulnerabilities due to the different hazard factors at stake and their relationships but, also, the potential effects due to the synergies among different hazard factors and to other factors such as lack of preparedness, not adequate interventions which may, in turn, increase or transfer vulnerabilities from one element to another or even form one area to another.

- ***Vulnerability of coupled ecological-human systems***

  The case studies related to na-tech events clearly highlight how the complex network of relationships between ecological and human systems may increase the complexity of such events. Modifications on the natural environment induced by human beings determine conditions that influence the trigger of hazards or increase their intensity and effects. Such hazards, mainly in case of na-tech, may induce in turn relevant consequences on the affected environmental systems. Since the latter often represents a key element of local economies, the damages on natural resources reverberate on social and economic systems which are often largely dependent on the integrity of a whole ecosystem rather than on a specific resource.

- ***From static to dynamic vulnerability assessment: the time factor***

  According to hazard evolution over time (sequences, chains, etc.), different areas and targets can be involved. Each target can be hit by different hazards over time (simultaneously or in a very short time) or the same target can be hit by the same hazard more than once during a given temporal span. Obviously, mainly with respect to physical vulnerability, which is the most hazard-dependent component of vulnerability, the assessment of vulnerability with respect to each hazard does not allow the evaluation of the progressive decrease of the structural efficiency of the exposed elements hit, over time, by the same phenomenon or by different phenomena.

  Furthermore, mainly in case of complex events, different aspects of vulnerability (to stress and to losses) arise in different temporal phases. Thus, vulnerability assessment has to take into account the changes over time of the peculiar aspects of vulnerability, the different aspects of vulnerability rising in the different phases of the disaster cycle (sometimes as a consequence of inadequate or wrong interventions carried out in emergency phase) and the changes over time of the relationships among vulnerabilities.

- ***Vulnerability assessment: cross-scale effects***

  Complex hazardous events generally induce cross-scale effects which cannot be neglected in vulnerability assessment. For example, multi-site phenomena may affect different points within a wide area: therefore, both detailed vulnerability analyses for each site potentially affected and large scale analyses aimed at analyzing potential relationships among exposed elements and areas will be required. Moreover, in case of chained events (na-na or na-tech), spread phenomena may trigger very localized ones. For example, an earthquake may induce one or more technological accidents which, in turn, will affect a small area surrounding the industrial plant: in this case, vulnerability analyses have to be developed at different scales and potential overlapping among different impacts have to be taken into account.

  Furthermore, due to the many interactions among different hazards and different aspects of vulnerability, both internal and external systemic vulnerabilities (del 2.1.2 § 4), which are often related to different spatial scales, become relevant in vulnerability analysis.

- ***Resilience dimensions in facing complex disasters***

  Most of the mentioned dimensions of resilience (§ 4) are crucial to analyze the capacity of a system to adapt to and recovery from a complex disasters. For example, one of the main problems in case of complex hazardous events is the lack of preparedness both of communities and institutions. Such a lack is generally due to a lack of memory and experience. Since the rareness of such events, indeed, communities and institutions do not develop their capacity to learn from past experience, whereas learning capacity represents a key point for improving resilience and is crucial to build up mitigation measures able, in turn, to effectively reduce vulnerability. Moreover, in case of complex events, the emergency due to the triggering event combined with the effects of the generally unexpected secondary events compete for the few available resources, reducing efficiency and rapidity in response.

  Summing up, the main dimensions of resilience are very relevant to a better understanding of the behaviors of the territorial systems hit by complex events.

- ***Tools for analyzing vulnerabilities to complex hazardous events***

  As clearly arises from some case-studies, it is very difficult to identify main cause-effect relationships among vulnerabilities with respect to complex hazardous events. Thus, a systemic approach to understand vulnerabilities and their relationships is required and conceptual maps seem to fit this purpose. In fact, conceptual maps represent useful tools for exploring the chains of relationships among different vulnerabilities and their development over time and space. Such a tool, even though based on a qualitatively approach, can be very useful both for describing and interpreting past events and for outlining future scenarios.