1st IAVCEI-GVM Workshop

From Volcanic Hazard to Risk Assessment

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Consensual Document

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This consensual document has resulted from the contribution of all workshop participants (Appendix 1)

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1 Executive summary

The complexity of volcanic risk analysis typically resides in the interaction of multiple hazard, vulnerability and exposure aspects dynamically acting over various spatial and temporal scales. Risk analyses provide an evidence-based approach to development and implementation of proactive policies of risk reduction before an event, yet no comprehensive and multidisciplinary methods for vulnerability and risk analysis currently exist and data to inform such analyses are sparse. In this context, the first IAVCEI-GVM workshop "From Volcanic Hazard to Risk Assessment" took place in Geneva on 27-29 June 2018 (http://www.unige.ch/hazards/iavcei-gvm-workshop-2018/). About 40 participants from 15 countries working in various aspects of hazard, exposure, vulnerability, and risk assessment attended, the main goal of the workshop being to evaluate the state of the art of risk assessment in volcanology and to identify research priorities that would enable research scientists to more effectively engage with Disaster Risk Reduction (DRR) and to work across disciplines. This consensual document summarizes the outcomes of the workshop, also making use of a document compiled before the workshop gathering the opinions of the participants on the most pressing challenges in our communities and the efforts made across disciplines to overcome them. The issues addressed in the workshop, and the key findings include:

- Co-design and co-production of risk assessments with local stakeholders (e.g. local government, disaster risk managers, private sector, NGOs, the public) is a key step towards empowering various users to effectively manage and reduce risk. In fact, while scientists (local and international) can better characterize the volcanic settings, local stakeholders have a better understanding of the socio-political settings. In addition, when local stakeholders are involved in the risk assessment process this enhances the contextual/socio-economic understanding of scientists, may encourage more useful and targeted outputs and may enhance stakeholders understanding of the science so that it is more likely to be used;
- Risk assessments should be updated regularly or in response to significant changes in availability of new information concerning indicators of risk and/or methods for assessing risk;
- Crucial aspects of risk assessments include the identification of primary objectives and applications depending on stakeholder uses and time scales (before, during or after an event).
- When assessing volcanic risk, multiple hazards and various dimensions of exposure and vulnerability (e.g. physical, socio-economic, systemic) should be accounted for;
- Vulnerability and impact are different: vulnerability is an intrinsic feature of an element in relation to a specific hazard, while impact implies that the interaction between a certain element (with a specific vulnerability) and a certain hazardous event has either occurred or is predicted to occur. Impact (damage/loss) studies are one example of the type of research necessary to develop a better understanding of the differing dimensions of vulnerability and their importance under differing hazard conditions;
- Exposure and vulnerability are closely related: exposure quantifies what is exposed (e.g. number of people and buildings in the area), while vulnerability is an intrinsic feature of the exposed elements in relation to individual hazards;
- Different dimensions of vulnerability might be required by risk analysis at different time scales before, during and after a hazardous event. Vulnerability elements to be considered also vary for the different volcanic hazards. As a result, vulnerability assessments should be carried out individually for different hazards depending on context and purpose, although combined vulnerability from multiple volcanic hazards should also eventually be considered;

- There is a need to both strengthen collaborative research across disciplines and build strong partnerships with appropriate stakeholder communities to enable science to effectively contribute to building resilience and DRR;
- Common language and coordinated resources are needed to facilitate collaborations across the volcanic risk community and optimize the research effort across disciplines. It would enhance the efforts of the community if, collectively, we establish good practices for risk assessment, and associated data collection, data usage and data sharing. There is also a need to develop a framework to record and catalogue post-eruption damage and impact data that is widely accepted, recognized and used by the volcanic risk community.

Specific research priorities include:

- Better characterization of specific vulnerability dimensions (e.g. socio-economic, systemic) and their dynamic characteristic before, during and after eruptive events;
- Better understanding of which dimensions of vulnerability, or which combinations thereof, contribute the most to risk caused by different volcanic hazards and to different elements;
- Investigation of the hazards, or combinations of hazards over time that are most important in terms of: casualties, health impacts, building and infrastructure damage, business and network disruption, loss of livelihoods and impacts on sustainable development;
- Better understanding of the information and methods required by risk analysis undertaken for different purposes (e.g. risk to life, insurance purposes) and at different time scales (before, during and after a hazardous event);
- Where relevant, construction of reliable evidence-based fragility curves to relate modelled hazard intensity to expected impacts;
- Identification of impacts beyond the immediate acute damage;
- Cascading physical, social and economic consequences of volcanic unrest, eruption and post-eruption conditions;
- Improved analysis of the key drivers behind eruptive impacts via the systematic and coordinated collection of detailed damage/impact data syn- and post-event;
- Better characterisation of dynamic risk, intensive risk and extensive risk;
- Better understanding of adaptation during long-lived eruptions or associated with frequently active volcanoes;
- Investigation of challenges relating to recovery during and after eruptions.

2 Introduction

2.1 Background to the international effort on disaster risk reduction

[1] Science has a recognised underpinning role in disaster risk reduction (DRR) and sustainable development worldwide but there is still much to do in the volcano science community to ensure that scientific evidence is 'useful, useable and used' (Science and Technology Advisory Group, STAG, 2015; Aitsi-Selmi et al., 2016). The first IAVCEI-GVM workshop "From Volcanic Hazard to Risk Assessment" brought together a cross-section of the scientific community active in aspects of volcanic risk research and practice and stakeholders, to discuss challenges and next steps in volcanic risk assessment.

[2] Risk assessments are diverse in purpose, scale and context. Key users and creators of risk assessments include national and local government departments, private sector, civil society and other stakeholders. '*By identifying and assessing the likelihood and consequences of potentially disastrous events, risk assessment provides governments with a basis for prioritisation of DRR activities, the improvement of emergency management capabilities and the design of protection strategies to meet local conditions, needs and preferences*' (*OECD, 2012*).

[3] '*Risk assessments may also be used to inform and educate all relevant stakeholders about the most important threats society faces and thereby contribute to developing an informed culture of risk amongst communities and individuals. Risk assessment is thus an essential prerequisite for a full and comprehensive array of DRR plans and policies that contribute to the overarching governmental objective of reducing society's vulnerability and enhancing its resilience. By using a comprehensive all-hazards approach to risk assessment, with definitions of core terms and a transparent methodology, it is possible to identify underlying drivers and uncertainties. Key to ensuring useful planning information is the understanding that it is not the risks themselves that people have to deal with when things go wrong, but their consequences*' (STAG, 2015).

[4] The UN Sendai Framework for Disaster Risk Reduction (SFDRR) is a 15-year, voluntary, non-binding agreement signed by UN member states in 2015 (https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf). It recognizes that the State has the primary role to reduce disaster risk, but that responsibility should be shared with other stakeholders including local government and the private sector. It provides a very useful framework for scientists and all stakeholders of risk information. Four priorities for action are: 1) Understanding disaster risk; 2) Strengthening disaster risk governance to manage disaster risk; 3) Investing in DRR for resilience; 4) Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction. Important is also the commitment to 'leave no one behind' (reaching first those who are furthest behind). It fundamentally aims for a *'substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries*' (UNISDR, 2018; https://www.unisdr.org/we/coordinate/sendai-framework).

[5] The UNISDR Science and Technology Advisory Group report (2015) makes the following recommendations to help strengthen DRR policies and practices through the use of science: (i) share knowledge for action; (ii) use a multidisciplinary approach to research; and (iii) build system resilience through local, national, regional and international partnerships. It offers guiding principles and illustrations through case studies to promote this sharing of information, and thus promote knowledge exchange with policy-makers and other DRR partners. In this document we use UNISDR definitions and terminology unless otherwise stated https://www.unisdr.org/we/inform/terminology.

[6] The UN Sustainable Development Goals (SDGs) are 17 broad goals (http://www.undp.org/content/undp/en/home/sustainable-development-goals.html) with targets

to achieve the 2030 Agenda for Sustainable Development. Importantly these recognize and reaffirm the urgent need to reduce the risk of disasters. In addition to direct references to the SFDRR, there are specific opportunities to achieve SDGs, for example, by reducing exposure and vulnerability of the poor, building infrastructure and cities resilient to disasters, or building resilient communities.

[7] In the New Urban Agenda, UN Habitat commits to improving networks, households and public spaces to make cities more resilient to natural hazards and climate change (https://unhabitat.org/habitat-iii/). The call for improved land use and spatial planning based on sound risk assessments is key because the world is becoming increasingly urbanizing, having reached a threshold of population living in cities (54% in 2014) that is unprecedented in history and projected to increase. This is particularly relevant in the case of volcanic risk, given that for some volcanic hazards (e.g. lava flows) it is not possible to diminish the physical vulnerability of individual buildings and assets and the most effective mitigation measure is working to reduce exposure.

2.2 Volcanic risk assessment

[8] Regardless of large international efforts to reduce volcanic risk, unfortunately, lives are still tragically lost in volcanic eruptions (e.g. Fuego 2018, Guatemala; Sinabung 2014, 2016, Indonesia; Ontake 2014, Japan; Merapi 2010, Indonesia) in addition to the large socio-economic impacts that often affect communities at various scales even when there are few or no casualties (e.g. Ambae 2018, Vanuatu; Eyjafjallajökull 2010, Iceland). The complexity of assessing and managing the risk of volcanic unrest and eruption is related to several factors. These include the intrinsic multi-hazard aspect of volcanoes, the variability of single volcanic hazards at different temporal and spatial scales, the variability of the magmatic system, the uncertainties related to specific volcanic hazards (e.g. *National Academies of Sciences, Engineering, and Medicine 2017*), the dynamic aspect of both exposure and vulnerability, the low frequency of occurrence at the local scale and the necessity of efficient collaborations and partnerships amongst multiple actors involved (e.g. volcanologists, geophysicists, sociologists, engineers, urban planners, risk managers, communities; http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-17-partnerships-for-the-goals.html).

[9] Experience has shown that success in volcanic risk reduction strongly correlates with the degree to which effective crisis management, mitigation, preparedness and sustainable development are in place in all parts of society before unrest and eruption begin (e.g. *Andreastuti et al., 2017; Bakkour et al., 2016; Mei and Lavigne, 2012*). Such policies and activities should ideally be developed based on comprehensive analysis of the volcanic risk that encompasses the full spectrum of vulnerability dimensions (e.g. physical, systemic, social, economic, institutional) associated with individual volcanic hazards (e.g. pyroclastic density currents, lava flows, tephra accumulation and dispersal, lahars, gas emissions). Note that in this document '*vulnerability dimension*' is used to identify vulnerability types (e.g. physical, systemic, socio-economic), while vulnerability elements indicate specific items that make up the system (e.g. buildings, population, infrastructure). Still, no comprehensive methods for vulnerability and risk assessment exist and, while some models identify individual interactions between some volcanic hazards and aspects of physical vulnerability (e.g. *Dagá et al. 2018; Kappes et al. 2012; Jenkins et al. 2014; Maqsood et al. 2014; Pomonis et al. 1991; Spence et al. 2004a,b; Spence et al. 2005; Williams et al. 2014; Wilson et al. 2014, 2017*), the limited understanding of the role of other dimensions of vulnerability limits our ability to effectively assess the volcanic risk faced by society and it impedes the development of efficient mitigation strategies.

[10] Operational volcano scientists (e.g. volcano observatories/geological surveys) and scientific advisory groups recognise that real-time advice on how to respond to volcanic risk is legally the responsibility of disaster risk managers. Traditionally volcano scientists have provided mainly advice on volcanic hazard assessment rather than risk assessment. While this limits collaboration across disciplines, it is also recognised that these roles vary in different countries (e.g. *Aspinall 2011;*

Bretton et al. 2015; Marzocchi et al. 2012). There is nevertheless a role for volcano scientists to contribute to the understanding of risk by generating evidence through interdisciplinary and transdisciplinary research (e.g. *Armijos et al., 2017*). The relevance, and usability of scientific evidence can be enhanced by co-designing and co-producing the research with potential users of that science (e.g. disaster risk managers, civil protection, local government, urban planners, private sector and communities; https://www.unisdr.org/we/inform/publications/42848). This is being facilitated by increasing funding opportunities for interdisciplinary research that requires strong research partnerships with users of risk information (e.g. the 'Increasing Resilience to Natural Hazards' programme between the Natural Environment and Economic and Social Research Councils in the UK 2014 -18 and the UK Building Resilience GCRF initiatives).

[11] International collaboration is key to our advancement in volcanic risk assessment as volcanic eruptions are globally frequent but locally episodic, therefore, we need to learn from each other globally. Building partnerships between different nations, disciplines and sectors requires investment, time, patience and trust as well as acknowledgement of any inequalities.

[12] Although DRR is the main responsibility of the state, all of society, from individuals to policy makers have a role. Site-based (local) strategies and models that link individual aspects of hazard and vulnerability have been developed (e.g. *Daly and Johnston 2015; Jenkins et al. 2015; Pomonis et al. 1999; Spence et al. 2004a,b*); however, a generalized risk framework across different spatial and temporal scales still does not exist due to the complexity and dynamic nature of volcanic risk and the wide range of assessments required by stakeholders. A strategic ambition of our community, to the extent possible, is to respond to this identified need.

[13] The first IAVCEI-GVM workshop "From Volcanic Hazard to Risk Assessment" took place in Geneva on 27-28 June 2018 with the main goal being to evaluate the state of the art of risk assessment in volcanology and identify research priorities (http://www.unige.ch/hazards/iavcei-gvm-workshop-2018/). It gathered about 40 participants from 15 countries working in various aspects of hazard, vulnerability, exposure and risk assessment (see Appendix 1 and 2 for list of participants and workshop program). Specific objectives included: i) to discuss the benefits of risk assessment, current research gaps and potential for increased scientific input; ii) to identify key vulnerability aspects that need to be assessed for a comprehensive and efficient risk assessment in a multi-hazard context; and iii) to evaluate the optimum hazard and vulnerability products necessary for risk assessment at different scales. Appendix 3 describes the basic definitions on DRR provided by UNISDR in order to aid in the promotion of a common language on the subject for use by the public, authorities and practitioners (https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf).

[14] This consensual document attempts to summarize the outcomes of two days of dedicated talks, posters, break-out sessions, and extensive plenary discussions focusing on i) the benefits of volcanic risk assessment; ii) some current perspectives of volcanic risk assessment; iii) how to analyse vulnerability in a volcanic context; and iv) how to combine hazard and vulnerability in a volcanic context. The consensual document also makes use of a document compiled before the workshop that gathered the opinions of the participants on the most pressing challenges in our communities and the efforts made across disciplines to overcome them.

3 Some perspectives on volcanic risk assessment

[15] Risk assessment and recognition of key underlying risk factors (drivers) are key steps towards empowering communities to manage and reduce risk. When communities are involved in risk assessment and risk reduction it can enhance their awareness of their environment and their vulnerabilities, encouraging them to prepare and, therefore, increase their resilience (e.g. *Cronin et al. 2004; Hicks et al. 2017; Mercer et al. 2010; Stone et al. 2014*). The complex and multi-faceted

nature of risk makes it important to define the purpose of a volcanic risk assessment. Any scientific evidence on risk compiled for a particular use and stakeholder will be context specific. Partnerships with key stakeholders of science (e.g. Civil Protection) enable different science outputs for different contexts to be co-designed, co-produced and used appropriately. Risk assessment is crucial to emergency managers, legislators, industrial stakeholders, land-use planners, NGOs and civil society. Life safety is the most important priority (often from Civil Protection and scientific perspectives) but it is one of many aspects to consider. As an example, Civil Protection has a responsibility to carry out risk assessment to support disaster risk management, as currently laid out in the SFDRR framework. This must be underpinned by scientific evidence. Even though scientists cannot always provide what Civil Protection requires based on specific contexts, any evidence-based information that can help decision making could be useful, e.g. hazard evaluation, hazard likelihood, eruptive scenarios, possible impacts, and mitigation options. In Italy, for example, quantitative multi-hazard scenarios and physical vulnerability studies for Vesuvio and Campi Flegrei caldera have been used to define the red and the yellow danger zones, which represent the basis for the national emergency plan. A key point here is that several strands of science, including sometimes highly involved and rigorous methods, are brought together in order to define broad hazard zones, which can ultimately appear quite simple. A more simplified approach has been used to map the tsunami hazard area for Stromboli island, which is based on the impact of the 2002 event.

[16] It is useful to document a range of purposes for which volcanic risk assessments have been or could be undertaken. These include: risk to life for volcanoes which produce life-threatening hazards, including pyroclastic density currents and lahars (e.g. Montserrat, Scientific Advisory Committee Reports 20-23; http://www.mvo.ms/pub/SAC_Reports/); global scale assessments to compare risk across nations to guide resource allocations (e.g. GAR, Global Assessment Report; https://www.unisdr.org/we/inform/gar) and which are used mostly to prioritize interventions; and risk to insured assets from tephra fall (e.g. global probabilistic volcano model of Swiss Re developed to support its clients in assessing volcanic risks and in developing suitable insurance products; https://www.swissre.com/japan/protecting_against_volcanic_eruption.html).

[17] Examples of aspects that need to be addressed in the compilation of risk assessments include: who is generating the volcanic risk assessment and are they credible? What is the purpose, and who are the stakeholders of the volcanic risk assessments? Should a multi-risk approach be used? Should a short-term and/or a long-term volcanic risk assessment be considered? How will a risk assessment assist in reducing volcanic risk? What specific questions are being asked in a risk assessment? How will the assessment deal with uncertainty? Is volcanic risk important with respect to the other risks in the area considered? Where are population and infrastructure in relation to the anticipated distribution of volcano hazards (e.g. on a volcanic hazard map)? What kinds of risk products are expected by stakeholders? Is a simple overlay of hazard map with exposed infrastructure and population density easier to read and to use than more advanced products for example combining hazard probability with estimated damage? What is most appropriate for particular purposes, e.g. probabilistic or scenario-based hazard/risk maps? Many of these issues are not unique to volcanoes but are applicable to many types of hazards. Further, the methods employed in different global regions have to be built for purpose, depending on the local situation. The latter includes human and financial resources, available technology and expertise.

[18] Communication of uncertainty is also important alongside any hazard or risk output. A key aim for the community should be that full characterisation and treatment of uncertainties (epistemic and aleatory) be developed throughout the risk assessment processes. It is acknowledged that within hazard science, and in fact more broadly, uncertainties are commonly underestimated. It is important that this is taken into account in risk assessments. Finally, it is important to acknowledge the time and cost it takes to compile and implement a comprehensive risk assessment (e.g. building

trust and working across disciplines), and that currently research in volcanic risk is very much a young and emerging research area.

3.1 Spatial, temporal and dynamic scale of volcanic risk assessment

[19] Volcanoes have the tendency to shift between phases of low and high intensity, multi-hazardous activity causing dynamic and interacting hazards that can propagate into dynamic risk. Further, vulnerabilities and exposures related to modulation in the volcanic activity, as well as human activities within the specific socio-economic context of a given volcano, can be highly dynamic over time and space. These situations result in dynamic risk both spatially and temporally, so risk assessment could/should consider dynamic volcano behaviour as well as evolving societal and other asset (e.g. infrastructural) behaviour and capacities. Dynamic aspects of hazard have started to be considered (e.g. *Wolpert et al. 2018*), however, dynamic aspects of exposure and vulnerability (e.g. *Few et al. 2017*) are also important and require attention (e.g. evacuations, road closures, relocation, urban development, interconnectivity). In addition, and to the extent possible, a risk assessment should be updated when changing hazard and technology, exposure and vulnerability require.

[20] <u>Time scale of risk assessment depends on context and stakeholder needs</u>. Short-term risk analysis is important during unrest and on-going crises, whereas long-term risk assessments are important for planning, preparedness and sometimes recovery. Timely risk assessment (both compilation and communication/ensuring understanding) is important to allow effective actions.

a. Main objective of long-term risk assessment **before the event** is risk management (e.g. land use planning, preparedness, such as implementation of mitigation measures and education); the time scale is usually years/decades, but typically updated every 3-5 years). It should be multiscale and multitemporal to consider possible impacted areas and the evolution of exposure based on, for example, seasonal fluctuations in visitor populations.

b. Main objective of rapid risk assessment **during unrest** is for dynamic and real-time emergency management. The elements to be considered are: identification of potential hazard scenarios, structure and demography of population, lifelines, critical infrastructures, potentially hazardous infrastructures that can cause cascading technological disasters. The timing of re-assessing the risk should ideally be: daily to weekly depending on the type of phenomena. In some cases, it can be built on, and developed from, the long-term risk assessment and is important for all the stakeholders (e.g. Civil protection at all levels, decision-makers in national and local level, private sector, communities, scientists, etc.).

c. Main objective of rapid risk assessment **during the event** is emergency management; The elements to be considered are: new potential hazard scenarios, changes in population distribution, population movements, access, population needs. The timing of reassessment should ideally be: daily to weekly depending on the type of phenomena. It should be combined with impact assessments/impact scenarios to plan and coordinate response.

d. Main objective of risk assessment **after the event** is reconstruction that should take into account lessons learnt and the potential for building back better. It will take some time to understand and assess the overall long-term impacts/damage (not only physical, but economic, social, etc).

[21] <u>Spatial scale of risk assessment depends on purpose, context and stakeholder needs</u>. Local scale assessments can improve risk management, but city and regional scales can be combined to support national scale assessments. National scale assessments can contribute to regional and

global scale assessments. By mainly being a quantitative measure of people, assets and goods located in a hazardous area, exposure can be analysed similarly at multiple scales, but measures of vulnerability are likely to be different. At the global scale a risk assessment is a snapshot in time generally meant to compare risk across nations to guide resource allocations. Global assessments (e.g. GAR, Global Assessment Report; https://www.unisdr.org/we/inform/gar) cannot be used at sub-national levels; they should be used mostly to prioritize interventions. There is a big gap in scale between local (volcano scale) and global risk assessment; city, region, national and synoptic scale assessments help connect the two existing end-members. For example, volcanic arc scale assessment could provide important information for city-centric assessment where one city is exposed to several volcanoes (e.g. Jenkins et al., 2018) as well as different types of natural hazards.

a. **Global scale**: local complexity and heterogeneity cannot be accounted for at the global scale. The metrics used and sources of information are important (both value and documentation can be different in different localities), and there is a need to consider volcanic hazards across borders. Decisions at the regional or national scale can be important globally (stakeholders: reinsurance companies, global institutions, e.g. World Bank, OCHA, NGOs).

b. **National scale**: governments and civil protection authorities need risk assessments to manage planning, preparedness and mitigation at local to national scales (as, for example, required by the current legislation at the EU level, according to the new Civil Protection Mechanism approved on December 2013). A focus on scenarios is often employed in order to ensure that planning involves capability to deal with a range of events and consequences. Scenarios could include a reasonable worst case or some alternative deterministic or probabilistic scenario based on characterization of past and current activity of the volcano, e.g. Vesuvio and Campi Flegrei emergency plans are based on a VEI=4 (sub-plinian eruption) event which is, interestingly, not the most probable but neither the worst case scenario of VEI=5 (i.e. Pompeii eruption for Vesuvio and Agnano Monte Spina for Campi Flegrei).

c. **City scale**: there are growing opportunities to support city-scale multi-hazard disaster risk management (e.g. Determining Volcanic Risk in Auckland (DEVORA); *Deligne et al. 2015*). Stakeholders are: Civil Protection, municipality and critical infrastructures managers, scientists, local populations.

d. **Local scale**: detailed risk assessments at the volcano scale are currently rare. A good example is that of Tongariro national park (New Zealand) where GNS performs risk assessments and the Department of Conservation takes the decisions on whether or not to open the hiking trails. High spatial and temporal resolution of information for exposure, vulnerability, and hazards (including cascading effects and compounding hazards) are necessary at local scale. It is difficult to manage national scale regulations with specific local needs (stakeholders: local civil protection, individuals, companies, local governance, NGOs). The level at which local information is accepted is different because of high stakeholder interests. For example: a local mayor might not want to accept that a large part of the region is classified as high risk. Local knowledge is key and only after accumulation of many case studies can this be upscaled. Risk assessments can feedback both positively and negatively to local economy.

4 Vulnerability in a volcanic context

[22] Within the document, we use '*vulnerability*' as a generic term to address the relationship between hazard intensity and impact. It is important here to clarify how vulnerability and impact are

different, in a way that vulnerability is an intrinsic feature of an element in relation to a specific hazard, while impact implies that the interaction between a certain element (with a specific vulnerability) and a certain hazardous event has occurred (either in real life or in predictions of future activities). Exposure and vulnerability are closely related: exposure quantifies what is exposed (e.g. number of people or buildings in the area), while vulnerability is an intrinsic feature of the exposed elements in relation to individual hazards. There are a number of different expressions that describe how a societal element (be it a person, infrastructure component, building, crop, system, community, etc...) responds to a hazard including: vulnerability, coping capacity, resilience, and fragility. See Appendix 3 for current terminology developed by UNISDR.

[23] Vulnerability assessments are used in a wide variety of applications, e.g. supporting land-use planning, settlement status, housing, shelters, critical infrastructure, among many others. In many applications it is desirable that they are dynamic and operational. However, relative to other natural hazards, vulnerability in a volcanic setting has not been characterized, and there are clear gaps in our understanding that need to be addressed. There are multiple reasons for this situation, primarily the complex, dynamic multi-hazard aspects of eruptions in time and space and the multiple interacting and cascading consequences and their relatively lower frequencies compared to other natural hazards. Also, multidisciplinary teams are needed to provide a comprehensive vulnerability assessment and building and funding such teams has until recently been challenging.

[24] The most studied dimension of vulnerability with respect to volcanic hazards is physical vulnerability. This might in part be due to our readiness, as a science community, to bring in quantitative approaches used in engineering, and for which we have the expertise and ability to employ within our own work. This is significantly harder for us, as a volcanology community, to do with social, economic or systemic dimensions of vulnerability. Within physical vulnerability, the agriculture sector (in a context of food production) has been the least considered in terms of vulnerability analysis; few examples include *Blong (1984), Neild et al. (1998), Wilson et al. (2007, 2011a,b)*. There are also only few examples of socio-economic vulnerability studies in volcanology (*Dibben and Chester, 1999; Donovan 2010; Few et al. 2017; Gregg et al. 2004; Gregg et al. 2008*). Cultural heritage and social connectivity are also interesting dimensions of vulnerability, where the intrinsic value of harm is harder to define. The value assigned may be different depending on who is asked (e.g. local vs national), for example it may be a site valued only by a local community, or, conversely it might be linked to national identity. Sometimes this value may not be related with the official perceptions about the most important elements in a specific context, but it may strongly affect the behaviour of individuals at risk. Anecdotal evidence suggests cultural heritage is particularly important in some contexts (e.g. *Gaillard J-C 2008; Cronin and Cashman 2008*) and social networks are demonstrated to offer real value in response and recovery in other hazard contexts (e.g. *Aldrich, 2012*).

[25] Vulnerability studies are typically driven by accessibility to, or availability of, quantifiable data (e.g. damage data); an important aspect going forward could be to expand current studies to also focus on components of vulnerability where the most benefit/mitigation gains can be made. In many cases, this may not be physical vulnerability but other dimensions of vulnerability, that are perhaps harder to characterise, or in some cases can only be qualitatively characterised. In this context forensic strategies are crucial to understand the critical drivers behind vulnerability and loss (e.g. *Wantim et al. 2018*). Complementary to forensic studies are various analyses of impact (e.g. *Blake et al. 2015; Durand et al. 2001; Sword-Daniels et al. 2011; Wardman et al. 2012; Wilson et al. 2013*). Physical impact may need to be characterised before other impacts can be (e.g. systemic, social, economic), e.g. need to know how badly damaged one infrastructure site is before understanding cascading impacts. Physical vulnerability, as with other dimensions of vulnerability, will be unique for each type of volcanic hazard.

[26] The hazard associated with tephra fall has the most developed vulnerability studies because of the wide-ranging and far-reaching impacts of tephra fall and the relatively larger number of published damage or impact studies (e.g. *Blong 2003; Jenkins et al. 2014; Spence et al. 1996; Spence et al. 2005; Wilson et al. 2014*). These efforts largely focus on the characterisation of vulnerability functions for built infrastructure. Vulnerability related to other volcanic hazards has had less attention. There are a number of reasons for this, but one is likely to be the more localised and binary nature of impacts. It is also harder to fully characterise hazard for flowage phenomena (lava flow, pyroclastic flows and lahars), so the community have not advanced to the same degree into risk. In some cases, however, and especially when considering the risk to life, the impact of flowage phenomena can be usefully reduced to a binary effect (i.e. impacted/not impacted). Although at the margins of these flows, we recognise that impact can be less, this is not information that can be employed in practical purposes for risk mitigation. The potential for loss of life in flow hazards is such that evacuation should remain the best and preferred option; reducing the potential for impact through engineering approaches such as building strengthening is less of an option than in fall hazards. As the community develops further, we anticipate being able to consider various dimensions of vulnerability as well as their specific relation to the lesser-studied hazards.

[27] It is important to establish which dimensions and elements of vulnerability are unique to volcanoes. Some vulnerability dimensions (e.g. socio-economic vulnerability) may be common across different natural hazards (e.g. *Wilkinson et al., 2016*) and our community can develop partnerships to ensure efficiencies of effort where this is the case. Nevertheless, many important dimensions and elements of vulnerability are unique to volcanic unrest and eruptions and require special attention (e.g. vulnerability of air traffic system that is unique to volcanic eruptions).

[28] Some approaches to understanding vulnerability can be adopted from other disciplines even though there could be different time scales of recovery from different hazards, e.g. a flood comes and goes whereas a lava flow is permanent. It is again strategies for understanding and quantifying physical vulnerability that are the easiest to be adapted.

a. The determination of physical vulnerability of infrastructure to tephra fall and snow cover has some parallels; in particular, the metrics relating to loading on roofs, can be transferable (although there are aspects like heat, chemical surface coating or increased load through rainfall that mean that there are important differences in impact, and transferability of approaches has to be carefully considered and adapted).
b. The determination of physical vulnerability of infrastructure to lahars and floods has some parallels; one metric that can be used is dynamic pressure, a function of the velocity and flow density. However, the dynamic pressure of lahars is known to be very heterogeneous in space and time, particularly because of the inclusion of missiles, such as boulders, trees or building debris. Numerical models are not yet able to fully capture the heterogeneity displayed by lahars (or any volcanic flows). Therefore, it is difficult to use dynamic pressure as a metric on its own to assess physical vulnerability. For both PDCs and lahars given the heterogeneity of their characteristics, reasonable first order approaches would be to consider the maximum dynamic pressures that those flows might impart as a method for forecasting impact to infrastructure, although this would not account for missile damage. However, unlike tephra fall where the physical resistance to a roof is a very relevant consideration, the resistance of the built infrastructure to volcanic mass flows is perhaps less so, given the intensity is already sufficient to impact life.

4.1 Current state of vulnerability assessment in a volcanic context

[29] Vulnerability in a volcanic context is complex. The purpose of the risk assessment (e.g. crisis management, long-term land use planning) should be considered when designing a vulnerability assessment, along with the spatial and temporal scales of interest to the stakeholder.

[30] Vulnerability assessment can be carried out quantitatively or qualitatively or as a combination of both. In fact, assessments are neither purely quantitative or purely qualitative but tend to be a mixture of both, i.e. quantitative assessments always have a qualitative component and vice versa. Quantitative assessments can give the impression that they are more detailed and robust, but, in fact, detail is sometimes lost as information moves from qualitative to quantitative (depending on how well the qualitative data correspond to the quantitative).

[31] Vulnerability assessments (i.e. parameters and indices) are intrinsically connected with hazard type/intensity. For physical vulnerability the link to hazard intensity for damage estimation is clearer and more straightforward than for other dimensions of vulnerability. Vulnerability and hazard assessments should be coordinated and compatible. The hazard assessment can be done independently but knowing a-priori the vulnerability parameters can be helpful to ensure that appropriate and useful data are collated during the hazard assessment stage. Vulnerability assessment should be carried out for a wide range of relevant sectors (i.e. not only residential, but also business, networks and critical infrastructures, natural and cultural assets, public facilities, agriculture) and at different spatial and temporal scales. In fact, also areas that are not likely to be affected by physical damage may suffer indirect and systemic consequences; in addition, impact may last for many years after the immediate emergency.

[32] There are different dimensions of vulnerability that need assessing and they may be interconnected / interdependent. The amount of available data, and methodologies for collection, compilation and analysis, varies across different sectors (e.g. residential buildings, critical infrastructures, natural and cultural assets, public facilities, agriculture). There are a number of different ways of assessing vulnerability and different metrics are used to assess different vulnerability dimensions. Bringing all these dimensions into one coherent vulnerability assessment is challenging, and indeed with the current stage of research and practice development there is no established approach to undertake this; however, understanding how they fit within a common reference framework would be valuable.

[33] The assessment of different vulnerability dimensions is relevant to different phases of risk management, e.g. physical vulnerability is likely to be considered immediately/soon after the event but could also be included in pre-event emergency and long-term mitigation planning, whereas socio-economic and systemic vulnerability might have longer time scales (and they also refer to wider geographical scales in respect to the area directly affected by the hazard/hazards). However, physical vulnerability is the most advanced and structured field, and perhaps the only vulnerability dimension that can be addressed independently of the other vulnerability dimensions such as socio-economic, and systemic. In fact, even though all vulnerability dimensions are related (e.g. the collapse of a building may block an evacuation road; people aware of living in a weak house might adopt different behaviours in the face of a volcanic threat), the intrinsic physical vulnerability of an element can be assessed independently of other vulnerability dimensions. Volcanic risk assessment and loss estimation typically does not currently capture all dimensions of vulnerability. Below, we outline the main vulnerability dimensions that have so far been considered in volcanic context. All these are difficult to bring into a map, but a common reference framework can be developed. It is also important to note that certain vulnerability assessments are also valuable without being incorporated into a traditional risk assessment.

[34] <u>Physical vulnerability</u>. As mentioned earlier, physical vulnerability is the most developed dimension of vulnerability due to more evidence from case studies, published damage studies,

possibility to test through laboratory experiments and the established engagement of engineers in DRR. However, fragility and vulnerability functions are available predominantly for tephra fall. Depending on stakeholders, physical vulnerability for some hazards may be reduced to a binary relationship (impacted or not impacted), while for other hazards it is a gradient (e.g. tephra fall). PDCs and lava flows, for example, are commonly considered of binary impact (e.g. by insurance companies) and, therefore the associated physical vulnerability assessment can be estimated by exposure. It can be argued that vulnerability is considered binary in part due to a lack of data/observations (even for PDC and lava flows that could be associated to a high degree of variation in the spatial distribution of hazard intensity; e.g. *Jenkins et al. (2013), Baxter et al. (2005)*). It is important to bear in mind the purpose of such studies: while teasing out the variability of physical vulnerability across a set of buildings impacted by a PDC, in practical terms and for risk to loss of life, the site needs to be considered as 'vulnerable' as a whole.

[35] There are five main sources of data that inform physical vulnerability assessments:

a. Empirical data: we have a relatively small number of case studies, which are invaluable; but we clearly need more. Coherence across research teams globally is needed to ensure that data collected can be as useful as possible to all sectors, and consistently compared and analysed across multiple case studies.
b. Experimental data: this approach is difficult to replicate across the other vulnerability dimensions but provides reproducible data and is crucial in the absence of empirical data and for cross validation.
c. Remote-sensing data, and social media/social networks (e.g. Fuego), images of casualties (e.g. Merapi); possibility of interpreting social media images in a scientific context based on robust and reproducible approaches.
d. Theoretical data
e. Expert judgement

[36] <u>Socio-economic vulnerability</u> is the susceptibility of individuals, communities or institutions to experience the impact or loss as a consequence of socio-economic conditions (e.g. *Dove and Hudayan 2006; Few et al., 2017; Hicks and Few 2015; Scaini et al. 2014; Morin et al. 2009*). It can include indicators related to the mobility, number of vehicles, income, demographic (e.g. age, gender), economic activities, risk perception (i.e. both knowledge of the phenomenon and how people place that into the context of their lives) and preparedness of both populations and institutions.

[37] <u>Systemic vulnerability</u> is related with the functionality of systems, e.g. emergency facilities' system, Civil Protection system, healthcare system, transport system (e.g. *Galderisi et al., 2013; Scaini et al., 2014*). An important system is the early warning system; in particular, a detailed vulnerability analysis of the emergency management capacity should always be carried out (including volcano observatories). Systemic vulnerability is also strictly linked to functional vulnerability and both are important considerations for crisis management (e.g. accessibility, transport routes during evacuation; e.g. *Leone et al. 2018*).

4.2 Key dimensions and elements of vulnerability in a volcanic setting

[38] Different vulnerability dimensions should be treated differently for different needs at different time scales:

a. **Before the event**: (long term - planning and preparedness): physical vulnerability (i.e. vulnerability elements that could be reinforced to sustain potential impacts); economic vulnerability (i.e. specific funds to put in place for recovery and reconstruction).

b. **During the event** (short term - crisis management): physical vulnerability (i.e. structures, roads - relation between physical and systemic vulnerability); systemic vulnerability (i.e. transport routes during evacuation, critical infrastructure: roads, electricity, communications, health system); socio-economic vulnerability (i.e. needs of population to be evacuated).

c. **After the event** (long term - recovery, planning and preparedness): the interaction between hazard and vulnerability will be different with respect to the situation before the event; long-term cascading effects also need to be considered.

[39] Below we report some examples of vulnerability aspects and elements to be considered in a vulnerability assessment before, during and after an event:

a. **Before the event**: the main aspect to be considered before an event is the impact on people's life through development of emergency plans, the evaluation of the efficiency of evacuation procedures and of the emergency management capacity, the assessment of the vulnerability of the system and the monitoring and prediction of hazardous events. Additional elements include: land-use planning, settlements status, housing, shelters, population density, critical infrastructure, interdependency, accessibility, agriculture (crops and livestock), ecosystems. The following elements should also be considered: buildings, location, critical infrastructure, industry, business disruption.

b. **During the event**: measuring 'in the field' during an event can be sensitive (e.g. access restrictions; e.g. *Beaven et al. (2016), Gaillard and Gomez (2015)*), however, important elements to consider include: social and institutional interactions, search and rescue, and medical care. Precious data sources could involve social and professional media and remote observations (i.e. photos, images, videos). In case of a long-lasting event it is important to monitor the damage to infrastructure, (e.g. corrosion or degradation through repeated impacts), efficiency of systems (e.g. electricity usage (open access), lifeline access to data may be restricted (privatised vs public). Risk assessments should ideally be continuously updated accounting for the evolution of hazard, vulnerability and exposure.

c. **After the event**: after an event it is important to collect post-eruption damage data (e.g. number of buildings suffering roof collapse in relation to both material of roofs and thickness/load of tephra fall), assess the causes of damages and losses through forensic studies and assess the recovery of the system (e.g. housing, employment, business, critical infrastructure) over time. Interviews and focus groups should be carried out in order to assess the perceptions on future vulnerability. Physical, socio-economic and systemic vulnerability should be assessed beyond most impacted areas. Public health and general well-being should also be addressed through psychological and general practitioner visits. Impact on the agricultural sector should be assessed in detail in relation to food supply. Timelines of recovery/change of ecosystem and biodiversity should also be monitored (it may increase).

[40] Vulnerability elements to be considered also vary for different hazards. As a result, vulnerability assessments should be carried out individually for different hazards depending on context and purpose although cumulative vulnerability from multiple hazards should also be considered. In particular, physical vulnerability mostly requires hazards to be considered separately, while humanitarian/life safety might require integration of all hazards simultaneously (e.g. multi-hazard approach to design shelters).

[41] Examples of vulnerability elements to be considered for different hazards:

a. **Tephra fall** – physical: roof features (material, pitch, geometry, openings), susceptibility of crops and other infrastructure; social: health (respiratory problems); systemic: accessibility, transport, communications; economic: clean-up operations, aviation; environmental: clean-up, corrosion, contamination of crops and water supplies
b. **PDCs and lahars** – physical: features of buildings (material, openings and protection of openings, geometry, orientation), rebuilding/returning; systemic: blockages of roads cutting access for communities to evacuate, supply chains; economic: structure of towns/features of infrastructures
c. **Lava flows** – physical: features of buildings, fires, rebuilding/returning, flow thickness, temperature thresholds; systemic: blockages of roads cutting access for communities to evacuate, supply chains; economic: structure of towns/features of infrastructures; cultural heritage: can excavate sites of importance
d. **Volcanic gases and aerosols** – physical and systemic: corrosion on buildings (metallic components) and critical infrastructures (e.g. electricity, communications); social: health impacts; economic: impact on agriculture.

5 Recommendations and research priorities

5.1 Communication within the volcanic risk community

[42] The volcanic risk community agrees that there is a need to strengthen collaborative research and partnership building across disciplines and with stakeholders. A common language is needed to facilitate collaboration within the volcanic risk community and optimize the research effort across disciplines.

5.2 Good practice

[43] Defining good practices or guidelines (somewhat more prescriptive) helps communities move forward. With respect to risk assessments, the development of good practice would help collect data (e.g. non-traditional data: social media, internet; citizen science; communities/authorities) and store / share data (e.g. USHAHIDI, volcanic risk platform). Good practice could be based on existing guidelines for risk reduction strategies associated with other hazards (e.g. earthquakes), and/or global frameworks (e.g. ISO EU – Iceland strategies are based on these). There is a need to develop a framework to record and catalogue post-eruption damage data that is widely accepted, recognized and used by the volcanic risk community (as it is done, for example, by the European seismic risk community with the European Macroseismic Scale 98).

5.3 Methodology

[44] Risk assessments should be co-designed and co-produced between scientists and stakeholders as they should answer specific needs. Efficient risk assessment needs to be built on trust (e.g. community involvement). There should also be some consistent messaging across all entities and relationships with public and social media.

[45] Harmonisation of approaches is needed but country differences also need to be recognized and being aware of cultural context is critical. A review of existing case studies should be conducted in order to identify existing methodologies, methodology/data gaps, and lessons learnt. An assessment of the utility and advancement of research towards better risk reduction is needed. Among other methods that can be proposed, a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis of our research experience could be conducted in order to advance more efficiently as a community.

[46] Existing approaches for assessing various dimensions of vulnerability (e.g. physical, social, systemic, economic) should be refined and better adapted to the volcanic case (e.g. methods are more developed for physical vulnerability to tephra fall and less developed for local-scale economic indicators, and social and systemic vulnerability need to be much better understood in the volcanic context). A dynamic and comprehensive volcanic risk framework should integrate multiple hazards and multiple dimensions of vulnerabilities at multiple scales (spatial and temporal). This framework should not be prescriptive, nor necessarily form the basis of a standard risk model. Rather, it is intended to capture the main dimensions of vulnerability and where they fit within the larger risk context. This is a significant undertaking limited by both inadequate data and method availability. There are many general vulnerability frameworks in the literature (see reviews by *Wisner (2016)* and by *ENSURE project*: http://ensure.metid.polimi.it/web/guest/training). These are generic and could well apply to volcanoes, but typically focus more on root causes, than on specific dimensions of the direct vulnerability. They generally highlight that economic inequalities and poor governance are fundamental in controlling the distribution and magnitude of impacts.

[47] A sensitivity analysis of risk assessment should be carried out in order to identify the key / crucial dimensions to consider and prioritize the effort. This requires first the development of a holistic understanding of how all dimensions of vulnerability interact and feedback. A strategy should also be developed in order to assess the effectiveness of risk assessment.

5.4 Research priorities

[48] Forensic analysis should be applied to dissect the key drivers of vulnerability and how they can be measured. A recovery dataset should also be created starting with the few well studied areas (e.g. Patagonia, Philippines, Iceland and Japan).

[49] The scientific evidence required to enable decisions about thresholds for action and evaluating compound risk needs to be determined: e.g. for risk assessment used in emergency management: what is the best way to determine a radius of evacuation, for example, that is not overly cautious, but also does not impose unnecessary danger? And what evidence does a decision maker need in order to do this in light of potential cascading consequences (i.e. compound risk)? How to prioritize evacuation, e.g. who should evacuate first considering the existing vulnerabilities?

[50] Critical gaps in risk assessment across or within a context should be identified. Critical gaps between knowledge and actions to increase preparedness should also be identified. Ideally, communities at-risk should participate in risk assessments because they can provide context and meaning to data that are collected. Interdependencies amongst different hazards and different dimensions of vulnerability should be addressed. Propagation of uncertainty from the assessment of hazard and vulnerability to the compilation of risk assessment should be evaluated and incorporated in the final outcomes. An effort should also be made in reducing uncertainty (i.e. strengthen the research aspect to better constrain various dimensions of hazard and vulnerability).

[51] Key priorities for volcanic vulnerability include:

a. Better characterization of specific vulnerability dimensions:
   i. Socio-economic dimension (e.g. livelihood, poverty)
   ii. Institutional dimension (e.g. emergency management); including drivers for development (very different in different countries/cities)
   iii. Systemic dimension; including lifelines, infrastructures and identification of possible cascading failures
   iv. Physical vulnerability for agriculture (crucial to food security)

b. Identification of the hazards that are most important in terms of:
   i. Health, casualties and loss of life
   ii. Building and infrastructure damage
   iii. Business and network disruption

c. Construction of reliable fragility curves to relate modelled hazard intensity to expected impacts

[52] Key priorities for volcanic impact include:

a. Identification of impacts beyond the immediate area of acute damage
b. Comprehension of cascading consequences of an eruption that communities may face and how these issues can be incorporated /addressed in preparedness activities, response, and recovery plans in an integrated approach
c. Collection of detailed damage/impact data syn- and post-eruption

[53] Key priorities for risk assessment include:

a. A definition of risk assessment must be decided and agreed upon for those collaborating or communicating about risk. In fact, risk assessment means many different things to different people, which does makes collaborations more challenging.
b. Quantification of the uncertainty at different levels (e.g. monitoring, forecasting, hazard assessment, vulnerability assessment, exposure assessment, risk assessment)
c. Development of more reliable evaluations of potential eruptive scale and time of eruption occurrence based on the monitored parameters in pre-event phases
d. Strategy for risk assessment in case of underestimated/incomplete knowledge of associated hazards and scenarios due to rare and infrequent eruptive events
e. Implementation of the dynamic aspect of risk during long-lasting eruptions as well as for long-term risk assessments (e.g. rate of population growth/urbanization)

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Appendix 2. Workshop program

27 June – Day 1

8:00 – 8:30	**REGISTRATION**	**Ground floor**
8:30 – 8:45	Welcome and Workshop Opening (Costanza Bonadonna)	Room H8-01-D
	THEME 1: Volcanic risk assessment: current perspectives	
8:45 – 10:30	*Talks:* ➢ Sue Loughlin (BGS, GVM) "Needs for volcanic risk assessment worldwide" ➢ Pascal Peduzzi (GRID-Geneva) "The GAR approach to risk assessment" ➢ Sahar Safaie (Canada, Sage Risk Management) "Relevance of Understanding Volcanic Risk: From Sendai Framework Implementation to Planning My Life In Guatemala" ➢ Guðrún Jóhannesdóttir (CP, Iceland) "From risk assessments to mitigation measures for volcanic eruptions" ➢ Domenico Mangione (CP, Italy) "Risk assessment from a civil protection perspective"	*Moderator: S. Takarada* *Rapporteurs: A. Bear-Crozier; P. Jarvis (UNIGE)*
10:30 – 11:00	*Coffee Break*	
11:00 – 12:30	Breakout sessions	Room H8-01-D
12:30 – 13:00	Plenary	Room H8-01-D
13:00 – 14:00	*Lunch*	
	THEME 2: How to analyse vulnerability in a volcanic context – Part I	
14:00 – 15:45	*Talks:* ➢ Russell Blong (Macquarie University, AU) "Analysing vulnerability" ➢ Giulio Zuccaro (Univ. of Naples Federico II) "Physical vulnerability for quantitative risk assessments" ➢ Tom Wilson (Univ. of Canterbury, NZ) "What's the Consequence? Using field and laboratory volcanic impact assessment approaches to inform volcanic vulnerability assessment" ➢ Luis Martins (GEM) "Assessing the impact from earthquakes and volcanoes: what is different and what is not" ➢ Chris Gregg (East Tennessee State University) "Social Vulnerability" (via SKYPE)	*Moderator: C. Magill* *Rapporteurs: K. Wallace; A. Fries (UNIGE)*
15:45 – 16:15	*Coffee Break*	
16:15 – 17:45	Breakout sessions	Room H8-01-D
17:45 – 18:30	Plenary, Poster presentation	Room H8-01-D
20:00	*Workshop Dinner – Café Papon*	Geneva old town

28 June – Day 2

	THEME 2: How to analyse vulnerability in a volcanic context – Part II	Room H8-01-D
8:30 – 10:00	*Talks:* ➢ Scira Menoni (Politecnico di Milano, Italy) "Aspects and concepts of systemic vulnerability applied to volcanic risk assessment: learning lessons from real events and improving modelling capacity" ➢ Giulia Pesaro (Politecnico di Milano, Italy) "Economic vulnerability in disasters: lessons learnt from the field" ➢ Susanna Jenkins (EOS, Singapore) "Case study vulnerability assessments across volcanic hazards" ➢ Eliza Calder (University of Edinburgh) "The 3 June 2018 eruption of Fuego volcano, Guatemala: hazard, vulnerability and risk in a dynamic environment"	*Moderator: F. Viveiros* *Rapporteurs: J. Phillips; A. Fries (UNIGE)*
10:00 – 10:30	*Coffee Break*	
10:30 – 12:00	Breakout sessions	Room H8-01-D
12:00 – 12:30	Plenary, Poster presentation	Room H8-01-D
12:30 – 13:30	*Lunch*	
	THEME 3: How to combine hazard and vulnerability in a volcanic context	Room H8-01-D
13:30 – 15:00	*Talks:* ➢ Cees Van Westen (ITC, Netherlands) "Changing multi-hazard risk assessment after major disasters" ➢ Jenni Barclay (Univ. of East Anglia, UK) "The Ultimate Volcanic Risk Equation: Myth or Reality? Risk in practice in the STREVA study regions" ➢ Sebastien Biass (EOS, Singapore) "Scenarios in volcanology: causes and implications of deterministic and probabilistic choices" ➢ Adriana Galderisi (Univ. of Campania, Italy) "Scenario-based approach to understand the multi-temporal and multi-scale consequences of volcanic eruptions"	*Moderator: M. Kervyn* *Rapporteurs: J. Crummy ; P. Jarvis (UNIGE)*
15:00 – 15:30	*Coffee Break*	
15:30 – 17:00	Breakout sessions	Room H8-01-D
17:00 – 17:30	Plenary	Room H8-01-D
17:30 – 18:00	Workshop Closing	Room H8-01-D

29 June – Day 3

This half-day was dedicated to the compilation of the consensual document, which was then circulated among all participants for review.

8:30 – 10:00	**Compilation of consensual document - I:**	*Costanza Bonadonna, Sebastien Biass, Eliza Calder, Corine Frischknecht, Chris Gregg, Susanna Jenkins, Sue Loughlin, Scira Menoni, Tom Wilson, Shinji Takarada*
10:00 – 10:30	*Coffee Break*	
10:30 – 12:30	**Compilation of consensual document – II:**	
12:30 – 13:30	*Lunch*	

Appendix 3. UNISDR Terminology on Disaster Risk Reduction

Basic definitions on disaster risk reduction to promote a common understanding on the subject for use by the public, authorities and practitioners (source: https://www.unisdr.org/we/inform/terminology)

The open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction was established by the General Assembly in its resolution 69/284 for the development of a set of possible indicators to measure global progress in the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, coherent with the work of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators, and the update of the publication entitled "2009 UNISDR Terminology on Disaster Risk Reduction". The report (https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf) was adopted by the United Nations General Assembly on February 2nd, 2017.

Affected (02 Feb 2017)

People who are affected, either directly or indirectly, by a hazardous event. Directly affected are those who have suffered injury, illness or other health effects; who were evacuated, displaced, relocated or have suffered direct damage to their livelihoods, economic, physical, social, cultural and environmental assets. Indirectly affected are people who have suffered consequences, other than or in addition to direct effects, over time, due to disruption or changes in economy, critical infrastructure, basic services, commerce or work, or social, health and psychological consequences.

Annotation: People can be affected directly or indirectly. Affected people may experience short-term or long-term consequences to their lives, livelihoods or health and to their economic, physical, social, cultural and environmental assets. In addition, people who are missing or dead may be considered as directly affected.

Build back better (02 Feb 2017)

The use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment.

Annotation: The term "societal" will not be interpreted as a political system of any country.

Building code (02 Feb 2017)

A set of ordinances or regulations and associated standards intended to regulate aspects of the design, construction, materials, alteration and occupancy of structures which are necessary to ensure human safety and welfare, including resistance to collapse and damage.

Annotation: Building codes can include both technical and functional standards. They should incorporate the lessons of international experience and should be tailored to national and local circumstances. A systematic regime of enforcement is a critical supporting requirement for the effective implementation of building codes.

Capacity (02 Feb 2017)

The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.

Annotation: Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

<u>Coping capacity</u> is the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

<u>Capacity assessment</u> is the process by which the capacity of a group, organization or society is reviewed against desired goals, where existing capacities are identified for maintenance or strengthening and capacity gaps are identified for further action.

<u>Capacity development</u> is the process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals. It is a concept that extends the term of capacity-building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems and the wider enabling environment.

Contingency planning (02 Feb 2017)

A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses.

Annotation: Contingency planning results in organized and coordinated courses of action with clearly identified institutional roles and resources, information processes and operational arrangements for specific actors at times of need. Based on scenarios of possible emergency conditions or hazardous events, it allows key actors to envision, anticipate and solve problems that can arise during disasters. Contingency planning is an important part of overall preparedness. Contingency plans need to be regularly updated and exercised.

Critical infrastructure (02 Feb 2017)

The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society.

Disaster (02 Feb 2017)

A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Annotations: The effect of the disaster can be immediate and localized, but is often widespread and could last for a long period of time. The effect may test or exceed the capacity of a community or society to cope using its own resources, and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels.

Emergency is sometimes used interchangeably with the term disaster, as, for example, in the context of biological and technological hazards or health emergencies, which, however, can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society.

Disaster damage occurs during and immediately after the disaster. This is usually measured in physical units (e.g., square meters of housing, kilometres of roads, etc.), and describes the total or partial destruction of physical assets, the disruption of basic services and damages to sources of livelihood in the affected area.

Disaster impact is the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.

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

- Small-scale disaster: a type of disaster only affecting local communities which require assistance beyond the affected community.
- Large-scale disaster: a type of disaster affecting a society which requires national or international assistance.
- Frequent and infrequent disasters: depend on the probability of occurrence and the return period of a given hazard and its impacts. The impact of frequent disasters could be cumulative, or become chronic for a community or a society.
- A slow-onset disaster is defined as one that emerges gradually over time. Slow-onset disasters could be associated with, e.g., drought, desertification, sea-level rise, epidemic disease.
- A sudden-onset disaster is one triggered by a hazardous event that emerges quickly or unexpectedly. Sudden-onset disasters could be associated with, e.g., earthquake, volcanic eruption, flash flood, chemical explosion, critical infrastructure failure, transport accident.

Disaster loss database (02 Feb 2017)

A set of systematically collected records about disaster occurrence, damages, losses and impacts, compliant with the Sendai Framework for Disaster Risk Reduction 2015-2030 monitoring minimum requirements.

Disaster management (02 Feb 2017)

The organization, planning and application of measures preparing for, responding to and recovering from disasters.

Annotation: Disaster management may not completely avert or eliminate the threats; it focuses on creating and implementing preparedness and other plans to decrease the impact of disasters and "build back better". Failure to create and apply a plan could lead to damage to life, assets and lost revenue.

Emergency management is also used, sometimes interchangeably, with the term disaster management, particularly in the context of biological and technological hazards and for health emergencies. While there is a large degree of overlap, an emergency can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society.

Disaster risk (02 Feb 2017)

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Annotation: The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped, in broad terms at least.

It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.

Acceptable risk, or tolerable risk, is therefore an important subterm; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.

Residual risk is the disaster risk that remains even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

Disaster risk assessment (02 Feb 2017)

A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

Annotation: Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.

Disaster risk governance (02 Feb 2017)

The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy.

Annotation: Good governance needs to be transparent, inclusive, collective and efficient to reduce existing disaster risks and avoid creating new ones.

Disaster risk information (02 Feb 2017)

Comprehensive information on all dimensions of disaster risk, including hazards, exposure, vulnerability and capacity, related to persons, communities, organizations and countries and their assets.

Annotation: Disaster risk information includes all studies, information and mapping required to understand the disaster risk drivers and underlying risk factors.

Disaster risk management (02 Feb 2017)

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

Annotation: Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management.

Prospective disaster risk management activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place. Examples are better land-use planning or disaster-resistant water supply systems.

Corrective disaster risk management activities address and seek to remove or reduce disaster risks which are already present and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.

Compensatory disaster risk management activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced. They include preparedness, response and recovery activities, but also a mix of different financing instruments, such as national contingency funds, contingent credit, insurance and reinsurance and social safety nets.

Community-based disaster risk management promotes the involvement of potentially affected communities in disaster risk management at the local level. This includes community assessments of hazards, vulnerabilities and capacities, and their involvement in planning, implementation, monitoring and evaluation of local action for disaster risk reduction.

Local and indigenous peoples' approach to disaster risk management is the recognition and use of traditional, indigenous and local knowledge and practices to complement scientific knowledge in disaster risk assessments and for the planning and implementation of local disaster risk management.

Disaster risk management plans set out the goals and specific objectives for reducing disaster risks together with related actions to accomplish these objectives. They should be guided by the Sendai Framework for Disaster Risk Reduction 2015 2030 and considered and coordinated within relevant development plans, resource allocations and programme activities. National-level plans need to be specific to each level of administrative responsibility and adapted to the different social and geographical circumstances that are present. The time frame and responsibilities for implementation and the sources of funding should be specified in the plan. Linkages to sustainable development and climate change adaptation plans should be made where possible.

Disaster risk reduction (02 Feb 2017)

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Annotation: Disaster risk reduction is the policy objective of disaster risk management, and its goals and objectives are defined in disaster risk reduction strategies and plans.

Disaster risk reduction strategies and policies define goals and objectives across different timescales and with concrete targets, indicators and time frames. In line with the Sendai Framework for Disaster Risk Reduction 2015-2030, these should be aimed at preventing the creation of disaster risk, the reduction of existing risk and the strengthening of economic, social, health and environmental resilience.

A global, agreed policy of disaster risk reduction is set out in the United Nations endorsed Sendai Framework for Disaster Risk Reduction 2015-2030, adopted in March 2015, whose expected outcome over the next 15 years is: "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".

Early warning system (02 Feb 2017)

An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.

Annotations: Effective "end-to-end" and "people-centred" early warning systems may include four interrelated key elements: (1) disaster risk knowledge based on the systematic collection of data and disaster risk assessments; (2) detection, monitoring, analysis and forecasting of the hazards and possible consequences; (3) dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and

(4) preparedness at all levels to respond to the warnings received. These four interrelated components need to be coordinated within and across sectors and multiple levels for the system to work effectively and to include a feedback mechanism for continuous improvement. Failure in one component or a lack of coordination across them could lead to the failure of the whole system.

Multi-hazard early warning systems address several hazards and/or impacts of similar or different type in contexts where hazardous events may occur alone, simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects. A multi-hazard early warning system with the ability to warn of one or more hazards increases the efficiency and consistency of warnings through coordinated and compatible mechanisms and capacities, involving multiple disciplines for updated and accurate hazards identification and monitoring for multiple hazards.

Economic loss (02 Feb 2017)

Total economic impact that consists of direct economic loss and indirect economic loss.

Direct economic loss: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage.

Indirect economic loss: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts.

Annotations: Examples of physical assets that are the basis for calculating direct economic loss include homes, schools, hospitals, commercial and governmental buildings, transport, energy, telecommunications infrastructures and other infrastructure; business assets and industrial plants; and production such as crops, livestock and production infrastructure. They may also encompass environmental assets and cultural heritage.

Direct economic losses usually happen during the event or within the first few hours after the event and are often assessed soon after the event to estimate recovery cost and claim insurance payments. These are tangible and relatively easy to measure.

Indirect economic loss includes microeconomic impacts (e.g., revenue declines owing to business interruption), mesoeconomic impacts (e.g., revenue declines owing to impacts on natural assets, interruptions to supply chains or temporary unemployment) and macroeconomic impacts (e.g., price increases, increases in government debt, negative impact on stock market prices and decline in GDP). Indirect losses can occur inside or outside of the hazard area and often have a time lag. As a result they may be intangible or difficult to measure.

Evacuation (02 Feb 2017)

Moving people and assets temporarily to safer places before, during or after the occurrence of a hazardous event in order to protect them.

Annotation: Evacuation plans refer to the arrangements established in advance to enable the moving of people and assets temporarily to safer places before, during or after the occurrence of a hazardous event. Evacuation plans may include plans for return of evacuees and options to shelter in place.

Exposure (02 Feb 2017)

The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Annotation: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Extensive disaster risk (02 Feb 2017)

The risk of low-severity, high-frequency hazardous events and disasters, mainly but not exclusively associated with highly localized hazards.

Annotation: Extensive disaster risk is usually high where communities are exposed to, and vulnerable to, recurring localized floods, landslides, storms or drought. Extensive disaster risk is often exacerbated by poverty, urbanization and environmental degradation.

Hazard (02 Feb 2017)

A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Annotations: Hazards may be natural, anthropogenic or socionatural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards, or human-induced hazards, are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are socionatural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.

Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission.

Multi-hazard means (1) the selection of multiple major hazards that the country faces, and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects.

Hazards include (as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030, and listed in alphabetical order) biological, environmental, geological, hydrometeorological and technological processes and phenomena.

Biological hazards are of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Examples are bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents.

Environmental hazards may include chemical, natural and biological hazards. They can be created by environmental degradation or physical or chemical pollution in the air, water and soil. However, many of the processes and phenomena that fall into this category may be termed drivers of hazard and risk rather than hazards in themselves, such as soil degradation, deforestation, loss of biodiversity, salinization and sea-level rise.

Geological or geophysical hazards originate from internal earth processes. Examples are earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses and debris or mud flows. Hydrometeorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize: although they are triggered by undersea earthquakes and other geological events, they essentially become an oceanic process that is manifested as a coastal water-related hazard.

Hydrometeorological hazards are of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges. Hydrometeorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and in the transport and dispersal of toxic substances and volcanic eruption material.

Technological hazards originate from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. Examples include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires and chemical spills. Technological hazards also may arise directly as a result of the impacts of a natural hazard event.

Hazardous event (02 Feb 2017)

The manifestation of a hazard in a particular place during a particular period of time.

Annotation: Severe hazardous events can lead to a disaster as a result of the combination of hazard occurrence and other risk factors.

Intensive disaster risk (02 Feb 2017)

The risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards.

Annotation: Intensive disaster risk is mainly a characteristic of large cities or densely populated areas that are not only exposed to intense hazards such as strong earthquakes, active volcanoes, heavy floods, tsunamis or major storms but also have high levels of vulnerability to these hazards.

Mitigation (02 Feb 2017)

The lessening or minimizing of the adverse impacts of a hazardous event.

Annotation: The adverse impacts of hazards, in particular natural hazards, often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that, in climate change policy, “mitigation” is defined differently, and is the term used for the reduction of greenhouse gas emissions that are the source of climate change.

02 Feb 2017

National Platform for Disaster Risk Reduction (02 Feb 2017)

A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multisectoral and interdisciplinary in nature, with public, private and civil society participation involving all concerned entities within a country.

Annotations: Effective government coordination forums are composed of relevant stakeholders at national and local levels and have a designated national focal point. For such mechanisms to have a strong foundation in national institutional frameworks, further key elements and responsibilities should be established through laws, regulations, standards and procedures, including: clearly assigned responsibilities and authority; building awareness and knowledge of disaster risk through the sharing and dissemination of non-sensitive disaster risk information and data; contributing to and coordinating reports on local and national disaster risk; coordinating public awareness campaigns on disaster risk; facilitating and supporting local multisectoral cooperation (e.g., among local governments); and contributing to the determination of and reporting on national and local disaster risk management plans and all policies relevant for disaster risk management.

Preparedness (02 Feb 2017)

The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.

Annotation: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery.

Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, the stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term “readiness” describes the ability to quickly and appropriately respond when required.

A preparedness plan establishes arrangements in advance to enable timely, effective and appropriate responses to specific potential hazardous events or emerging disaster situations that might threaten society or the environment.

Prevention (16 Feb 2017)

Activities and measures to avoid existing and new disaster risks.

Annotations: Prevention (i.e., disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts of hazardous events. While certain disaster risks cannot be eliminated, prevention aims at reducing vulnerability and exposure in such contexts where, as a result, the risk of disaster is removed. Examples include dams or embankments that eliminate flood risks, land-use regulations that do not permit any settlement in high-risk zones, seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake and immunization against vaccine-preventable diseases. Prevention measures can also be taken during or after a hazardous event or disaster to prevent secondary hazards or their consequences, such as measures to prevent the contamination of water.

Reconstruction (02 Feb 2017)

The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.

Recovery (02 Feb 2017)

The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.

Rehabilitation (02 Feb 2017)

The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster.

Residual risk (02 Feb 2017)

The disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.

Annotation: The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

Resilience (02 Feb 2017)

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Response (02 Feb 2017)

Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Annotation: Disaster response is predominantly focused on immediate and short-term needs and is sometimes called disaster relief. Effective, efficient and timely response relies on disaster risk-informed preparedness measures, including the development of the response capacities of individuals, communities, organizations, countries and the international community.

The institutional elements of response often include the provision of emergency services and public assistance by public and private sectors and community sectors, as well as community and volunteer participation. "Emergency services" are a critical set of specialized agencies that have specific responsibilities in serving and protecting people and property in emergency and disaster situations. They include civil protection authorities and police and fire services, among many others. The division between the response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage.

Retrofitting (02 Feb 2017)

Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

Annotation: Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from particular hazards or hazard scenarios and the practicality and costs of different retrofitting options. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows and improving the protection of important facilities and equipment.

Risk transfer (02 Feb 2017)

The process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.

Annotation: Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer. Risk transfer can occur informally within family and community networks where there are reciprocal expectations of mutual aid by means of gifts or credit, as well as formally, wherein governments, insurers, multilateral banks and other large risk-bearing entities establish mechanisms to help cope with losses in major events. Such mechanisms include insurance and reinsurance contracts, catastrophe bonds, contingent credit facilities and reserve funds, where the costs are covered by premiums, investor contributions, interest rates and past savings, respectively.

Structural and non-structural measures (02 Feb 2017)

Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non-structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Annotation: Common structural measures for disaster risk reduction include dams, flood levies, ocean wave barriers, earthquake-resistant construction and evacuation shelters. Common non-structural measures include building codes, land-use planning laws and their enforcement, research and assessment, information resources and public awareness programmes. Note that in civil and structural engineering, the term “structural” is used in a more restricted sense to mean just the load-bearing structure, and other parts such as wall cladding and interior fittings are termed “non-structural”.

Underlying disaster risk drivers (02 Feb 2017)

Processes or conditions, often development-related, that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity.

Annotation: Underlying disaster risk drivers — also referred to as underlying disaster risk factors — include poverty and inequality, climate change and variability, unplanned and rapid urbanization and the lack of disaster risk considerations in land management and environmental and natural resource management, as well as compounding factors such as demographic change, non disaster risk-informed policies, the lack of regulations and incentives for private disaster risk reduction investment, complex supply chains, the limited availability of technology, unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics.

Vulnerability (02 Feb 2017)

The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Annotation: For positive factors which increase the ability of people to cope with hazards, see also the definitions of “Capacity” and “Coping capacity”.