Transcript: Introduction to Multi-hazards

Slide 3: In this introduction to Multi-hazards I am going to cover: What are multi-hazards, The importance of understanding multi-hazards, The different types and scales of multi-hazards, methods for modelling multi-hazards, and a few different ways of visualising multi-hazards.

Slide 4:What is a multi-hazard?

Before we consider what a multi-hazard is its important that we define a single hazard process. The United Nations Office for Disaster Risk Reduction (or UNDRR) states that a hazard is 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'. There are many models that have been developed to assess single hazards. These models vary, but fundamentally they make an attempt to quantify the nature, intensity and return period of specific hazards.

Multi-hazards, however are firstly the selection of multiple major hazards that a country faces and secondly, the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively overtime, taking into account the potential interrelated effects.

Slide 5: The importance of multi-hazards has long been recognised. In 1992 the United Nations Environment Program stated that pre-disaster planning should form an integral part of human settlement planning and that it should include the "Undertaking of complete multi-hazard research into risk and vulnerability of human settlements and settlement infrastructure, including water and sewerage, communication and transportation networks, as one type of risk reduction may increase vulnerability to another or example an earthquake-resistant house made of wood will be more vulnerable to wind storms'.

Furthermore, the 2015 Sendai Framework for Disaster Risk Reduction (SFDRR) recognises that "Disaster risk reduction practices need to be multi-hazard and multisectoral, inclusive and accessible in order to be efficient and effective".

Slide 6: In practice, assessing multi-hazard interactions is complicated. Each single hazard exhibits its own characteristics such as time of onset, duration and extent and because of this multi-hazard assessments have to be able to address: hazards may be related to each other, and potentially cumulative – something that we refer to as a hazard cascade, The impacts on elements at risk (such as buildings or infrastructure) can be different for differing hazards and occasionally may be opposing, the differences between the hazards characteristics and therefore the methods used to observe and monitor them, any of the existing measures of hazard quantification need to be adapted to allow for comparison of multiple hazards.

Slide 7: Not all multi-hazards are related to each other or to an area in the same way. These interactions can vary both spatially and temporally. The most comprehensive classification of the types of multi-hazards is a recent scheme defined by Tilloy et al. In this work the authors define 5 different hazard interrelations that demonstrate how hazards may be related to and effect each other:

The first of these types are independent hazards. Independent hazards are hazards whose causes are independent of each other but that have a spatial and / or temporal co-incidence. This may be, for example, the arrival of a tropical cyclone occurring simultaneously with a volcanic eruption. This was famously the case during the large eruption of Pintaubo volcano in the Philippines in 1991, when Typhoon Diding made landfall as the paroxysmal phase of the eruption began. This category of hazards can also take into account hazards that occur in the same place but at different times. For example, if a cyclone were to hit an area that had recently been impacted by an earthquake.

The second type of relationship defined in this scheme are Triggering or Cascading hazards. In this case there is an implication of a primary hazard that causes the onset of one or more secondary hazards. This secondary hazard maybe identical to or entirely different from the first. So, for example we may see an earthquake trigger a landslide – as occurred in Nepal in the 2015 Gorkha earthquake event. If an earthquake were to trigger a landslide, which then blocked a river and caused a flood, then this would be referred to as a hazard cascade.

The next type of hazards are those that create ‘Change Conditions’, by this we mean that the incidence of one hazard changes the probability of a further hazard occurring due to a change in background conditions. This maybe environmental conditions, for example when a wildfire causes areas of vegetation to become denuded and harden the underlying soil this can amplify the strength of following floods due to decreased infiltration and increased ground flow. This exact set of conditions in New Mexico in 2011 led to severe flooding a month after a large wildfire.

Compound hazards represent cases where the same primary event or large scale process can cause different hazards to occur. These hazards occur simultaneous and are therefore not considered to be ‘primary’ and ‘secondary’. For example, the co-occurrence of river flooding and sea surge that both result from the same cyclone event. This could be considered as a compound event.

The final type of hazard interaction is mutual exclusion. In this case we consider that two hazards have a negative dependency and therefore do not occur at the same time. This maybe something such as heavy rain and fire.

Slide 8: It is important to consider these interrelationships and the scales over which they occur, because it will have implications for how this multi-hazard information can be used.

If a hazard is only related to another hazard spatially for example, then we can assume that the hazards have different sources and can therefore occur at different times, even if they effect the same area. The spatial relationship of hazards may have implications for mitigation methods such as building codes and building design. It is possible that if these are not properly considered then the efforts made to stabilize a building from one hazard, may destabilise it in reference to another.

Slide 9: If a hazard is neither spatially nor temporally related to another event then we assume that these must be different hazards, occurring in different location at different times. This of course means that there is no relationship that may affect the physical vulnerability of buildings and / or infrastructure because of these hazards interacting. However, it may be important to consider the implications of this when considering public awareness and education campaigns at a national scale. So that populations can be informed of the hazards most relevant to them and their everyday lives.

Slide 10: Hazards that are related spatially and temporally occur at the same location, at the same time – potentially acting as triggering or compound hazards. Understanding the implications of hazard cascades or indeed of the simultaneous impact of hazards on: buildings, response and pre-positing planning. An area defined in a single hazard assessment scenario may be defined as low hazard, but when a multi-hazard aggregation is taken into account it may be that this location is more exposed to multiple events occurring at the same time of exacerbated by each other.

Slide 11: Finally, if hazards are only related temporarily to each other then we can assume that they are occurring at the same time but in different locations. This will have implications for emergency planners who may want to consider preparing for scenarios where they are called upon to manage two events from separate administrative units simultaneously, splitting resources and personnel.

Multi-hazard models can aim to address some or all of these interrelationships and scales, depending on the availability of underlying data and the purpose of the model.

Slide 12: The function of a multi-hazards model, is at the most the basic level, to develop a structured approach to aggregating two or more single hazard assessments so that they can be compared and potential integrated with vulnerability and exposure data.

The principle difficulty in the comparison of multiple hazards is that each hazard will have a distinct reference unit. Before any types of modelling can be employed it is necessary to perform some sort of standardisation of the data to a common measure. There are two main ways to do this that give rise to different types of modelling. These are: classification of hazards and development of indices. Depending on how these standardisation calculations are approached, a model can be thought to be qualitative, semi-quantitative or quantitative.

Slide 13: The classification of hazards is the most frequently used approach when standardising between hazards. Intensity and frequency thresholds are defined in order to classify the respective hazards into a predefined number of hazard classes (e.g. High, Medium and Low). This allows for an equivalency between hazards, a ‘high’ hazard earthquake would be in line with a ‘high’ hazard flood, for example. Classification creates compatibility between the hazard and vulnerability classes but also results in equivalence of all the single hazard classes, which may not reflect the frequency distribution of these hazards. Classification methods can therefore be thought of as ‘qualitative’ methods. The table on the right of this slide is an example of a hazard classification scheme that was developed as part of the European ARMONIA project. This simple scheme classifies the hazards as High, Medium or Low based on their intensity.

Slide 14: Comparatively to the classification method, the development of indices allows for a continuous standardisation of differing and therefore not directly comparable parameters. This is often achieved by developing indices that can then be uniquely weighted to reflect the more likely impact of the hazard or vulnerability class.

In their study that aims to identify areas in the Eastern Mediterranean where population are likely to be exposed to several hazards at the same time, El Morjani et al separately model a number of hazards which they then classify using separately defined thresholds. They then apply a weighting factor that accounts for the expected impact on humans and the economy. Once they have summed these weighted indices they are able to produce the multi-hazard index distribution map displayed here, defining five intensity levels of multi-hazards. The use of weighted indices in this study allows the authors to develop a semi-quantitative model which accounts for the different impacts of differing hazards.

Quantitative methods result in the calculation of absolute values on a determined scale. These therefore provide the most statistically robust information on potential damage or losses and are therefore predominantly developed by the re-insurance industries.

Slide 15: The complexities I have touched on in the previous slides have led to the development of many methodologies for assessing multi-hazards. It is perhaps not surprising that these methods can vary a lot from each other. There are several very useful and detailed reviews available that outline the current state of the art, the references for which can be found at the end of this talk.

Generally speaking, however, the variations of models fall into the following categories:

The type of hazard addressed; Some studies only address natural hazards, whereas others include anthropogenic hazards such as chemical spills or artificial hydrological changes, drainage and dewatering for example.

The scale of the model can vary greatly depending on the aims of the assessment. It may address an area as small as a city or catchment area or it may be designed to capture multi-hazards at a regional, national, continental or even global scale. Generally, those models that are designed for use at finer scale require a larger amount of input information than the models that have been designed for use over wider areas.

Depending on the focus of the study the model may require very different skill sets to collect the required input data. For example a study that focuses heavily on gathering detailed building information may require civil engineers to perform building surveys, a study requiring a focus on socio-economic parameters however will necessitate the inclusion of social scientists and economists during the data collection phase.

As I mentioned earlier the way in which a model standardises hazard data be it fully qualitative or fully quantitative is one of the key differences between the construction of the various available multi-hazard models. A fully quantitative approach usually requires that the user include probabilities calculated from well characterised frequency / magnitude relationships and complete inventories of economic, social and cultural impacts from previous events. As you can appreciate, for quantitative models we generally require a denser data set with well-established uncertainties. Semi-quantitative and qualitative models can be useful in cases where we don’t have access to this type of information.

For inputs, models may include only hazard information or may incorporate hazard and vulnerability data – for example the Disaster Risk Index by Peduzzi et al (2009), which includes hazard assessments as well as an assessment of 32 socio-economic indicators.

Finally an important variation is the type of end user that the model is aimed at. Models can be designed to provide information to: local authorities, urban planners, engineers, building owners, civil protection services, insurance companies or the public, this makes a difference in how they are constructed and what input parameters are included.

When designing a model for assessing multi-hazards it is important to consider variables such as these so that the final product is fit for purpose but also does not over-interpret the data available, allowing for uncertainties to be captured where possible. In the next presentation I will cover how we have developed a multi-hazard model to incorporate the single hazard and exposure assessments that have been generated as part of the METEOR project.

Slide 16: As well as making sure that you consider the inter-relationships between the hazards in your study, the scales that they occupy and the different methods and variations of modelling. It is necessary to consider how you may visualise the outputs of these models.

A single hazard visualisation refers to a set of maps that displays the single hazards ones by one. This is beneficial if you would like to observe and interpret the patterns for each process in detail. However, they are perhaps less useful than other methods as they keep data separated. One way to mitigate this is to arrange images next to each other so that attributes can be compared over several outputs. In the figure here we can see how this approach was used by Bartel and Muller in their risk analysis in the horn of Africa – in this study they separate out the different hazards such as flood, drought, earthquake and locusts and then display sets of maps for each one, projecting the hazard, exposure and risk separately.

Single hazard visualisations are often a first step towards understanding multi-hazards and are followed by a presentation of merged or joint variables

Slide 17: Visualising joint variables can be done in several different ways, variables can be summed, multiplied or counted thus reducing the multi-dimensionality to one parameter.

They can also be displayed as the number of relevant processes per pixel - as is shown in this simple representation from the World Bank's 'Natural Disaster Hotspots: Global Risk Analysis', which displays a multi-hazard index that reflects the number of hazards considered relatively significant in a particular grid cell.

It is also possible to display information such as the annual occurrence probability of the hazards addressed within a study. In the study by Bartel and Muller, they aggregate the single hazard visualisations from the previous slide to generate a hazard annual probability and most probable hazard output.

Slide 18: In contrast, maps that visualise multiple hazards or risk at once provide simultaneous information about hazard patterns and the spatial co-incidence of these. This can make figure busy and difficult to read, especially where hazards overlap. One way around this is to use an approach that divides hazards into type classes. This example from the 2009 Global Assessment Report (or GAR) divides hazards into weather related and tectonic hazards. This is just one of many approaches that have been taken by different authors. If you are interested in a summary of these methods then the review paper by Kappes et al., (2012) provides a great overview and also touches on digital GIS based maps that have the potential to be flexible visualisations.

Slide 19: The topic of multi-hazards has many different components and the above is designed to be a brief introduction only to highlight some of the parameters to keep in mind when exploring multi-hazard modelling.

Slide 20: In summary –

There are different types of hazard interrelations and scales of hazards. The comparison of hazards is difficult due to different process characteristics. Classification and index schemes can help to overcome this problem. There are many existing multi-hazard models that have been designed to address differing variables – it is therefore important to assess these parameters before apply or designing a model. Visualising multi-hazards is non-trivial and may require different outputs for different end users / purposes.

Slide 21: This is the end of this introductory talk on multi-hazards further information on all of the concepts discussed here can be found in these key references, which were used in the construction of this talk. The two review articles that I mentioned earlier are in bold font. In the next talk I will elaborate on how we have addressed multi-hazards in the METEOR project and show some initial results from our national models.