<u>Transcript:</u> Introduction to Disaster Risk Assessment for Earthquakes (Tanzania)

1. *[No script for this slide]*

2. Introduction to disaster risk assessment for earthquakes

3. First, I'd like to introduce the METEOR project, which enabled the creation of this video.

   METEOR stands for Modelling Exposure Through Earth Observation Routines, and was funded by the UK Space Agency through their International Partnership Program, as part of the Global Challenges Research Fund. The METEOR project aims to develop innovative application of earth observation technologies to improve understanding of exposure. Natural hazards have had escalating impacts, which are contributed to by an increasing exposure of population and assets. However, a major challenge when making disaster risk management decisions can be a poor understanding of the distribution and character of exposure. Robust quantitative methods are required to justify these decisions, and in this project we are looking at the use of earth observation technologies within that context.

   Within the METEOR project, there is also the aim to share knowledge. This video is produced as a part of a series of educational videos to enable the use of METEOR products and data.

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5. Disaster risk assessment is important because we need to be able to identify and understand our risk in order to reduce it. A comprehensive risk assessment can consider the range of underlying drivers and associated uncertainties.

   Using disaster risk models, we can raise the awareness of a community and promote local actions and inform decisionmakers so they can capture that risk in their planning decisions. Further, we can produce multiple disaster risk models to understand trends or to evaluate the benefit of proposed intervention strategies.

   In this particular video, we will focus on earthquake risk.

6. There are three components that make up risk: hazard, exposure, and vulnerability:

   The hazard component encompasses the likelihood of a potentially destructive phenomenon over time. For the case of earthquakes, this involves the estimation of frequency of different magnitude earthquake events from active faults in the region of interest, and what intensity of ground shaking they produce.

   The exposure component defines the location, value, and attributes of the assets of interest. For earthquakes, attributes that may be of interest include the construction material or year of construction.

   The vulnerability component relates the damageability of a given asset to a range of hazard values. This is often accomplished through fragility curves or vulnerability curves.

Finally, risk results from the spatial and temporal overlap of each of the three components. Different measures of risk, or losses, might include economic loss from damages, casualties, and business interruption.

I'll cover each of these components in more detail in the upcoming slides.

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8. Within a hazard model, there are two main components:

The seismic source characterization, or model, defines the location, frequency, and magnitude of all possible future earthquakes that could affect the region of interest.

The ground motion characterization is used to estimate the anticipated ground shaking generated by these earthquakes. This is a critical step, because damage of a given asset is directly related to the ground-shaking experienced at that asset's site and not solely based on the magnitude or size of a given earthquake rupture. Typically, ground motion prediction equations (GMPEs) are used for this purpose

Next, I will discuss some key features of each of these model subcomponents

9. Seismic sources, or faults, are planes of discontinuity in the earth's crust. When a seismic event occurs, only a portion of the fault breaks, which is called a rupture.

10. Here are examples of different fault styles, or mechanisms.

Both normal faults and reverse faults are types of dip-slip movements, where one side is moving predominantly up or down relative to the other. In the case of a "normal" fault, the hanging wall is moving downward (as we might expect under the force of gravity). If the hanging wall is moving upward, then it is called a "reverse" fault.

If the hanging wall is moving horizontally, then it is referred to as a strike-slip movement, Depending on the direction, it might be called a "right-lateral" or a "left-lateral" fault.

11. Some of the important geometric parameters of a rupture are the strike, drip, and rake.

The strike is the angle between the fault plane with the horizontal surface, relative to North, as indicated in green on the figures.

The dip is the angle between the fault and the horizontal plane. A vertical fault would have a dip of 90 degrees, while a horizontal fault would have a dip of 0 degrees. This is indicated by blue in the figures.

Lastly, the rake is the direction in which the hanging wall is moving during the rupture. A rake of 0 degrees means that the hanging wall is moving in the strike direction. If the rake is greater than 0 degrees, then the hanging wall is moving upwards (such as in a thrust or reverse fault). If the rake is less than 0 degrees, then the hanging wall is moving downwards (such as in a normal fault).

12. For the purposes of hazard or risk assessment, we define a seismic rupture using information about the fault source and the ground motion field that the rupture event produces.

    From the fault source, we need to specify information related to the geometry, the magnitude, and the mechanism.

    From the ground motion field, we want to know the intensity of ground shaking for a specific measure. For instance, we might be concerned with the peak ground acceleration, or PGA. These values are spatially distributed, such as for a radius from the earthquake epicenter.

13. To estimate ground motion fields, we often use ground motion prediction equations, or GMPEs.

    Ground motion prediction equations take information about the source, the source-to-site distance, and the site to estimate a distribution of ground shaking at the surface of a site given a rupture event.

    GMPEs are derived for specific ground motion intensity parameters. For example, the peak ground acceleration (PGA) or the spectral acceleration at a period of interest (SA).

    Common parameters required of GMPEs include the earthquake magnitude, the source-to-site distance, the faulting style or mechanism, the site location relative to the fault plane, and local site conditions.

14. It is important to note that there are several different distance metrics that are used with ground motion prediction equations. Common distance metrics include the Joyner-Boore distance, RJB, and the rupture distance, RRUP. The Joyner-Boore distance is the shortest distance between the surface projection of the rupture area and the site. The rupture distance is the distance between the hypocenter and the site.

15. It is also important to note that the ground motion at a given site for any one set of source parameters is variable. Therefore, ground motion prediction equations usually provide a distribution of different intensity levels.

    In seismic hazard modeling, it is common to use a truncation level for the ground motion prediction equations. Often, a truncation level of 3 is used, which for most GMPEs considers 99.7% the distribution. This is useful to avoid excessively high values of ground motion, which moreso arise from the mathematical models used than reality.

16. The conditions at a given site also affect the intensity of ground shaking.

    The most commonly used parameter to approximate this effect is the shear wave velocity in the top 30 meters, or VS,30. Softer soils, or those with lower VS,30, tend to amplify shaking at longer periods. This effect may be particularly important for urban areas located on historic lakebeds, such as Mexico City, or for built-up areas on top of fill. These effects are also impactful for taller buildings, which resonate or sway at longer time intervals, or periods.

17. There are two types of hazard calculations that might be performed, deterministic or probabilistic. Deterministic calculations are also referred to as scenario calculations, and will be the focus of this training series.

For the deterministic, or scenario, case, only an individual rupture event is investigated. This is useful for scenario planning exercises in disaster risk management, or as a validation exercise using historic events. For instance, we might want to look at a repeat of the 2020 Dar es Salaam earthquake for Tanzania. Alternatively, we might look at the hazard for the maximum magnitude event we expect to occur on the same fault. In this example, we look at both the actual magnitude of the event, an M6.0 and a hypothetical magnitude for a repeat of the event, an M7.0.

18. *[No script for this slide]*

19. The exposure model refers to the built environment and its contents and occupants, which are exposed to the seismic hazard.

The elements exposed can be individual assets, such as residential buildings and their inhabitants (as shown in the middle image), or schools and their students. However, the content and services they provide are also considered to be exposed to the hazard, as they may be damaged or interrupted due to a seismic event. Elements that do not have permanent occupation but have a significant heritage and cultural value for society may also be exposed. For example, religious temples (like the image on the left) or historical monuments.

In the same manner, we consider as exposed the infrastructure systems and networks. In this case, the exposure does not consist of one, but of several exposed assets that share a connectivity relationship with each other. These include sewage systems and telecommunication networks. Another good example is transport routes, such as the one shown in the image on the right, where damage to a single element, such as a bridge, can result in the interruption of the entire network.

Necessary parameters include the geographic location and the replacement values for all loss types of interest. For example, if one wants to calculate the number of casualties, then an estimate of the number of occupants is required. Alternatively, if economic losses due to damage area of interest, then an estimate of the capital stock of the building is required.

20. The geographic location of the exposed elements is necessary, as it indicates the source-to-site distance, which is required by ground motion prediction equations. Additionally, the location might indicate information related to the site conditions, such as the VS,30.

21. To understand the risk, it is necessary to identify the economic value and the number of people who are exposed to the hazard. For example, if you want to perform a risk analysis for residences, it is essential to identify all the housing facilities in the study area and how many residents occupy those housing facilities. It is also necessary to estimate how much it would cost to repair or replace each residence in the event of damage. This is called replacement value or cost since it is the cost incurred to the owner of the exposed asset in the event of its complete loss in a seismic event. The attributes of value and occupancy are considered indispensable in risk analysis, since without them it is not possible to quantify the potential for loss.

22. It is necessary to identify the physical characteristics of the exposed elements, to be able to classify them according to their fragility and seismic vulnerability.

Among the main physical attributes that must be identified are: the construction material, the structural system or system resistant to lateral loads, the height or number of floors and the construction method.

The structural attributes are considered essential since the damage or loss that an exposed element may suffer is a function of its physical and constructive state.

Let's take for example the two items shown in these images A and B. Both are single-family, masonry, two-storey residential structures. However, structure A is clay masonry, unreinforced and not properly confined. Most likely, this house was not designed following the construction normative to resist lateral loads imposed by earthquakes. Structure B, on the other hand, is made of concrete masonry, duly reinforced and confined, and is in good condition. Its construction most likely followed the construction regulations and was designed to support lateral loads. If these two structures, although similar in certain characteristics, were subjected to the same intensity of ground shaking, structure A would present much greater damage and loss than the other.

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24. The last critical component for risk assessment is the vulnerability.

By fragility and seismic vulnerability we mean the predisposition of the man-made environment, its contents and occupants to suffer damages and losses due to the ground shaking when an earthquake occurs. A fragility is associated with damage as a result of the seismic event, while vulnerability is associated with the loss, either economic or human, that results from such damage.

25. Let's start by taking a closer look at fragility. The concept of fragility is quite intuitive. We can see that there is a correlation between the level of intensity of the ground movement, and the level of damage suffered by an exposed element.

We can see in the images that, if there is no movement of the ground or lateral load, we should not see damage to the structure. Instead, we would expect that if a slight shaking of the ground occurs, it will produce visible damage, for example, in the form of cracks in the structure.

The greater the shaking, the greater the damage observed. The intensity of can be so great that it causes permanent damage to the structural elements, or even the collapse of the structure.

Although this process is continuous and occurs in a particular way in each structure, risk modelers usually discretize it in defined states of damage, for example, state of low, moderate, extensive and complete damage or collapse.

26. Damage states establish the level of damage that an exposed item will experience as certain demand parameters are met. For example, spectral acceleration, spectral displacement, interstory drift, inter storey acceleration, and so on.

A structure is considered in a specific state of damage when the ground shaking causes the limit established for the demand parameter to be exceeded. For example, the capacity curve in this image indicates that if the structure exceeds its ultimate spectral shift, it would end up in the state of complete damage or collapse.

27. The structural attributes of a building (e.g. construction material, construction system, height, design regulations) have a direct influence on its fragility, making it more or less resistant to ground shaking.

For example, these two curves correspond to two-story wooden structures, with the difference that the left represents a house without any earthquake-resistant provision, while the right represents a house designed and built following the guidelines established by the seismic regulations.

If we locate any intensity level on the X axis of the models, for example, a spectral acceleration of 0.6g, we can see that the structure without seismic regulations has a 60% probability of exceeding the light damage state compared to 25% probability of exceedance that would be obtained for the properly designed structure. In fact, it has a much higher chance of exceeding any of the stated damage states. That is why under the same level of seismic hazard, the most fragile structures present a higher level of seismic risk.

28. There is also a correlation between damage to a structure and the value it loses.

To understand the level of economic or human loss that results from damage to structural, non-structural components and contents, we use consequence or damage-to-loss models. The consequence models establish a relationship between the state of damage achieved and the percentage of the economic value or of occupants affected by reaching said state of damage. In this way, through the consequence model, the relationship described by a fragility model can become a vulnerability relationship.

We might specify consequence models for each level of damage by means of the expected value of loss (as in the graph on the left) or with its corresponding continuous distribution (as in the graph on the right).

29. Consequence models, such as shown on the previous slide, can be combined with fragility models to produce vulnerability models.

Example vulnerability models are shown here. We might model the variability of loss given an intensity of ground shaking as a continuous distribution, such as on the left, or we might estimate discrete probabilities of loss ratio such as on the right.

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31. Combining all of these components described earlier, we can conduct a risk assessment. In this video, we are focusing on deterministic, or scenario, earthquake risk analyses.

On the left-hand side, we have the inputs to our risk model. There is the hazard component, which is the definition of a seismic rupture of interest. Next, there is the exposure model, or location and description of the assets of interest. Finally, there is the vulnerability model, which entails either fragility or vulnerability curves which relate a seismic intensity with a level of damage and loss.

On the right-hand side, we have the outputs of our risk model. Typically, these include loss maps or loss statistics. I will show some examples of these in the next slides.

32. Here is an example of a scenario loss map for residences in Tanzania. In this map, we see that the darker red values indicate higher values of absolute loss. In general, we see these higher values of loss in locations that have higher population densities as there is an increased exposure there.

33. Next, we have an example of a loss ratio map where we normalize the results we saw on the previous slide by the exposed value. This map highlights areas where there is a combination of higher hazard and higher vulnerability.

34. That concludes this video, and thanks so much for watching. If you're interested in a hands-on exercise of what we discussed on this video, feel free to watch the companion demonstration video.