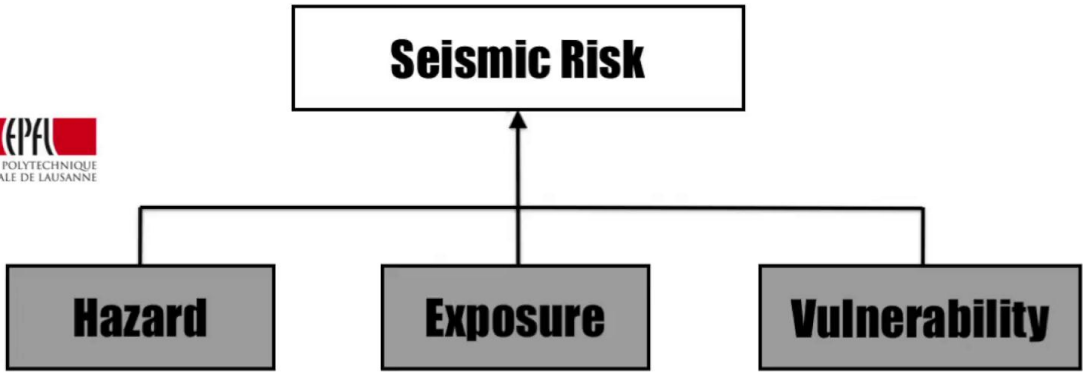

Seismic Risk: Overview and Calculation Models

A Resilient Future: Science and Technology for Disaster Risk Reduction

Dr. João Almeida
Former Postdoctoral Researcher
Earthquake Engineering and Structural Dynamics Laboratory

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Video

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Outline

- Components of seismic risk
- Exposure quantification
- Vulnerability quantification
- Calculation of seismic risk
- Main points

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Seismic Risk: Overview and Calculation Models Hello. This is João Almeida again. In one past video, I told you about seismic hazard and how it could be expressed by using different intensity parameters. Additionally, I mentioned that seismic hazard was one of the components required to compute seismic risk. In this video, I will tell you about the other components, namely, exposure and vulnerability, and briefly explain how they all come together to obtain a measure of seismic risk. I will also give you some examples of databases and tools that are currently available to compute components and risk in general.

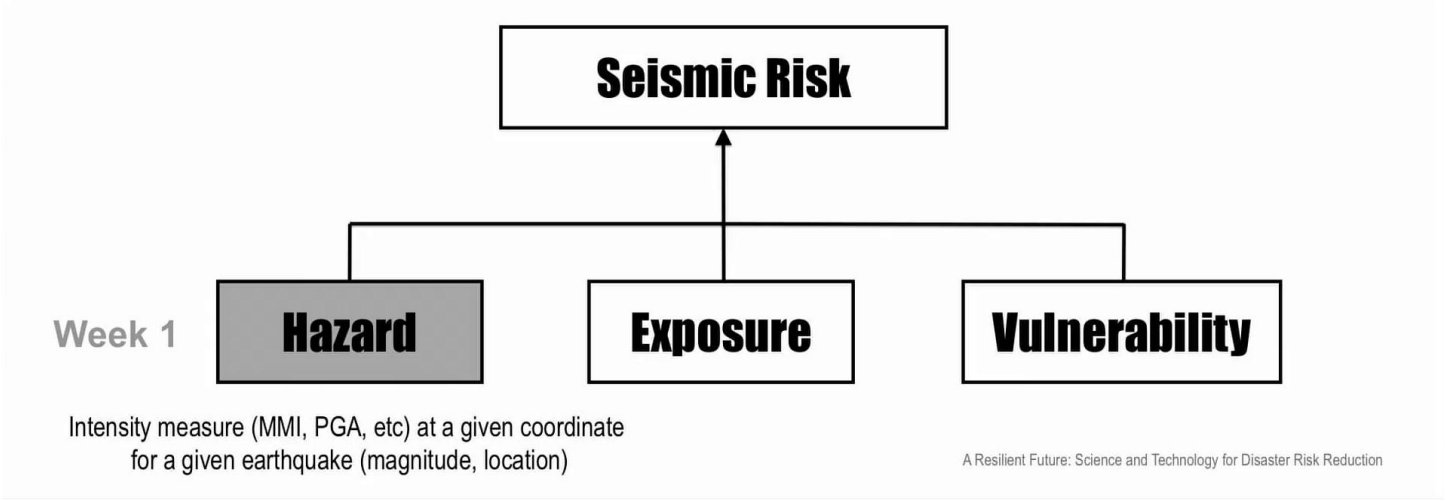
Notes

Summary

0m 00s

Components of seismic risk

Seismic Risk: The potential losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period due to earthquakes (Modified from UNISDR, 2009).



Seismic risk can be defined as "the probability of losses of different types, due to earthquakes in a particular region over a future time period." Ultimately we are interested in developing models that help us estimate the probability of loss due to a seismic event that has not yet occurred. To do so, we need to identify and assess, individually, each of the components that together make up seismic risk. These components are: the hazard, exposure, and vulnerability. The seismic hazard was discussed in detail in week one.

Notes

Summary

0m 43s

Exposure

Exposure: People, property, systems, or other elements present in hazard zones (so-called assets) that are thereby subject to potential losses (Modified from UNISDR, 2009).

Measures of exposure can include the number of people or types of assets in an area (UNISDR, 2009) Exposure models describe a set of assets grouped according to their geographical location, taxonomy and value (Crowley and Silva, 2013).

For what concerns exposure, these two photos illustrate the concept. They were taken from the same area. On the left, back in 1930, and on the right, more recently in 2005. It is apparent that unlike seismic hazard, exposure can be highly variable in time. Measures of exposure can include the number of people, GDP, buildings or others. And they are described by groups according to their geographical location, taxonomy, and value.

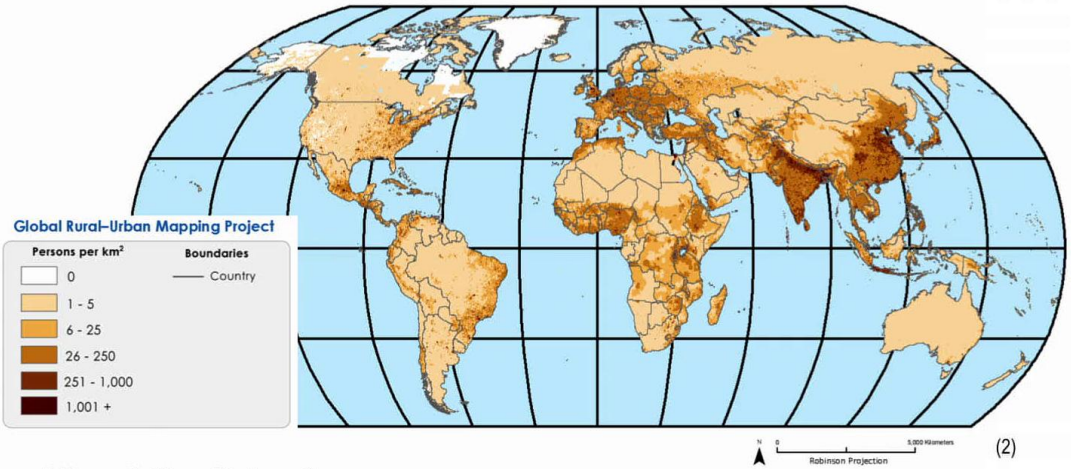
Notes

Summary

1m 24s

Exposure assessment

Population



(2)

Examples of Georeferenced Population Datasets:

1. Gridded Population of the World (GPW), version 3 – Publically accessible (Pozzi et al. 2003; Salvatore et al. 2005)
2. LandScan™ Global Population Database – Proprietary (Salvatore et al. 2005; Oak Ridge National Laboratory 2016)
3. Global Rural-Urban Mapping Project (GRUMP) – Publically accessible (SEDAC$_a$ 2016)

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Exposure models are based on global population distribution databases that consider both urban and rural areas. The data sources are censuses and surveys gathered at political or administrative units level. Various georeferenced global databases exist. They are generated with different methods. The project, Gridded Population of the World (GPW), was the first main effort to create a global georeferenced population data set. Available population data at the lowest sub-national administrative unit, is assigned uniformly across all the grid cells of the unit, without consideration of the type of area, urban or rural. By contrast, the LandScan Global Population Database distributes national populations following a model that takes into account different coefficients of population depending on the type of land cover. The use of aerial photography and high resolution satellite imagery helps to improve the collected data. This database also considers the average movement of individuals over 24 hours, the so-called *ambient population*. Finally, the Global Rural-Urban Mapping Project (GRUMP) combines the GPW with census and satellite data in order to build higher resolution gridded population data of urban and rural areas.

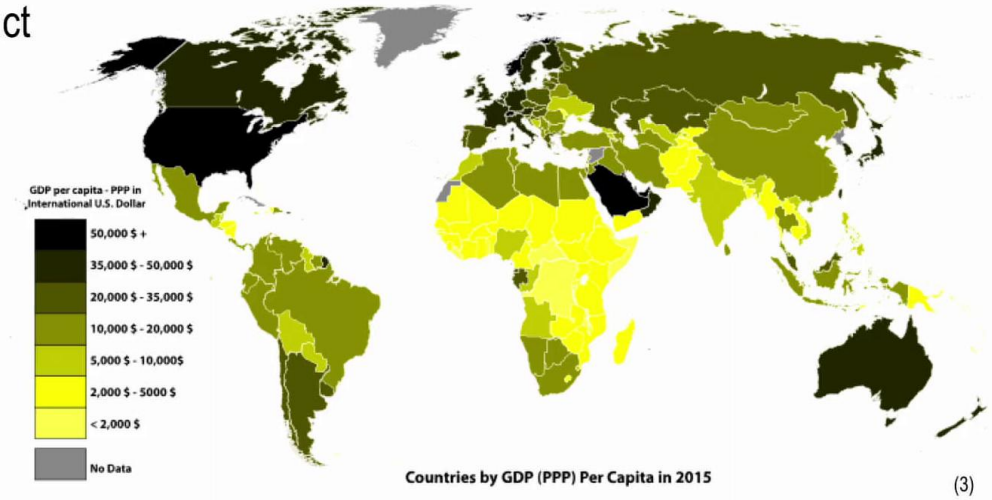
Notes

Summary

1m 55s

Exposure assessment

Gross Domestic Product (GDP)



(3)

World Bank GDP Database

Global gridded distribution of GDP obtained using GRUMP high resolution population data

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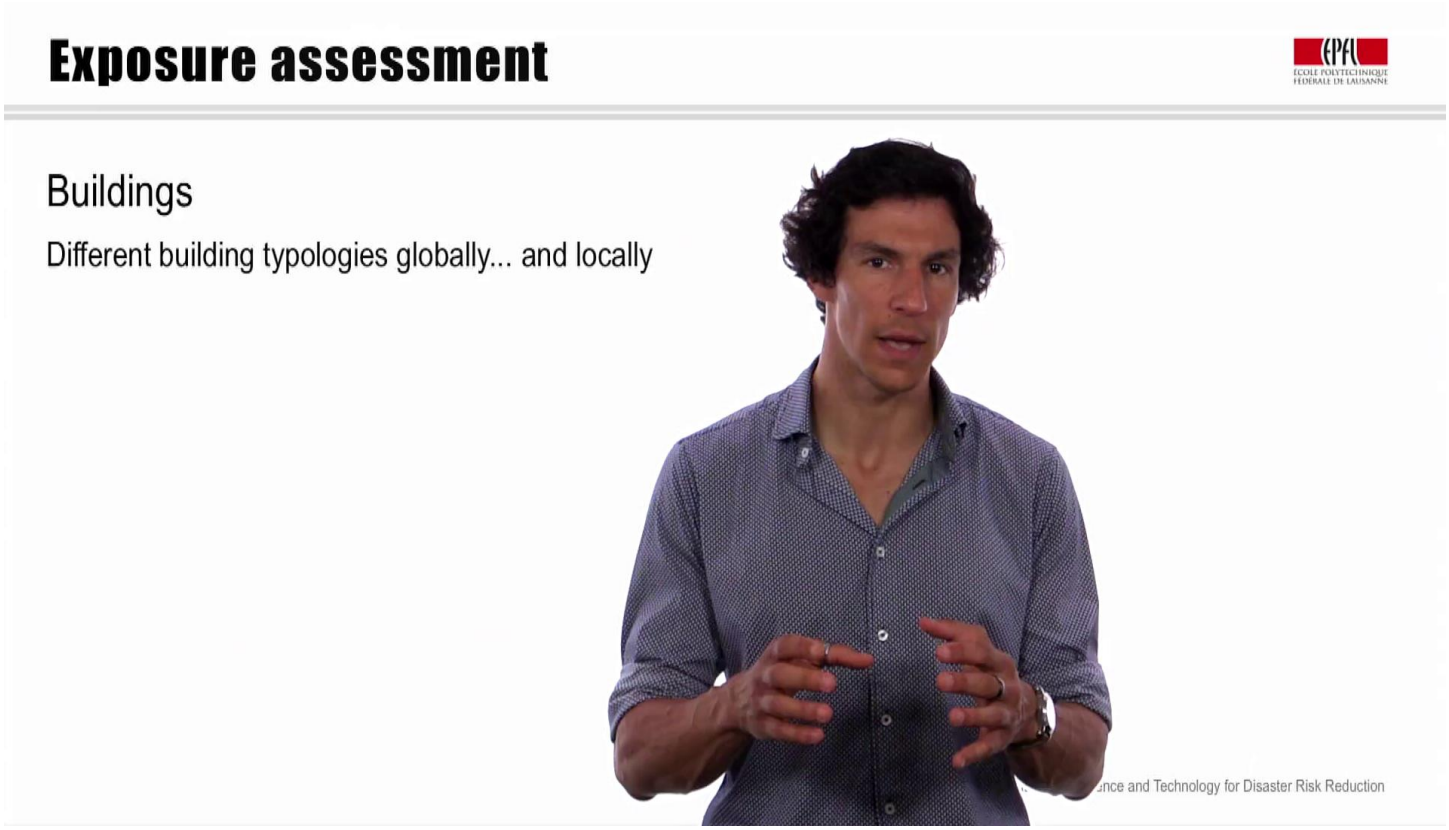
Exposure can also be expressed in terms of the gross domestic product. The World Bank created a global gridded distribution of GDP using GRUMP high resolution population data. It includes the sub-national gross regional product, where available.

Notes

Summary

3m 27s



Finally, building exposure models should take into account not only the different characteristic building typologies that can be found around the world, but also at the local scale, as these photos taken from the same city illustrate.

Notes

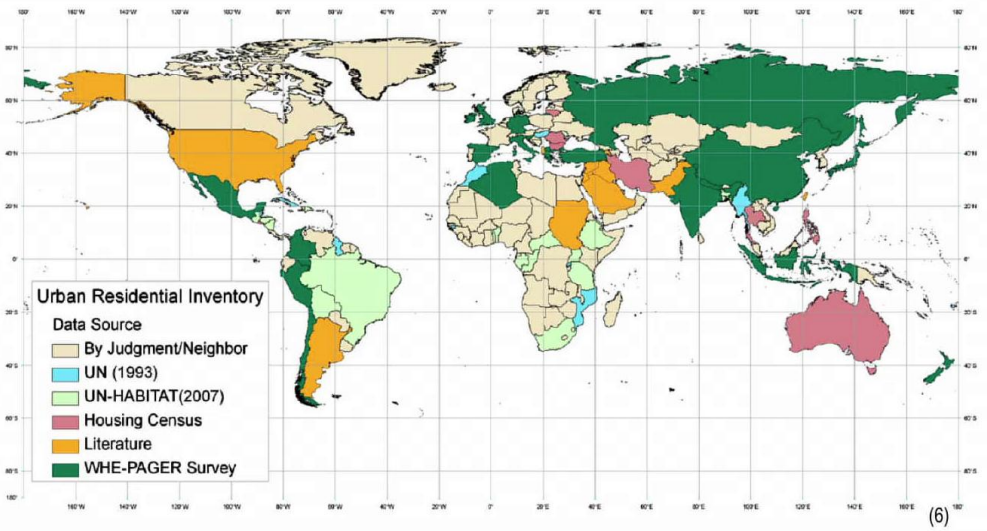
Summary

3m 44s

Exposure assessment

Buildings datasets

USGS PAGER Building Inventory V1.4



(6)

Global Exposure Database (GED) of the Global Earthquake Model (GEM) (Openquake, 2016)

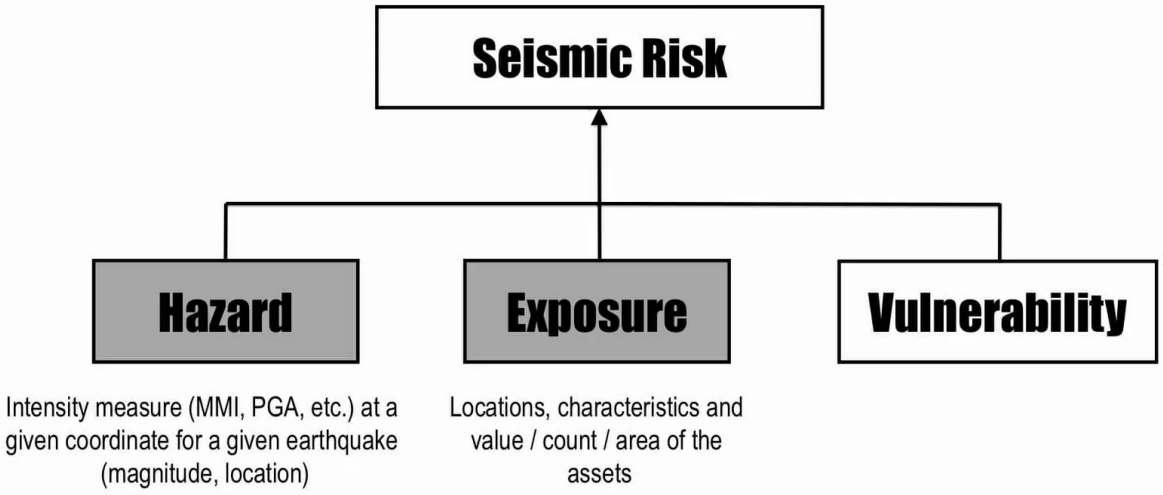
The United States Geological Survey PAGER system, to which I will come back later in this video, provides a building inventory with residential buildings' top distributions available for different countries. It uses a variety of sources such as UN-HABITAT, housing census, published literature, expert opinion, and so on. Finally, reference should also be made to the Global Exposure Database of the Global Earthquake Model, which I will also introduce in this video. The database structure is made for accommodating buildings and people data from the country level, to the individual building level. In the first version, the information on people and the number, built area and reconstruction cost of residential and non-residential buildings, is aggregated at the one kilometer resolution. Data on single buildings are accessible for some areas. This availability will become greater with time.

Notes

Summary

4m 00s

Exposure assessment



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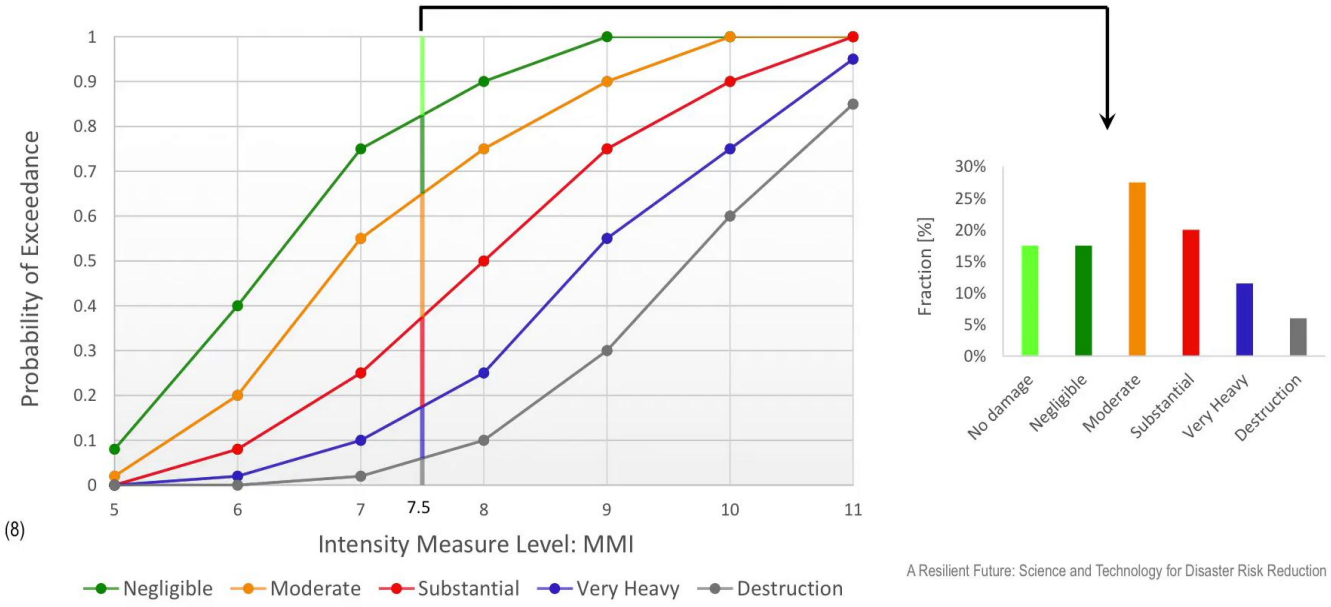
In a nutshell, exposure expresses the locations, characteristics, and the value, count, or area of the assets. We can now address the last component required to compute seismic risk: vulnerability.

Notes

Summary

5m 00s

Fragility: distribution of physical damage given an intensity measure level



Vulnerability can be quantified by a vulnerability function, which describes the distribution of loss, such as fatalities or repair costs, with increasing intensity measure levels. I recall that such intensity measure levels express the seismic hazard, as discussed in week one. When sufficient data is available, vulnerability can be further desegregated into fragility, and consequence functions. Fragility expresses the distribution of physical damage, given an intensity measure level. This graph illustrates this point. For any value of observational intensity in the Modified Mercalli Intensity Scale, one can obtain the fraction of buildings that are expected to show one of the five physical damage states indicated in the horizontal axis, which range from negligible to collapse.

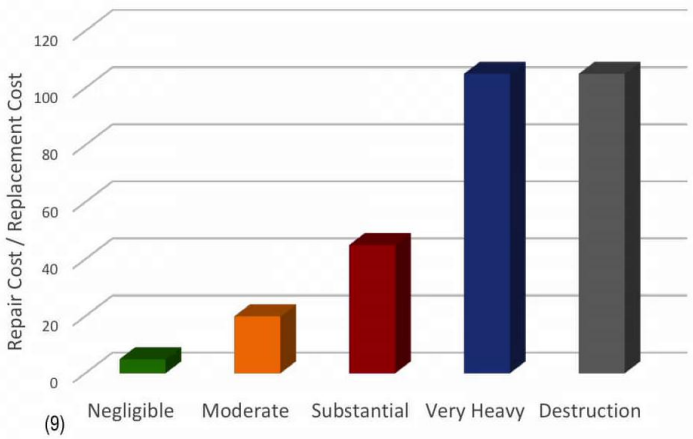
Notes

Summary

5m 15s

Vulnerability assessment

Consequence functions: distribution of loss (e.g., in terms of ratio of repair / replacement cost or fatalities) given a damage state



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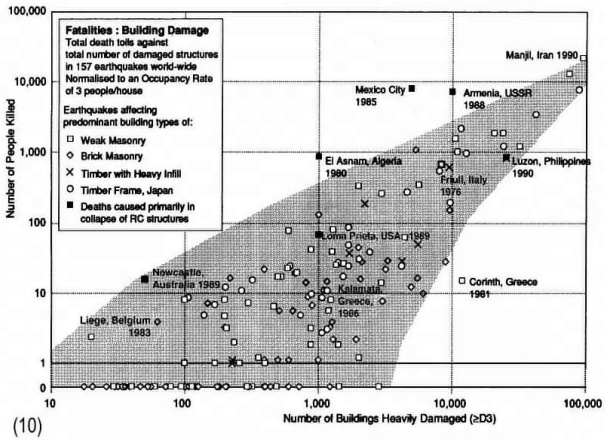

(10)

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Given one such damage state, a consequence function, as exemplified in this figure, can then be used to obtain the distribution of loss, herein expressed, for instance, in terms of repair to replacement cost. On the right we can see another example of a consequence function, where the number of buildings heavily damaged are related to the number of fatalities.

Notes

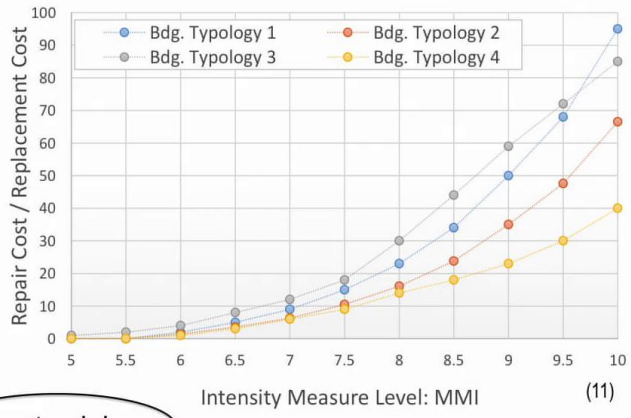
Summary

6m 12s

Vulnerability assessment

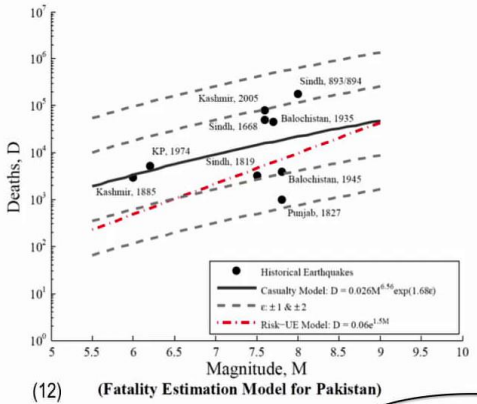
Methods for developing models

Vulnerability = **Fragility** + **Consequence functions**



(11)

Expert opinion



(12) **(Fatality Estimation Model for Pakistan)**

Empirical

In other words, vulnerability can be assessed directly as an independent component, or then as the aggregation of these two sub-components. The approach to be followed will depend on the availability of data for the particular region under study. There are roughly three categories of methods to develop the corresponding models: empirical, analytical, or those based on expert opinion. When assessed independently, vulnerability is typically based on expert opinion or on an empirical method. One can think of an example of expert opinion as the best estimates given by a group of similar earthquake engineering specialists, on the ratio of repair cost to replacement cost, for different building typologies. Their weighted mean, based on the experience and confidence levels for each building class, is an expedite way to obtain vulnerability functions, that can be used in situations when damage data is not available. However, its reliability in terms of producing realistic estimates of loss, is necessarily debatable. On the other hand, this figure illustrates a very simple empirical method to determine vulnerability. It estimates losses, shown in terms of number of deaths, with magnitude from past observations.

Notes

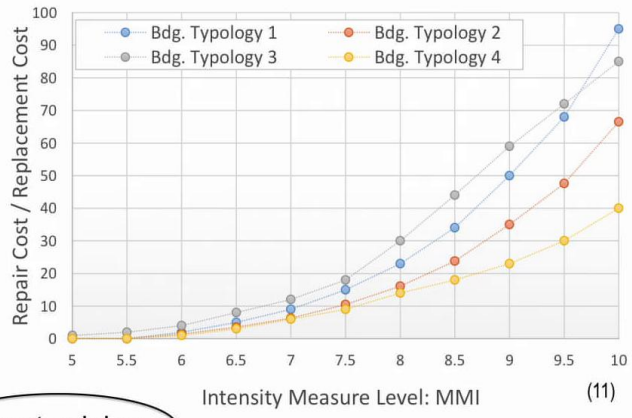
Summary

6m 36s

Vulnerability assessment

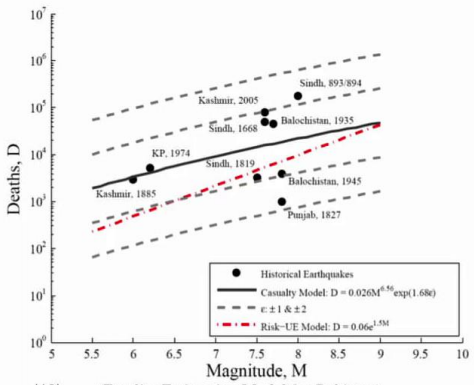
Methods for developing models

Vulnerability = **Fragility** + **Consequence functions**



(11)

Expert opinion



(12) **(Fatality Estimation Model for Pakistan)**

Empirical

The drawbacks of this approach are evident as it doesn't take into account the different levels of shaking across the affected region, or the associated distribution of population.

Notes

Summary

8m 02s

Vulnerability assessment

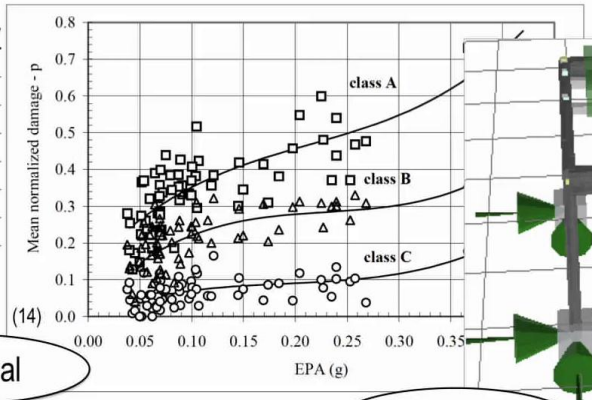
Methods for developing models

Vulnerability = **Fragility** + **Consequence functions**

Intensity Measure Level: MMI	Damage State: Negligible	Moderate	Substantial	V
V	Few			
VI	Many	Few		
VII		Many	Few	
VIII			Many	
IX				
X				
XI				
XII				

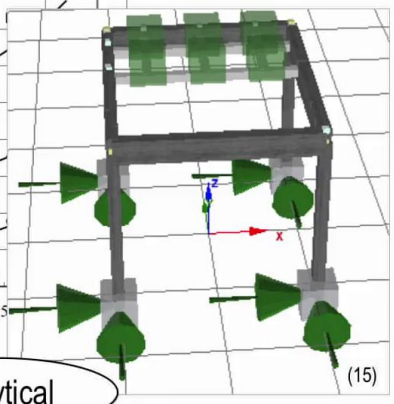
(13)

Expert opinion



(14)

Empirical



(15)

Analytical

Let us now consider the case where each sub-component of the vulnerability is evaluated. Expert opinion fragility, which, again, relates an intensity measure level with a damage state, has a questionable reliability, but provides damage probability matrices with minimal effort. Empirical fragility is based on the observed damage data, which is then related to observed ground shaking. Ideal sources of data should include all of the buildings in a given area, including the non-damaged ones. Finally, analytical fragility resorts to the application of numerical models to estimate the response and performance of buildings under increasing levels of seismic action.

Notes

Summary

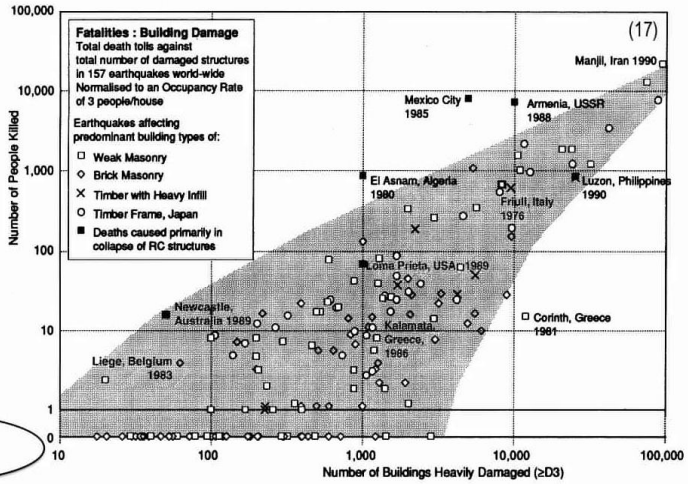
8m 13s

Vulnerability assessment

Methods for developing models

Vulnerability = **Fragility** + **Consequence functions**

Expert opinion



Empirical

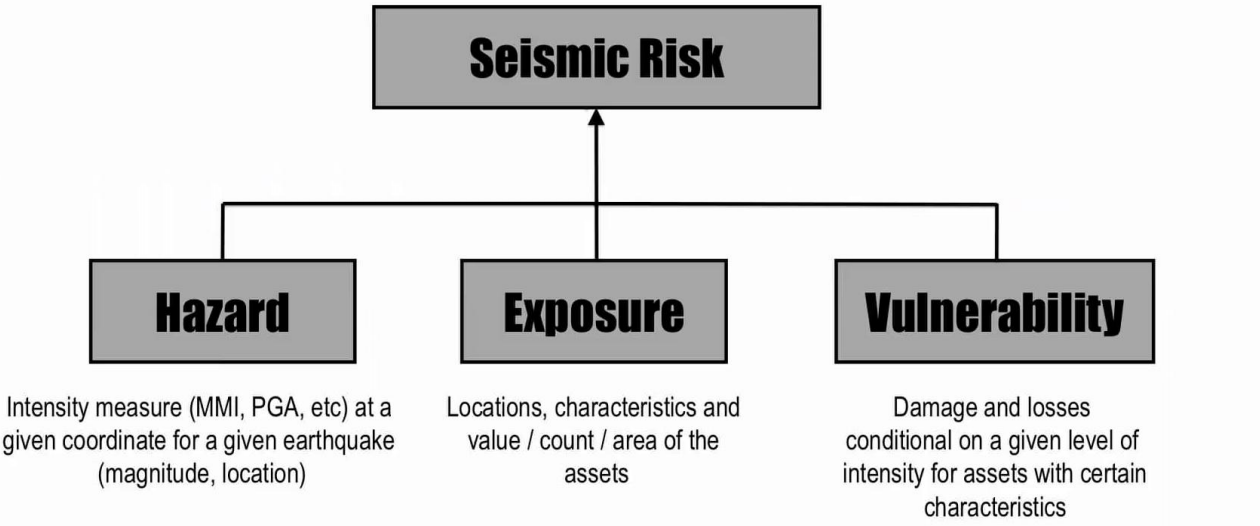
Consequence functions are generally expert opinion-based or empirical. And they are used to convert damage to loss, either in terms of repair or replacement cost, or fatalities.

Notes

Summary

9m 02s

Seismic risk



In summary, vulnerability expresses the damage and losses conditional on a given level of ground motion intensity, for certain assets. Finally, the three components, which we addressed separately, can then be combined to calculate the seismic risk. This is the probability of losses due to earthquakes.

Notes

Summary

9m 15s

Calculation of seismic risk

The probability of loss can be obtained by calculating the probability of levels of ground motion (**hazard**) to which populations/buildings are subjected (defined and classified within the **exposure** model), and multiplying this by the probability of loss, given a level of ground motion (physical **vulnerability**).

The result can be further factored by social, economic, political factors that influence vulnerability to obtain a risk index.

This probability can be obtained by calculating the probability of levels of ground motion (that is, the seismic hazard) to which populations or buildings are subjected (defined and classified within the exposure model), and multiplying this by the probability of loss, given a level of ground motion (that is, the physical vulnerability). Social, economic, or political factors that influence vulnerability should also be taken into account.

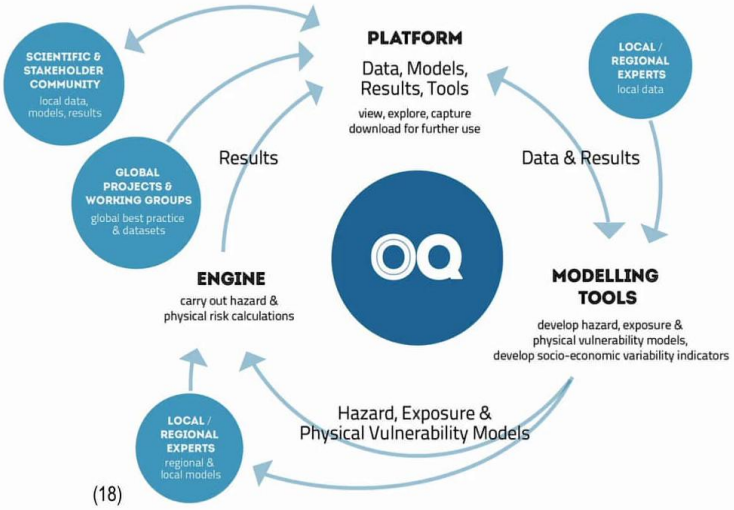
Notes

Summary

9m 36s

Calculation of seismic risk

OpenQuake (OQ): suite of open-source software developed for the Global Earthquake Model (GEM)



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One of the most relevant global collaborative efforts of the recent years, in terms of providing tools and resources for the assessment of earthquake risk anywhere in the world, is the Global Earthquake Model, or GEM. OpenQuake is the GEM suite of open-source software for seismic hazard and risk modeling. It comprises the platform which allows users to visualize, explore and share GEM's data sets; tools and models; the engine (which is GEM's state-of-the-art software for seismic hazard and risk assessment); and a great variety of modeling tools.

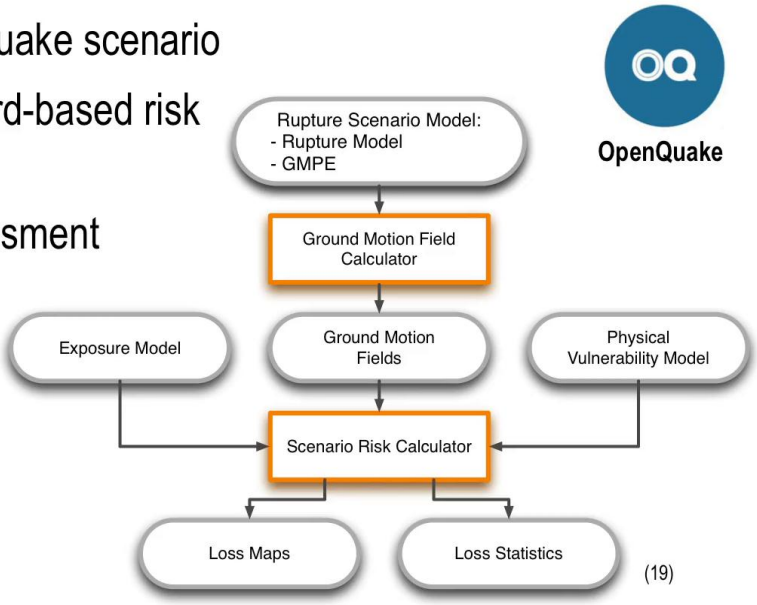
Notes

Summary

10m 07s

Calculation of seismic risk

- Risk assessment for specific earthquake scenario
- Classical probabilistic seismic hazard-based risk assessment
- Probabilistic event-based risk assessment



(19)

A Resilient Future: Science and Technology for Disaster Risk Reduction

OpenQuake allows to assess losses not only for single deterministic events (that is, for specific earthquake scenarios) but also considering all probable events, including classical probabilistic seismic hazard-based, and probabilistic event-based, risk assessment.

Notes

Summary

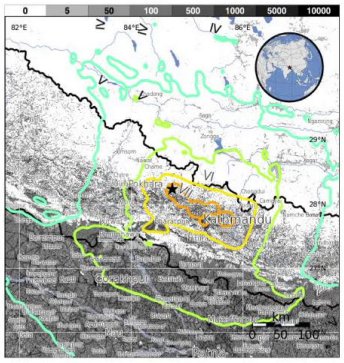
10m 46s

USGS PAGER: Prompt Assessment of Global Earthquakes for Response

M7.8 – 36km E of Khudi, Nepal

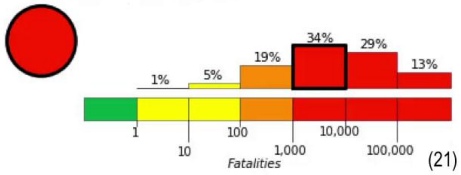
(20)

Estimated population exposure to earthquake shaking



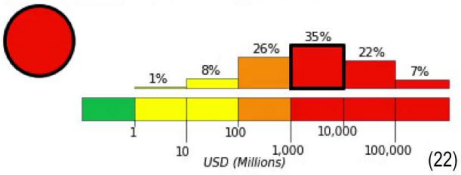
(23)

Estimated fatalities



(21)

Estimated economic losses



(22)

→ Rapid post-event assessment of losses (earthquake alert for geographic regions and magnitude range)

QLARM: EarthQuake Loss Assessment for Response and Mitigation.
ELER: Earthquake Loss Estimation Routine.

A Resilient Future: Science and Technology for Disaster Risk Reduction

The USGS PAGER, which I mentioned earlier in the context of building inventories, is an automated system that takes in seismic data from remote sensors following significant earthquakes worldwide, and provides fatality and economic loss impact estimates within 20 to 30 minutes of the earthquake's occurrence. That is well in advance of in situ observations or news accounts, and that can hence play a primary alerting role. Users can also sign up for earthquake alerts, for custom geographic regions, and magnitude ranges through the USGS earthquake notification service. Other seismic risk tools include the Earthquake Loss Assessment for Response and Mitigation (QLARM) which provides loss estimates for scenario earthquakes (that is, which are likely to occur in the future) and loss estimates for earthquakes just hours after they happen anywhere on the planet. Another tool is the Earthquake Loss Estimation Routine, developed as part of a European project, which provides rapid estimation of earthquake shaking and losses in the Euro-Mediterranean region.

Notes

Summary

11m 06s

Main points

- Hazard, exposure, and vulnerability are the three main components of seismic risk
- Seismic risk can increase in time even if seismic vulnerability decreases!
- There are many different models, tools, and software to compute seismic risk, at various levels of complexity and accuracy

A Resilient Future: Science and Technology for Disaster Risk Reduction

In short, what are the main points that we can take from this video? Firstly, that the seismic risk is the aggregation of three components, namely, the seismic hazard, the exposure and the vulnerability. The seismic hazard, as we discussed in a past video, is constant in time. The seismic vulnerability, which is the only factor that as humans we can actually try to control, tends to reduce as, fortunately, new structures are usually safer than old ones. However, since the exposure or the amount of assets present in hazard regions can increase very significantly over time, the resulting seismic risk can also grow, overshadowing desirable reductions on the vulnerability. Finally, we briefly overviewed some of the existing software and tools to model and compute seismic risk or each of its components which greatly vary in complexity and accuracy. The earthquake engineering community worldwide, has been and will continue to resolutely work on these models, and on making them available to the public. The reduction of seismic vulnerability must be one common goal of our society. Thank you for watching this video.

Notes

Summary

12m 23s

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Notes

Summary

13m 42s

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Notes

Summary

13m 45s

Acknowledgements

I would like to thank, **Dr. Helen Crowley** and **Prof. Rui Pinho,** for providing me with technical and educational input for this video.

Acknowledgements: I would like to thank Dr.

Notes

Summary

13m 48s

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(2) "Population density, 2000" by the Trustees of Columbia University in the City of New York, Center for International Earth Information Network (CIESIN), Columbia University, International Food Policy Research Institute (IFPRI), the World Bank and Centro Internacional de Agricultura Tropical (CIAT) is licensed under CC-BY 3.0.

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(9) EPFL - Dr. João Almeida

(10) Coburn, A., and R. Spence (2002). Earthquake Risk Modelling. *In*: Earthquake Protection, Second Edition, Wiley, 311-352.

(11) EPFL - Dr. João Almeida

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Helen Crowley and Prof. Rui Pinho for providing me with technical and educational input for this video.

Notes

Summary

13m 49s

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(14) Sabetta, F., Goretti, A., and Lucantoni, A (1998). Empirical fragility curves from damage surveys and estimated strong ground motion. *In:* Proceedings of the 11th European conference on earthquake engineering, Balkema.

(15) EPFL - Dr. João Almeida (using Seismostruct Software)

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(17) Coburn, A., and R. Spence (2002). Earthquake Risk Modelling. *In*: Earthquake Protection, Second Edition, Wiley, 311-352.

(18) OpenQuake Platform

(19) U.S. Geological Survey

(20) U.S. Geological Survey

(21) U.S. Geological Survey

(22) U.S. Geological Survey

Notes

Summary

13m 52s

Useful Links

- ELER: http://www.koeri.boun.edu.tr/News/NERIES%20ELER%20V3.1_16_177.depmuh
- QLARM: http://www.wapmerr.org/qlarm.asp
- SEISMOSOFT: http://www.seismosoft.com/

Notes

Summary

13m 54s