METEOR

Modelling Exposure Through Earth Observation Routines

Disaster Risk Assessment for Earthquakes

Produced as a part of a series of videos within the METEOR project

METEOR project

Modeling Exposure Through Earth Observation Routines

- Three-year project
- Funded by UK Space Agency
- Aims to develop innovative application of Earth Observation (EO) technologies to improve understanding of exposure
- Specific focus on pilot countries Nepal and Tanzania
- Consortium of eight organizations

funded by:

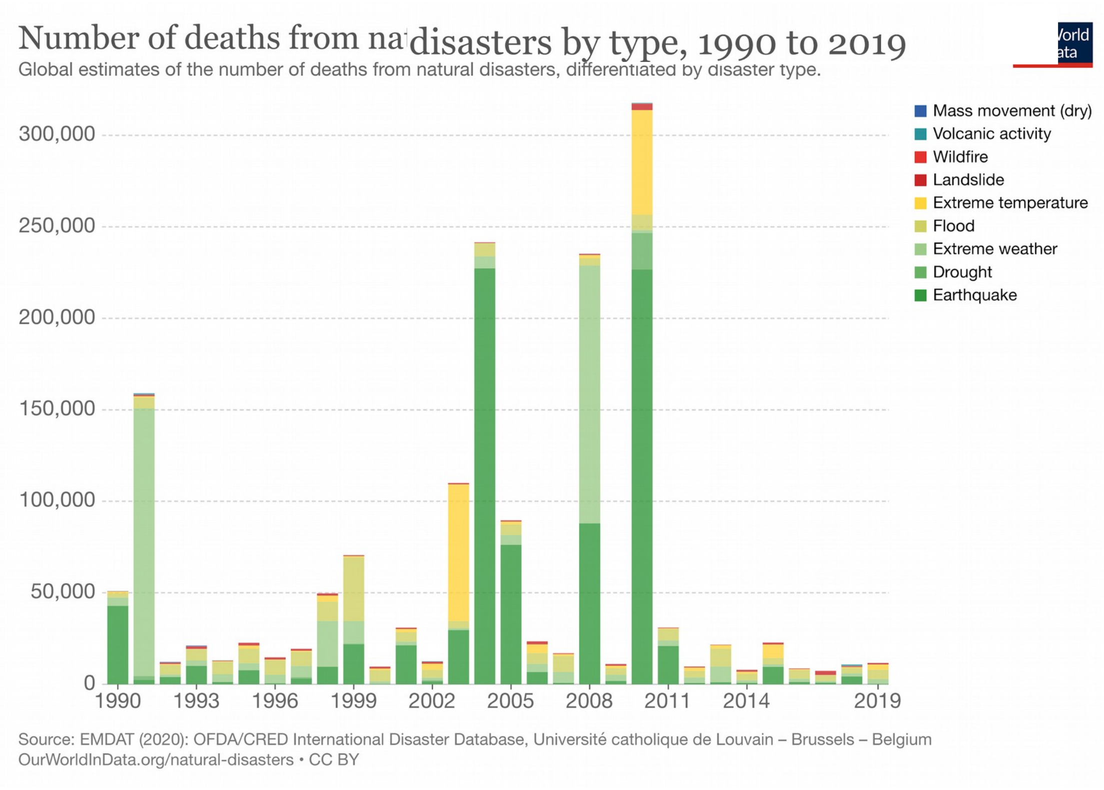
UK SPACE AGENCY

project consortium:

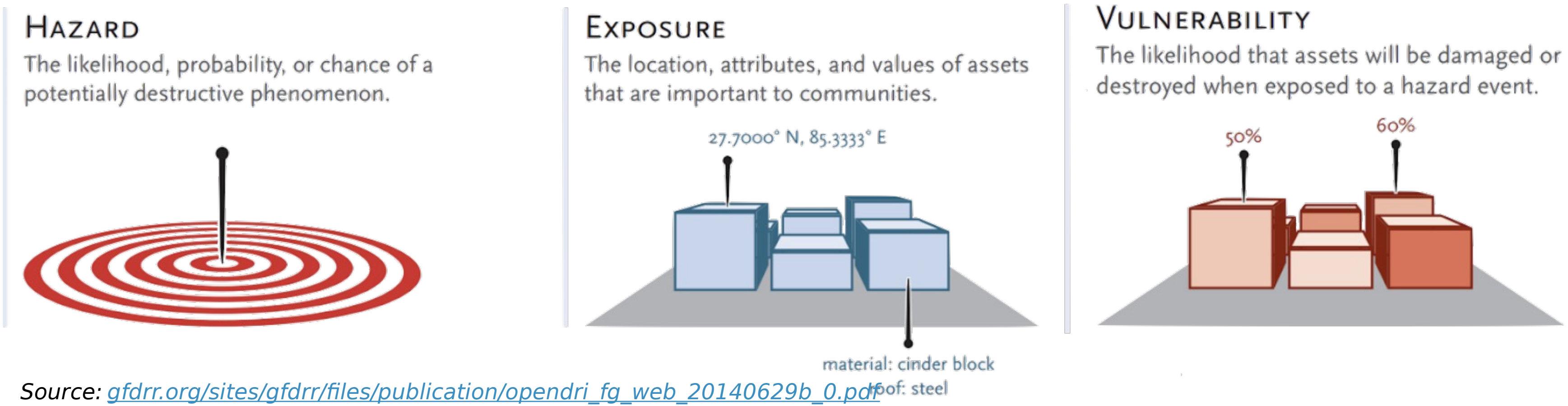
https://meteor-project.org

Introduction

Why disaster risk assessment?



Components of risk



Source: gfdrr.org/sites/gfdrr/files/publication/opendri_fg_web_20140629b_0.pdf

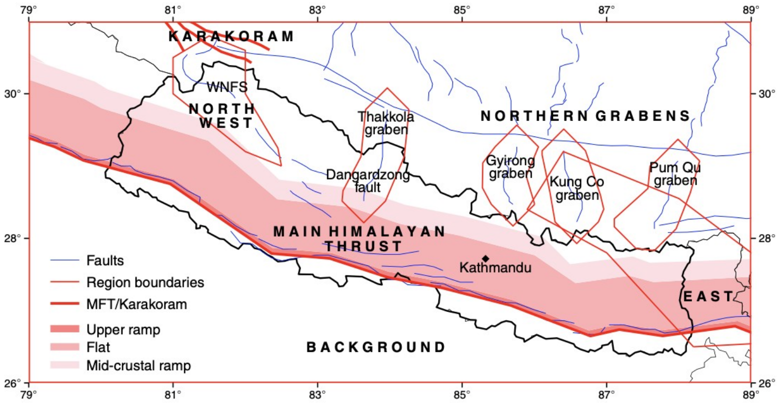
HAZARD **EXPOSURE** **VULNERABILITY**

The **RISK** occurs when there is a spatial and temporal overlap of these three elements

Hazard

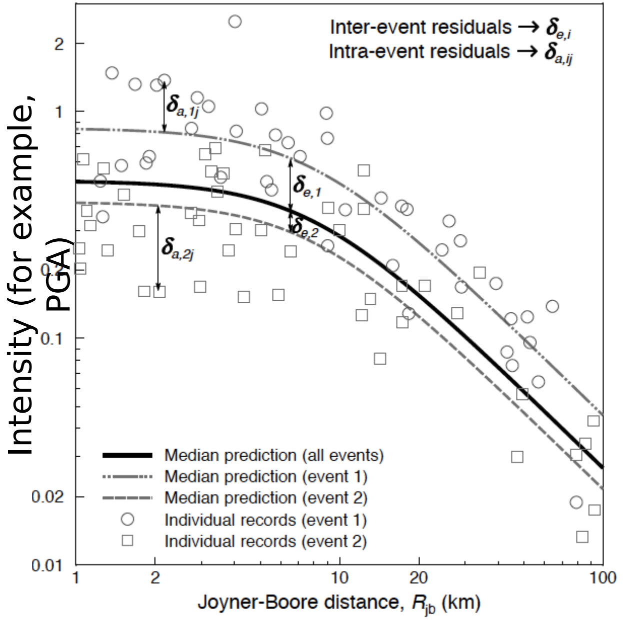
Hazard | Components of a hazard model

Seismic source characterization



Source: Stevens, V. L., S. N. Shrestha, and D. K. Maharjan. "Probabilistic Seismic Hazard Assessment of Nepal." *Bulletin of the Seismological Society of America* 108.6 (2018): 3488-3510.

Ground motion characterization



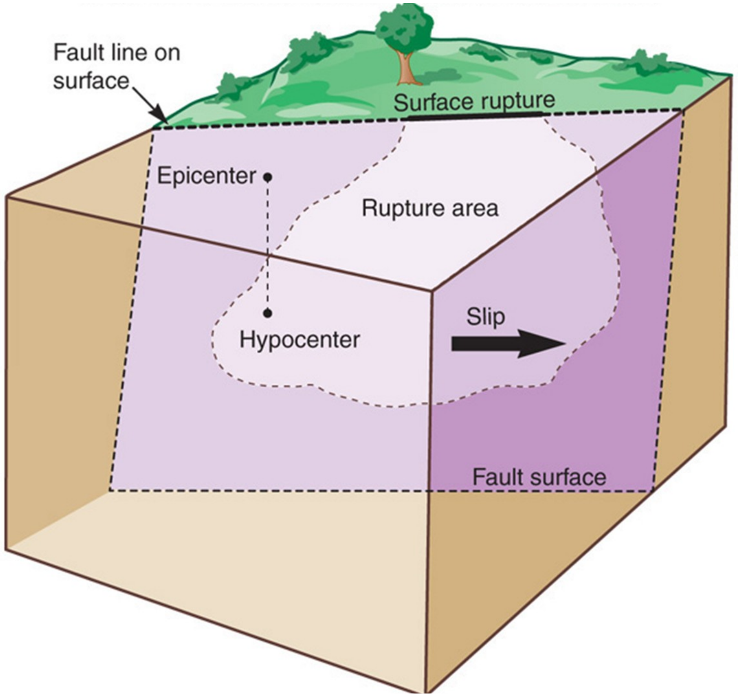
Hazard | Faults and ruptures

Fault

plane of discontinuity in the earth's crust

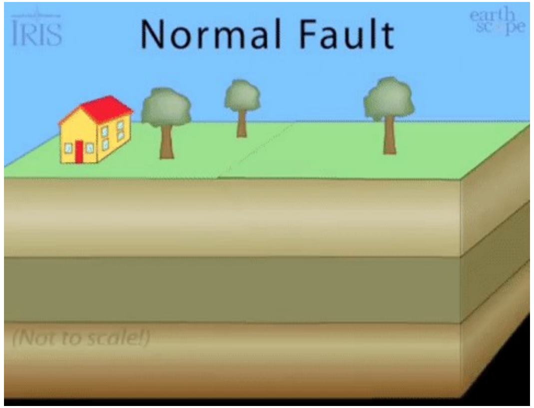
Rupture

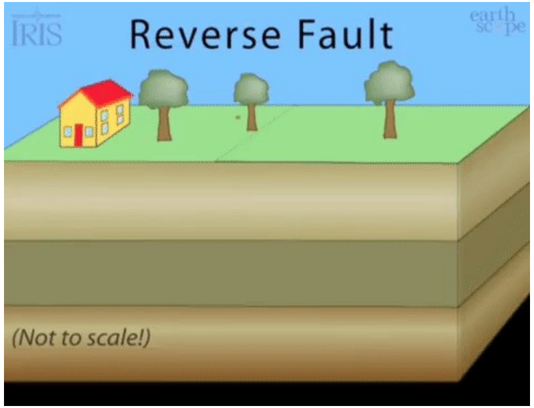
portion of the fault area that slips in a seismic event

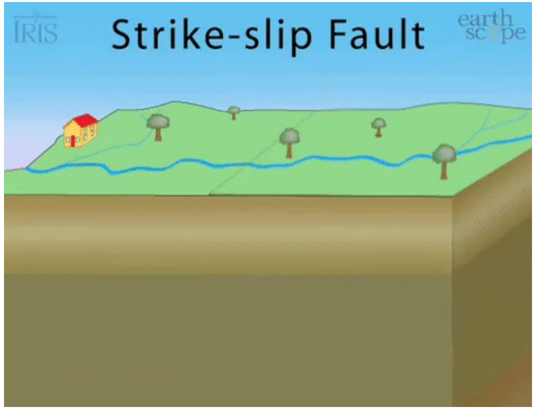


Source: J.Ziony, ed. “Earthquakes in the Los Angeles Region.” USGS

Hazard | Fault mechanisms







Normal Fault

The earth blocks move away from each other

Reverse Fault

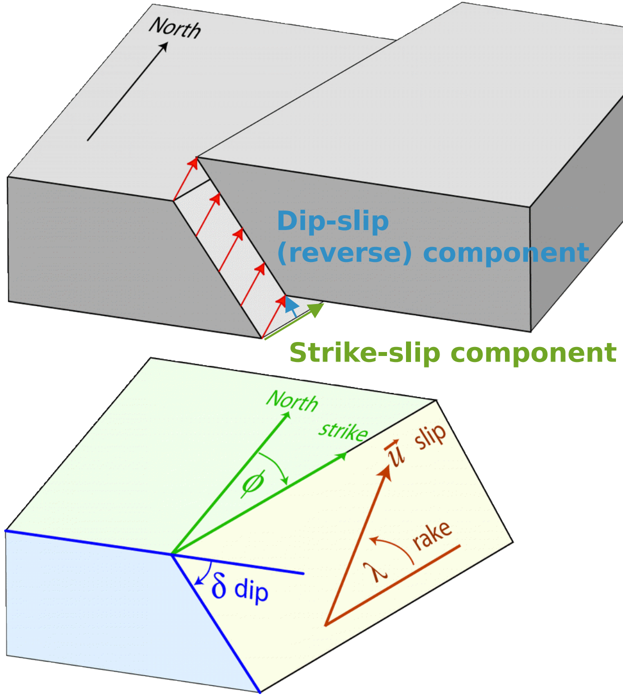
The earth blocks exert compression on each other

Strike-slip Fault

The earth blocks slide without compression or tension

Source: https://www.iris.edu/hq/inclass/animation/

Hazard | Rupture parameters



Source: [OpenQuake Manual]

Strike Angle between the intersection of the fault plane with a horizontal surface (relative to the North)

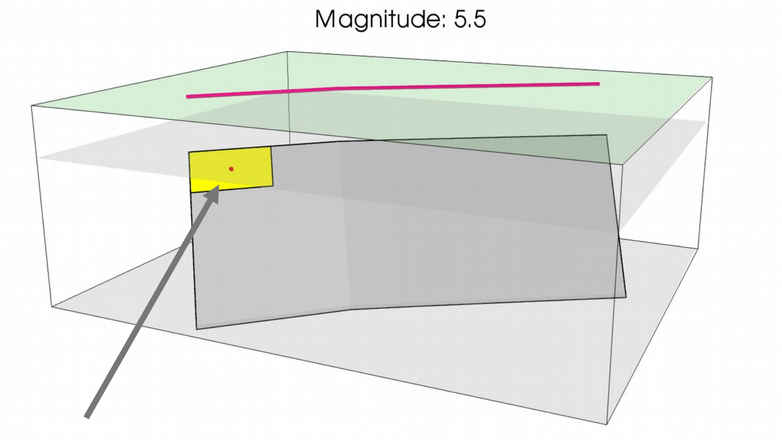
Dip Angle between the fault and a horizontal plane

Rake Direction in which the hanging wall moves during rupture

Hazard | Defining a seismic rupture

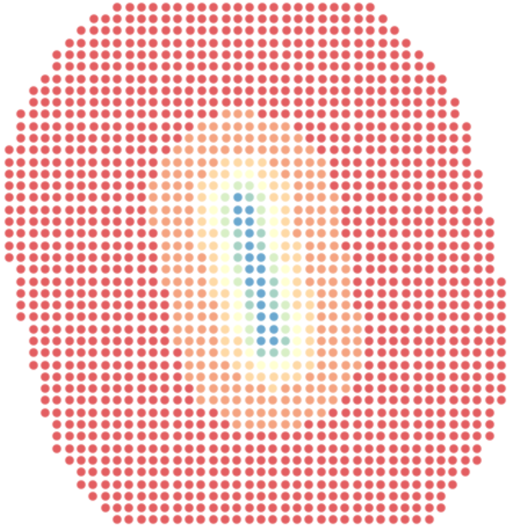
Fault Source

- Geometry
- Magnitude
- Mechanism



Seismic Rupture

Ground Motion Field from 1 Rupture



Acceleration - PGA

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FATHOM

GEM

HOT

ImageCat

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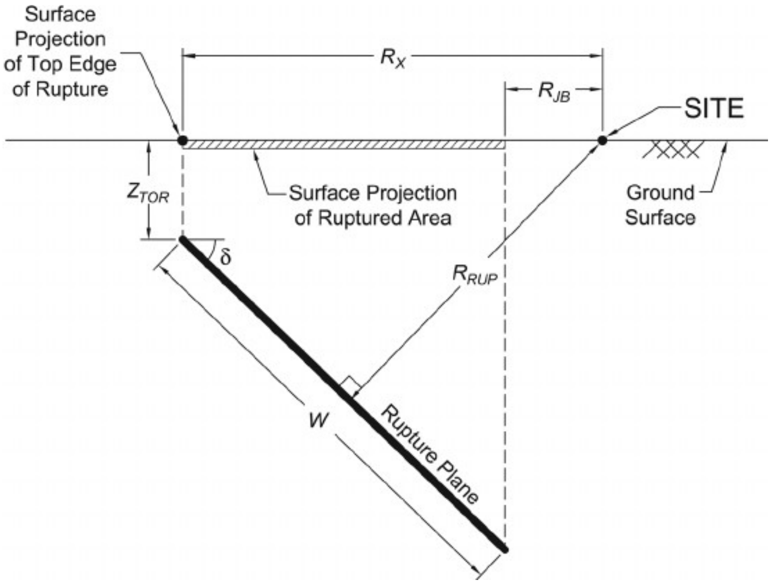
Hazard | Ground motion prediction equations

$$\underbrace{\ln y}_{1} = \underbrace{c_1 + c_2 m + c_3 m^{c_4}}_{2} + \underbrace{c_5 \ln r}_{3} + \underbrace{f(F) + f(HW) + f(S)}_{4}$$

y: Expected ground motion intensity (PGA, SA)
m: Magnitude
r: Distance
F: Fault mechanism
HW: Site location, with respect to the fault plane
S: Local site conditions

Hazard | Ground motion distance metrics

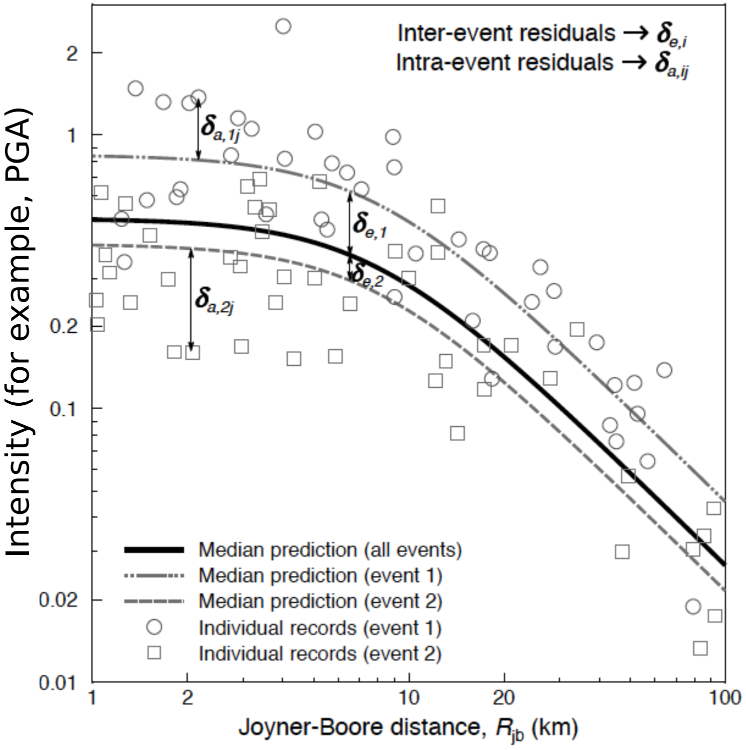
Kaklamanos et al. (2011) DOI: 10.1193/1.3650372



R_{JB} Joyner-Boore Distance

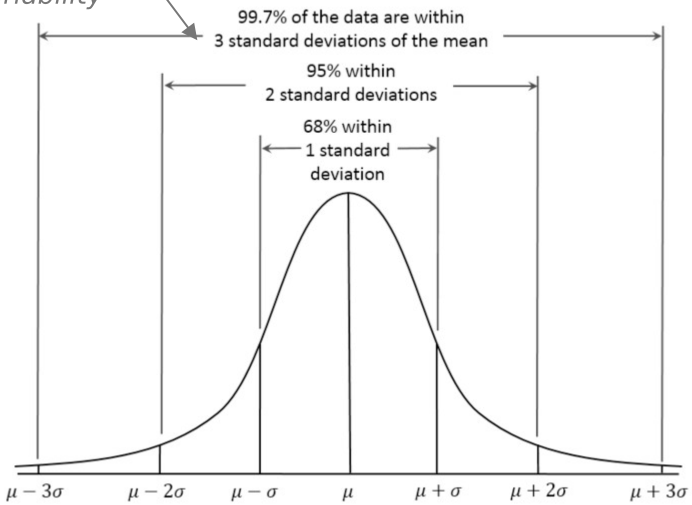
R_{RUP} Distance between the site and the hypocenter

Hazard | Ground motion variability

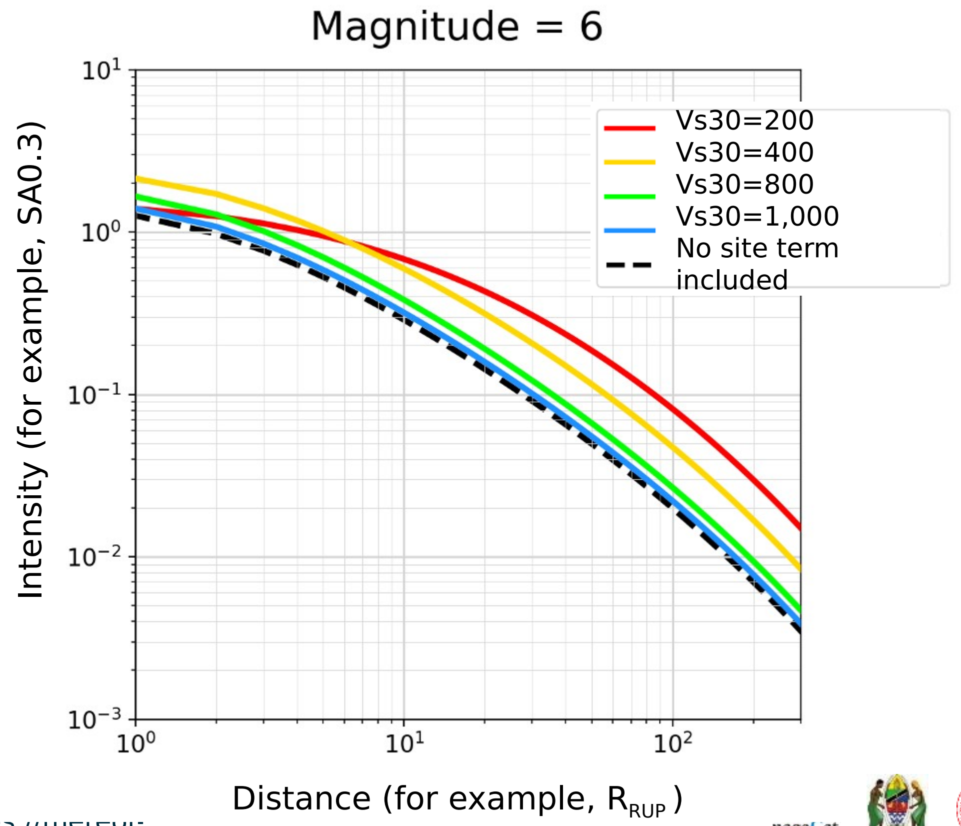


The ground motion intensity has an associated variability, observed in the same event and in different events, although it is the same type of rupture, magnitude and distance

A truncation level of 3 considers 99.7% of the variability



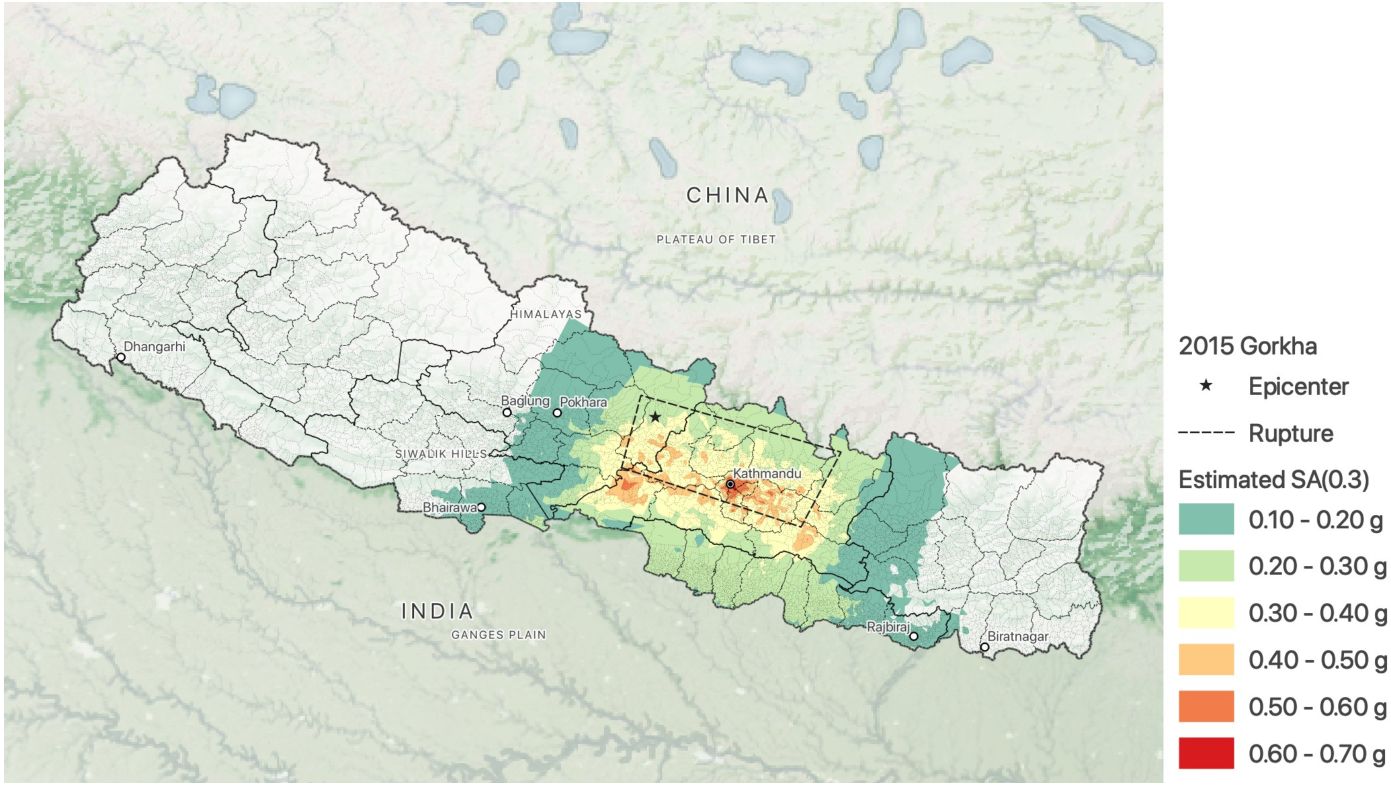
Hazard | Site effects



Softer soils can amplify ground shaking, often referred to as a "site effect"

The shear wave velocity in the top 30 meters, VS,30, is used as a proxy for modeling site effects

Hazard | Scenario hazard modeling



Exposure

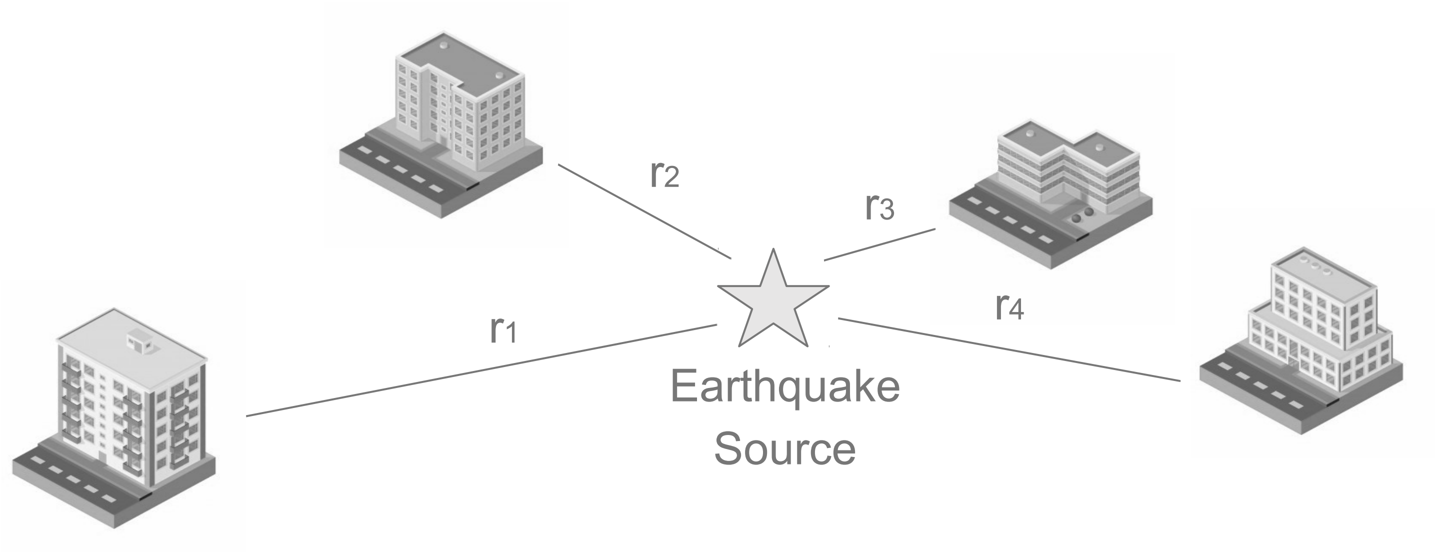
Exposure | Components of an exposure model

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

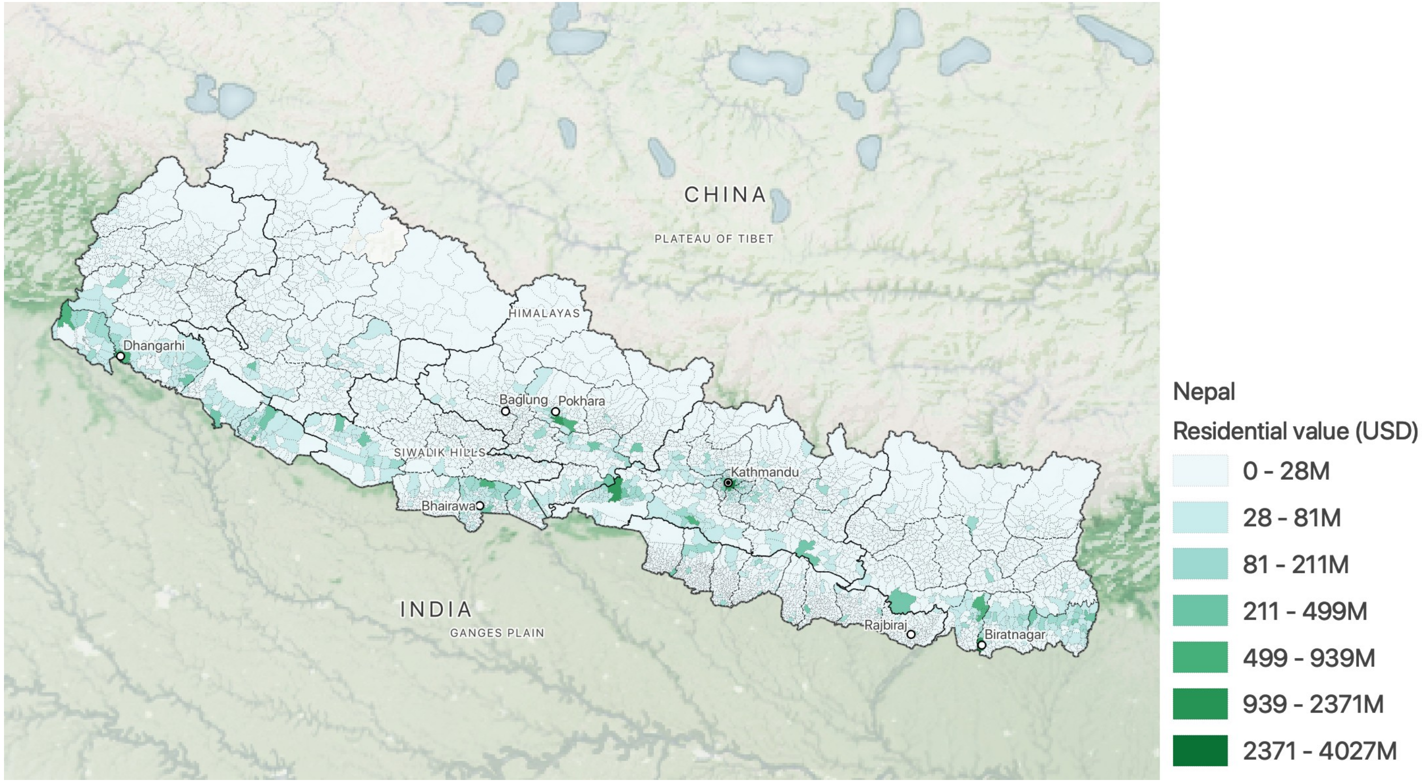
Necessary parameters include the geographic location and replacement value for all loss types to be considered (e.g. financial loss due to building damage, casualties).

Exposure | Geographic attribute of assets

It is necessary to identify the geographical location of the exposed elements with respect to the source(s) of seismicity, since the ground motion intensity is a function of the distance to the source.



Exposure | Value attribute of assets



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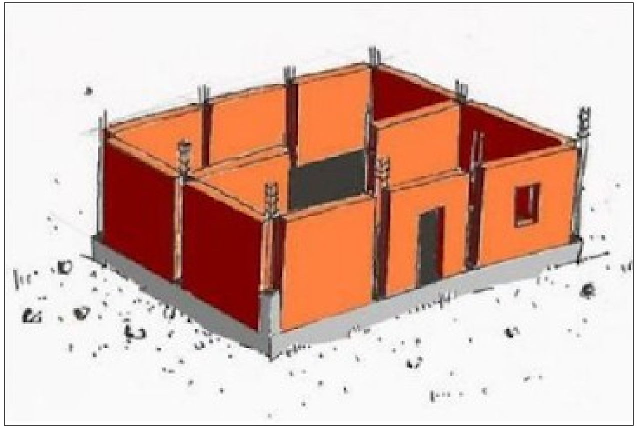
Exposure | Structural attributes of assets

It is necessary to identify the physical characteristics of the built environment, to classify each exposed element according to its fragility and seismic vulnerability



Some of the main attributes that can be identified are:

construction material, structural system, height and construction code compliance

GEM Taxonomy: https://platform.openquake.org/taxtweb/

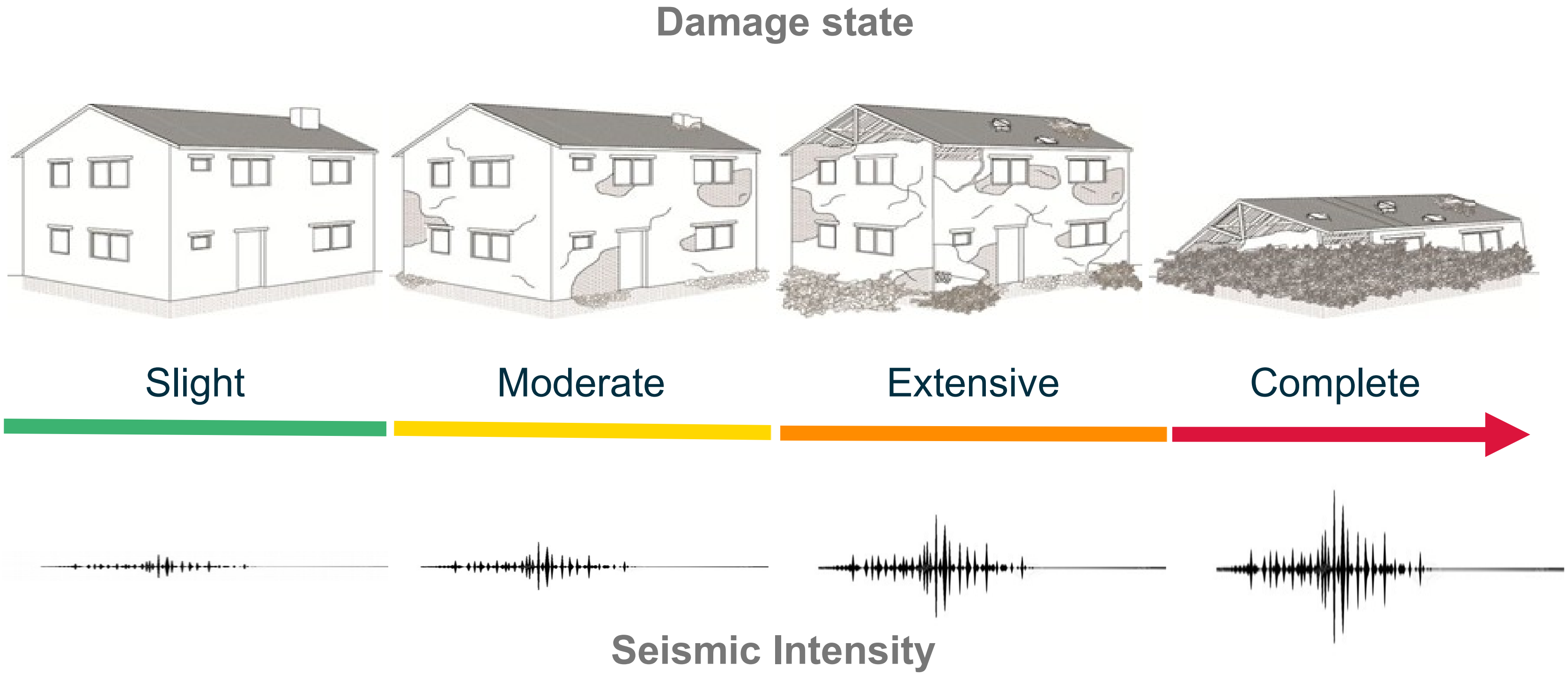
Vulnerability

Vulnerability | Fragility and vulnerability models

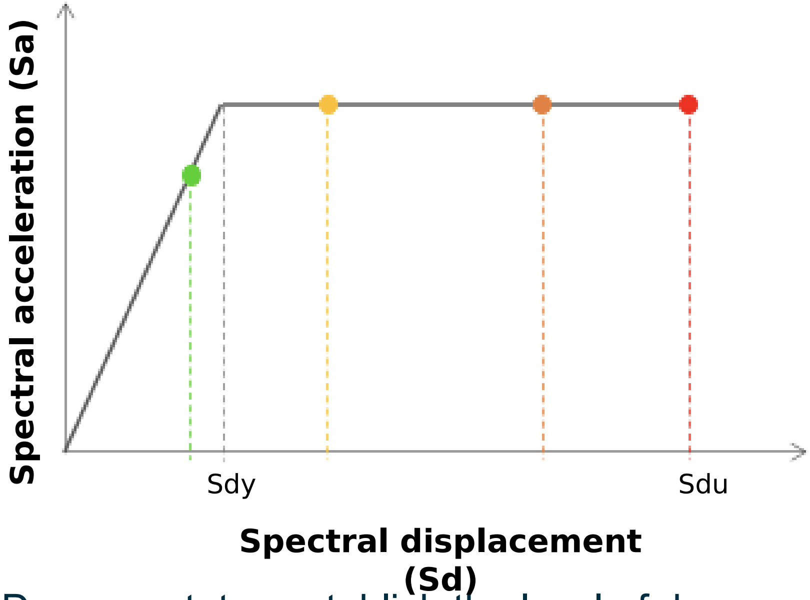
Seismic fragility and vulnerability refers to the likelihood that the built environment, its contents and occupants have, to suffer damage and losses due to earthquake ground shaking.

Fragilities require an additional consequence model (damage-to-loss) if losses are desired.

Vulnerability | Defining seismic fragilities



Vulnerability | Defining damage states



Example damage criteria

Slight = 0.7*Sdy

Moderate = 0.7*Sdy + 0.25*Sdu

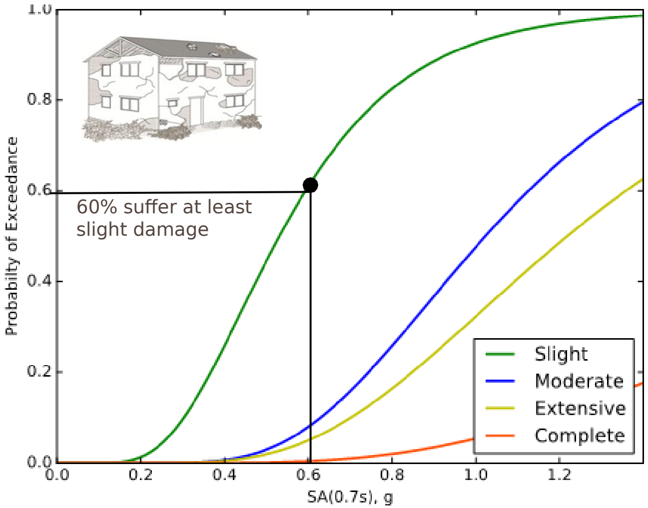
Extensive = 0.5*(Sdy + Sdu)

Complete = Sdu

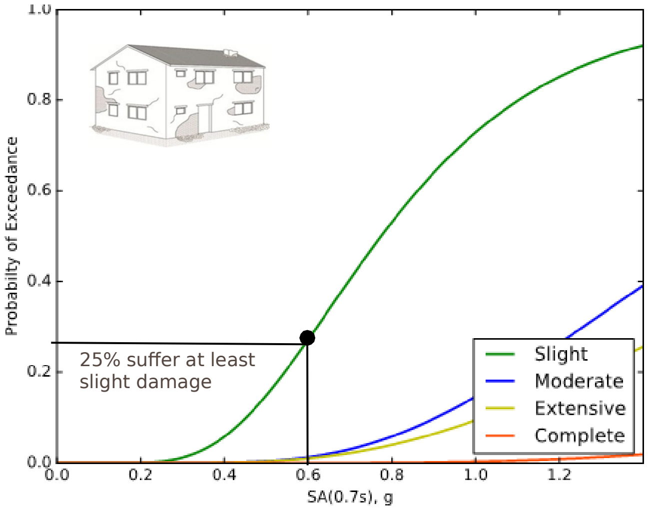
Damage states establish the level of damage that an exposed asset will experience under certain engineering demand parameters (EDPs) are met. Example EDPs include: spectral displacement, spectral acceleration, interstory drift, and peak floor acceleration.

Vulnerability | Fragility models

Pre-code Building



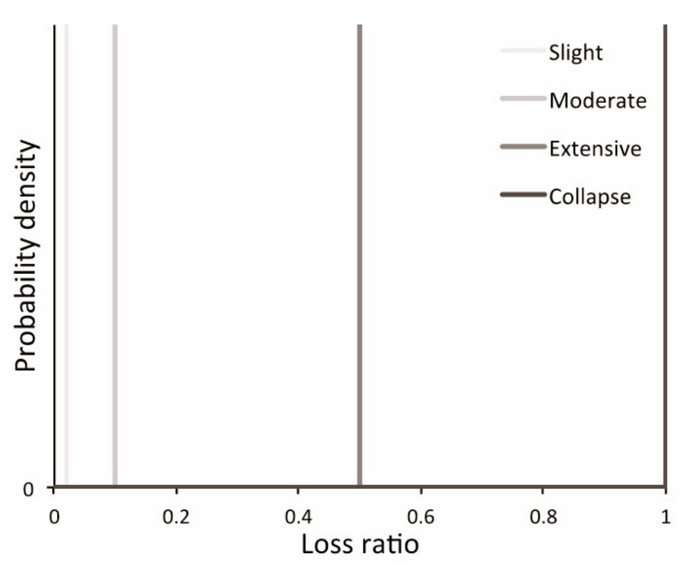
Code Compliant Building



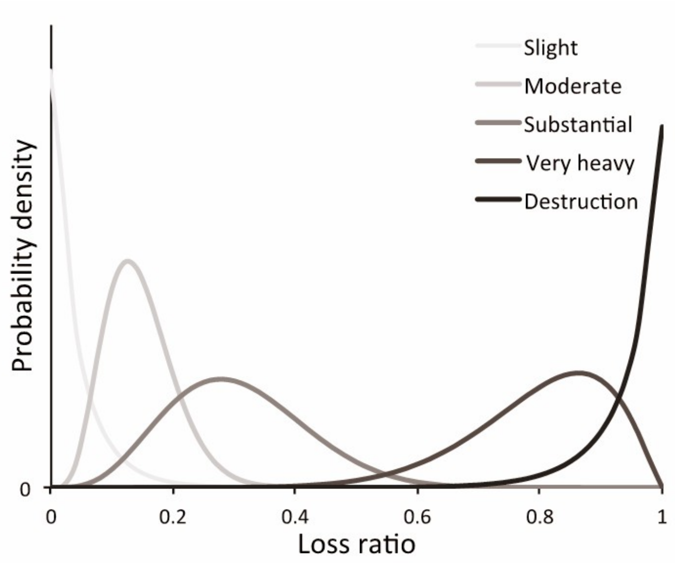
The structural attributes of a building (e.g. construction material, construction system, height, design regulations) directly influence its fragility, making it more or less vulnerable to ground agitation.

Vulnerability | Consequence models

Deterministic

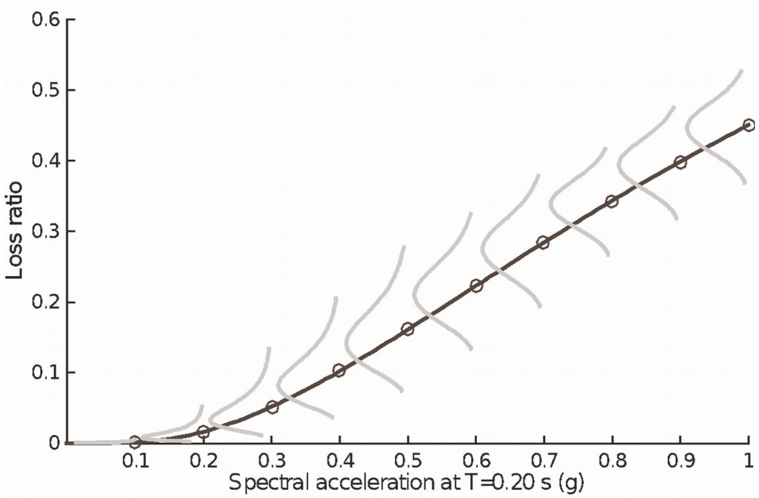


Probabilistic



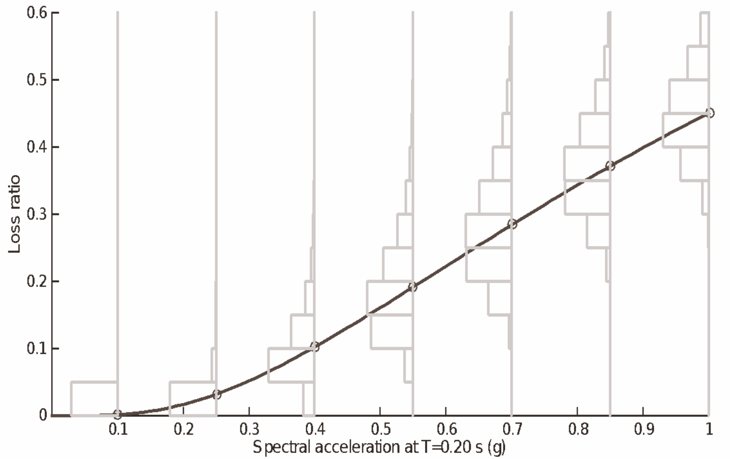
A consequence model (also known as damage-to-loss model) establishes the relation between a physical damage state and the corresponding loss-ratio.

Vulnerability | Vulnerability models



Continuous distribution of loss ratio

Lognormal distribution



Discrete distribution of loss ratio

with probability mass functions

A vulnerability model establishes the probability of a given loss ratio for a set of intensity measure levels

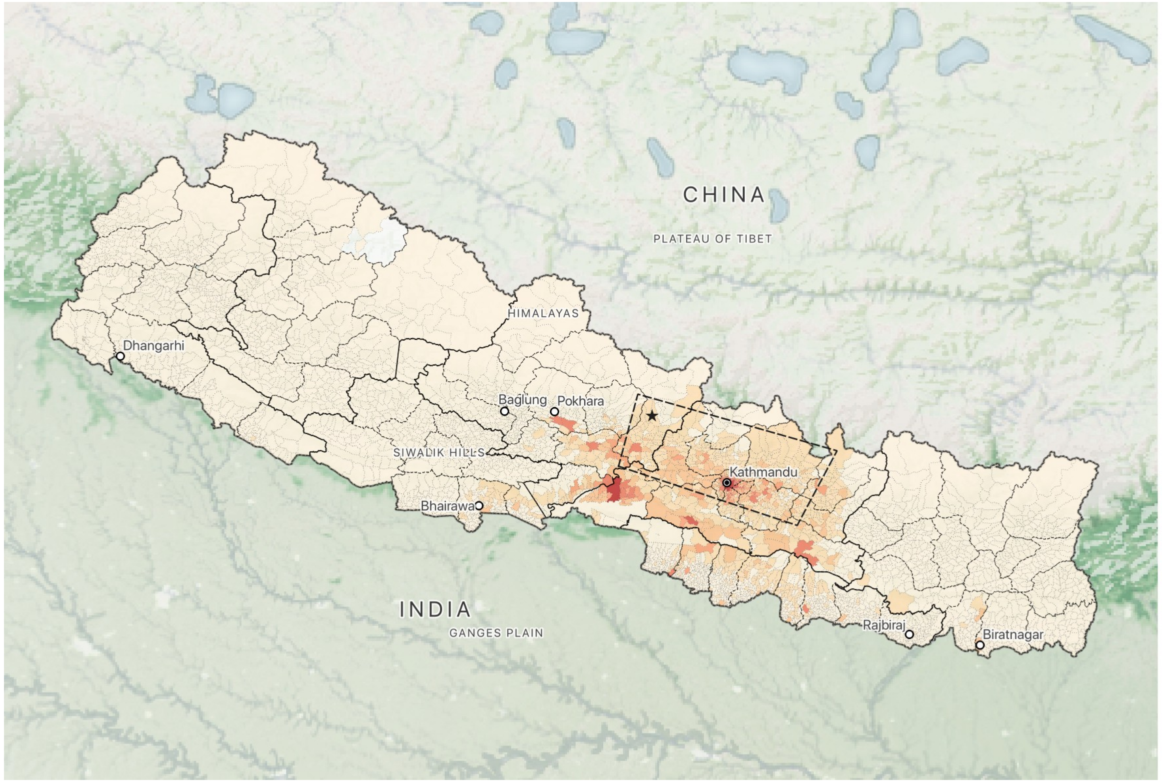
Risk

Risk | Conducting a risk analysis

Inputs

Outputs

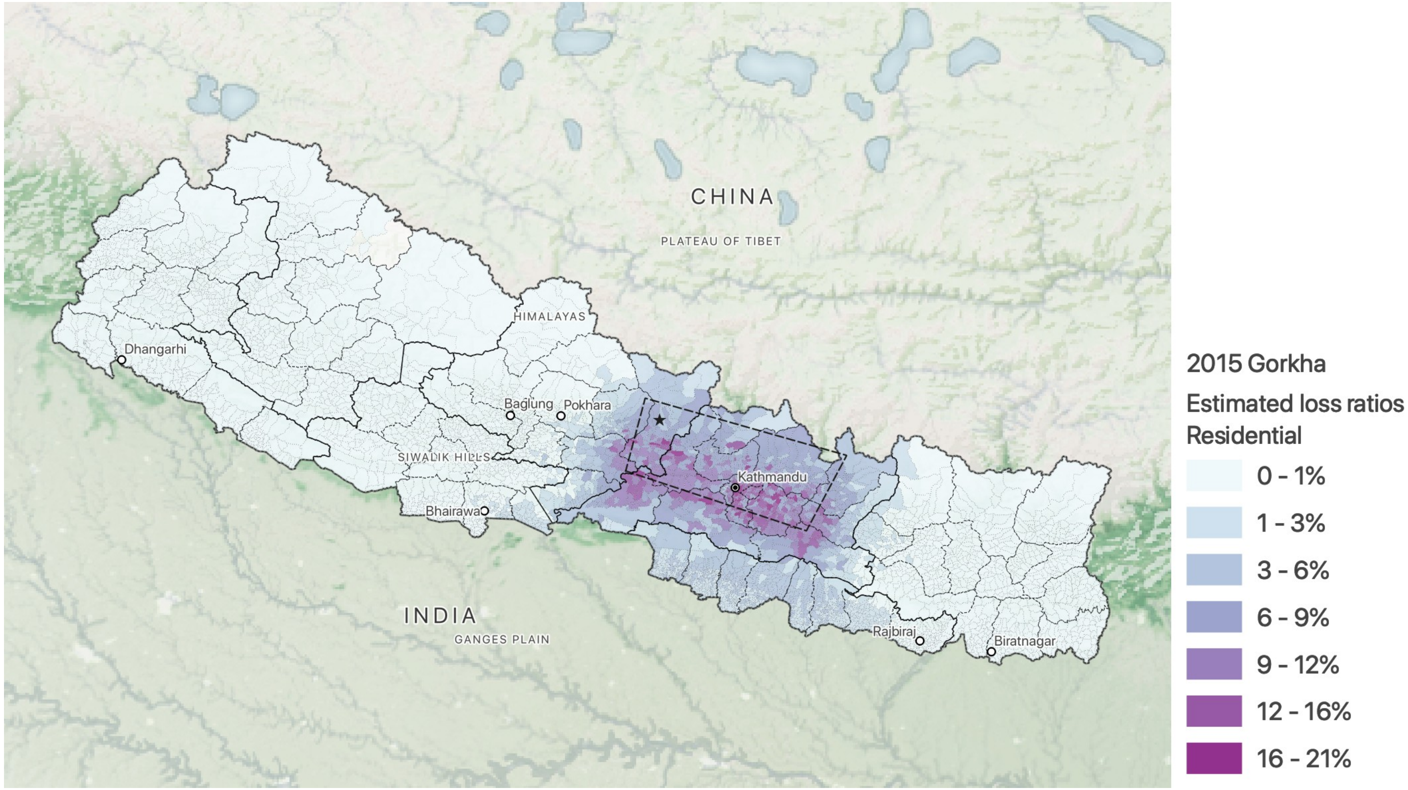
Risk | Scenario loss map



2015 Gorkha
Estimated losses
Residential (USD)

- < 0.6M
- 0.6M - 2M
- 2M - 6M
- 6M - 13M
- 13M - 45M
- 45M - 70M
- 70M - 747M

Risk | Scenario loss ratio map



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For further information please see
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Earthquake Safe Communities in Nepal

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