EARTHQUAKE HAZARD & RISK ASSESSMENT OF BANGLADESH

Presentation of Results at Upazila Level

working together
to assess risk

GLOBAL EARTHQUAKE MODEL FOUNDATION

3rd March 2024

GEM
GLOBAL EARTHQUAKE MODEL

OQ
OPENQUAKE

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GEM

About GEM Foundation

Non-profit scientific NGO, founded in 2009

Global, public-private partnership

We develop open software, tools and data for use in earthquake hazard and risk assessment worldwide, and work together with local governments and institutions to promote their use in DRR applications.

Our Vision

For a world that is resilient to earthquakes and other natural hazards

www.globalquakemodel.org

GLOBAL QUAKE MODEL .ORG

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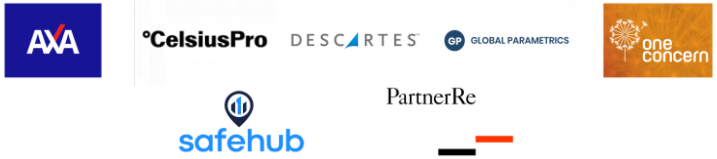


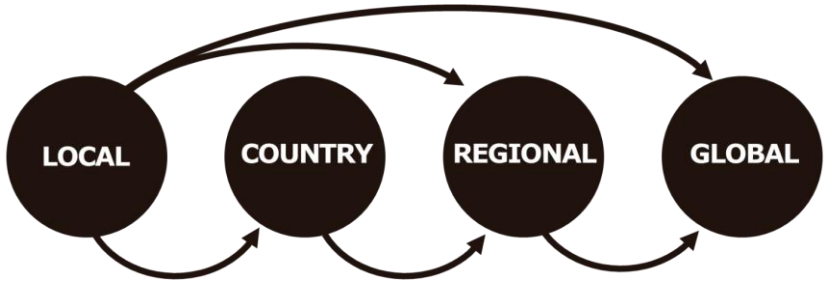
Associate Partners

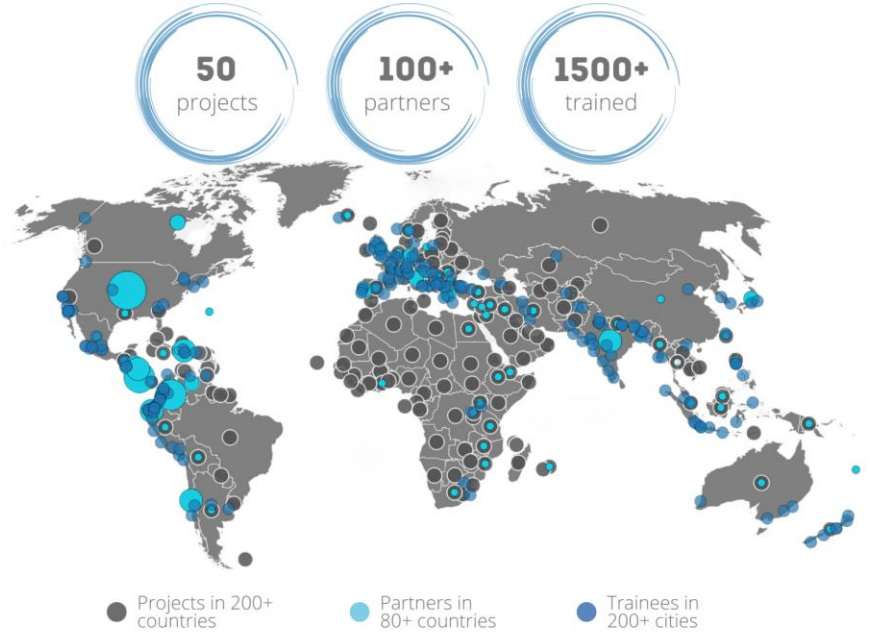
Project Partners

Product Distribution Partners

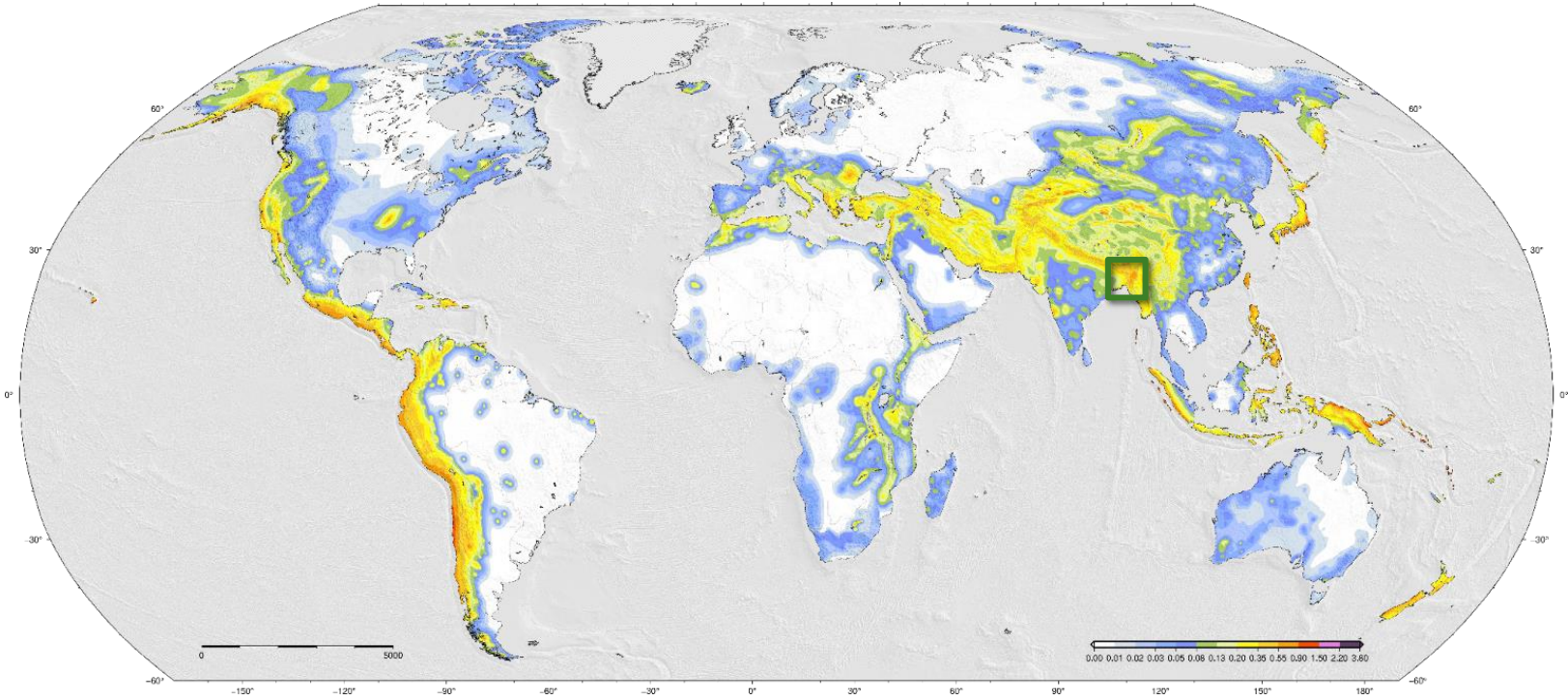
Collaboration Framework

- Built upon collaborations and partnerships
- Multi-level approach, linking local through to global scale
- Guided by GEM Principles:
  - Collaboration
  - Credibility
  - Openness
  - Public-good

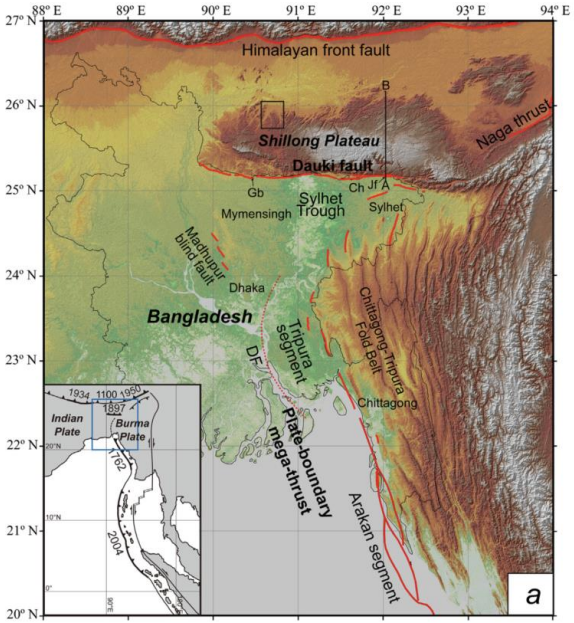




GEM's Global Seismic Hazard and Risk Maps

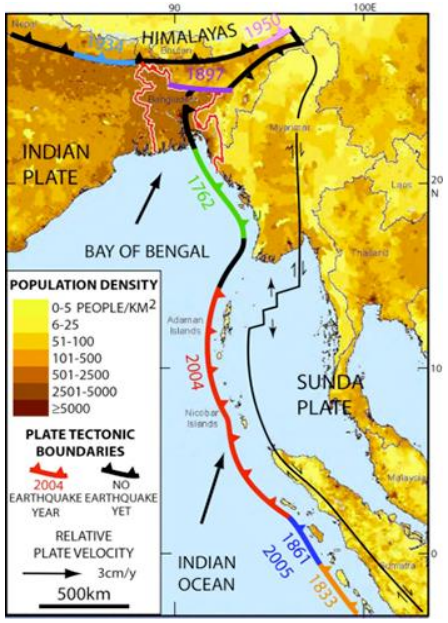


Context



Active fault map of Bangladesh

Morino et al. (2014). A paleo-seismological study of the Dauki fault at Jaflong, Sylhet, Bangladesh: Historical seismic events and an attempted rupture segmentation model. Journal of Asian Earth Sciences, 91, 218–226.

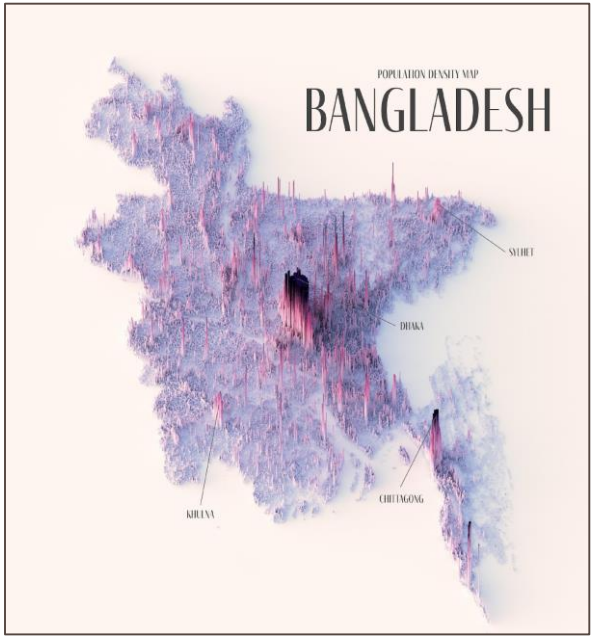


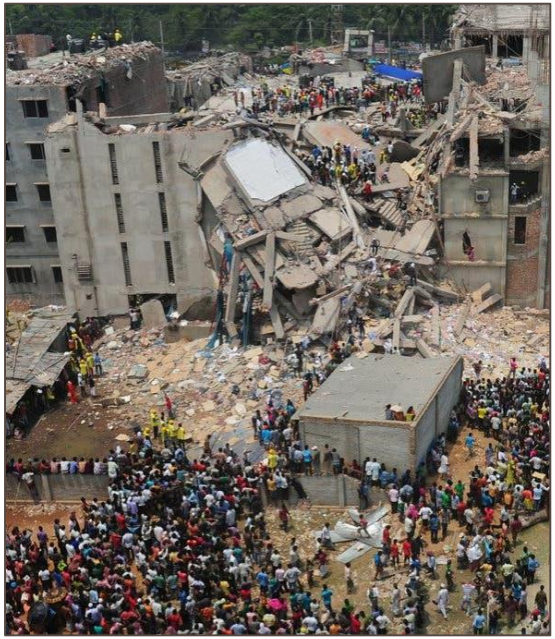
Subduction plate boundaries

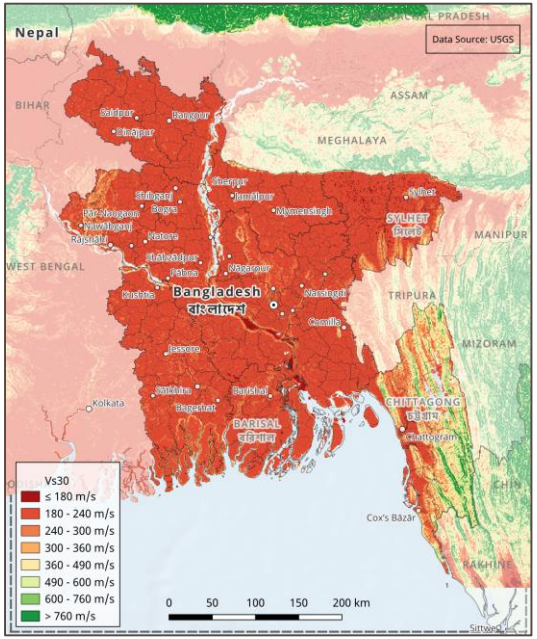
Source: Michael Steckler / Lamont-Doherty Earth Observatory

- No significant earthquake in the last century
- DRR resources almost exclusively devoted to cyclone and flood management
- Potential for earthquakes on the Madhupur and Dauki faults
- Potential for large subduction earthquakes

Context







High population across the country, with a particular concentration in Dhaka

Bangladesh population: 165 million (2022 census)
Dhaka metropolitan area: 22.5 million (2022 census)

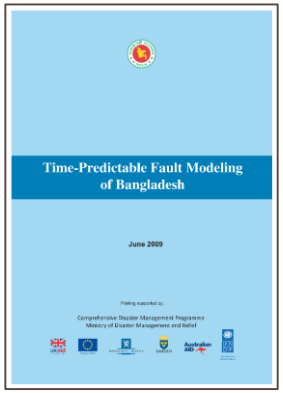
Rapid urbanization coupled with poor quality RC construction & slums

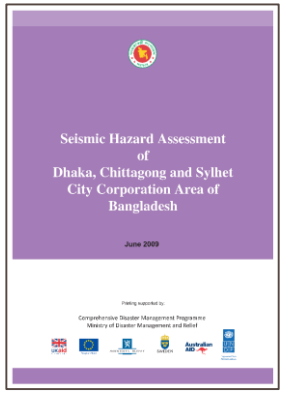
Collapse of Rana Plaza in Savar, Dhaka led to 1,134 fatalities and around 2,500 injuries

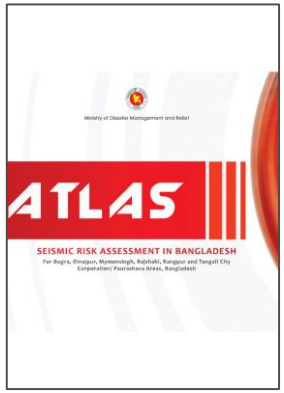
80% of the country is a river delta – deep deposits of soft clay & silt

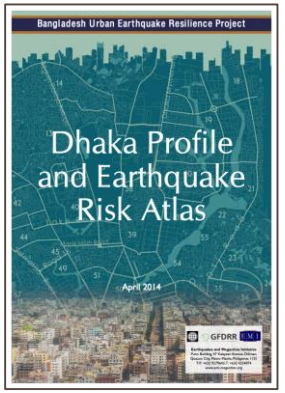
Potential for significant amplification of ground motions and liquefaction

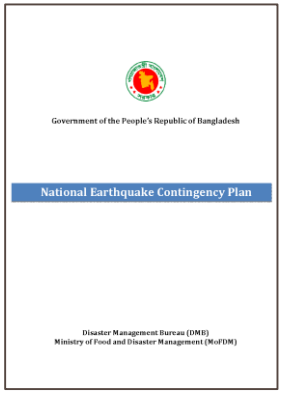
Previous Efforts, and Need for a Nationwide Earthquake Risk Assessment

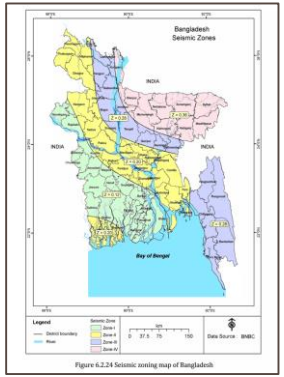


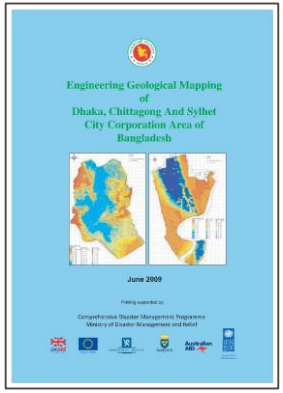


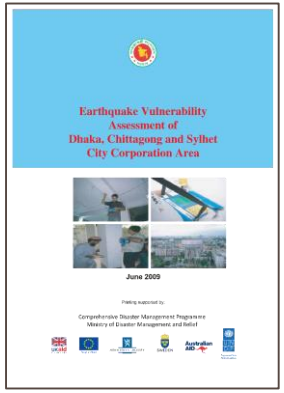


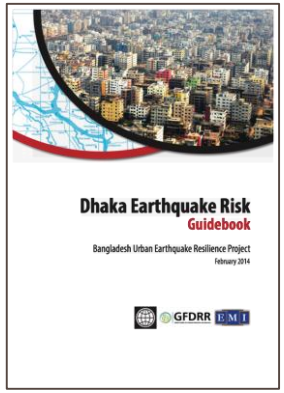


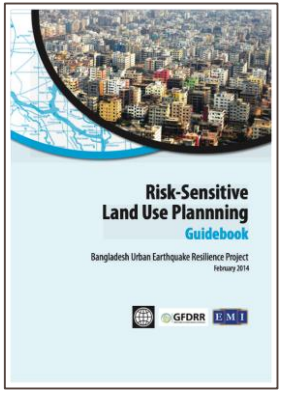






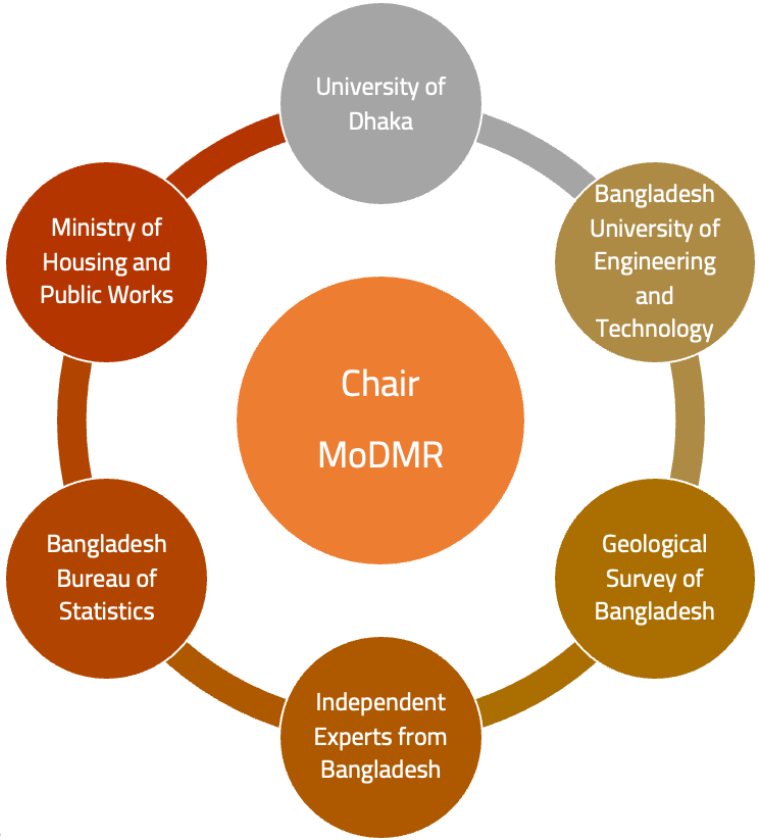






Project Activities

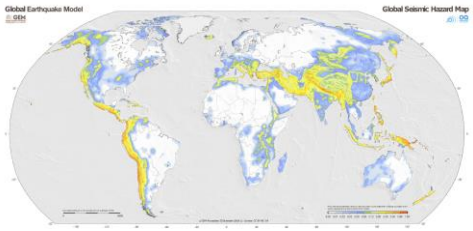
- Needs and Gaps Assessment
- Technical Panel Consultations
- Seismic Hazard Mapping
- Exposure Mapping
- Seismic Vulnerability Assessment
- Seismic Risk Mapping & Interpretation
- Stakeholder Consultation & Validation
- Dissemination and Training Workshop
- Publication of Final Results & Materials



Three Components of Seismic Risk

Seismic Risk

Risk occurs when there is a spatial and temporal overlap of these three elements

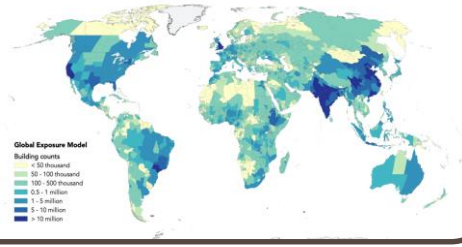


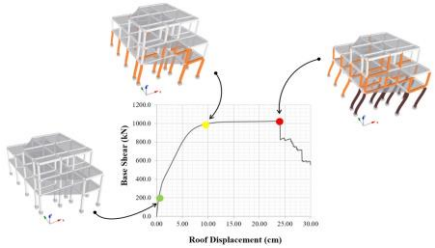
Hazard

Characterizing the potential locations, intensity or magnitude, frequency or probability of earthquakes

Exposure

Characterizing the built environment and people in hazard-prone areas



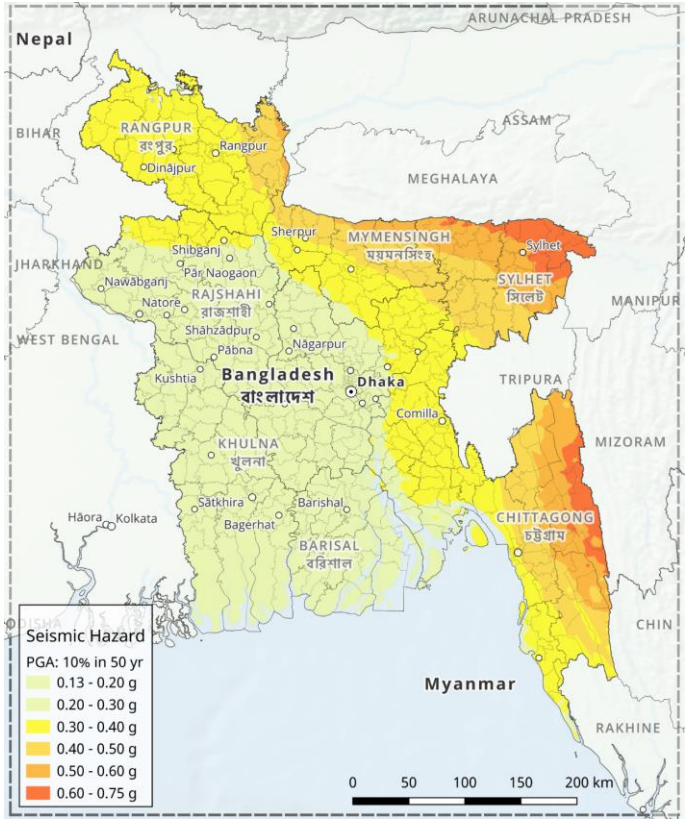


Vulnerability

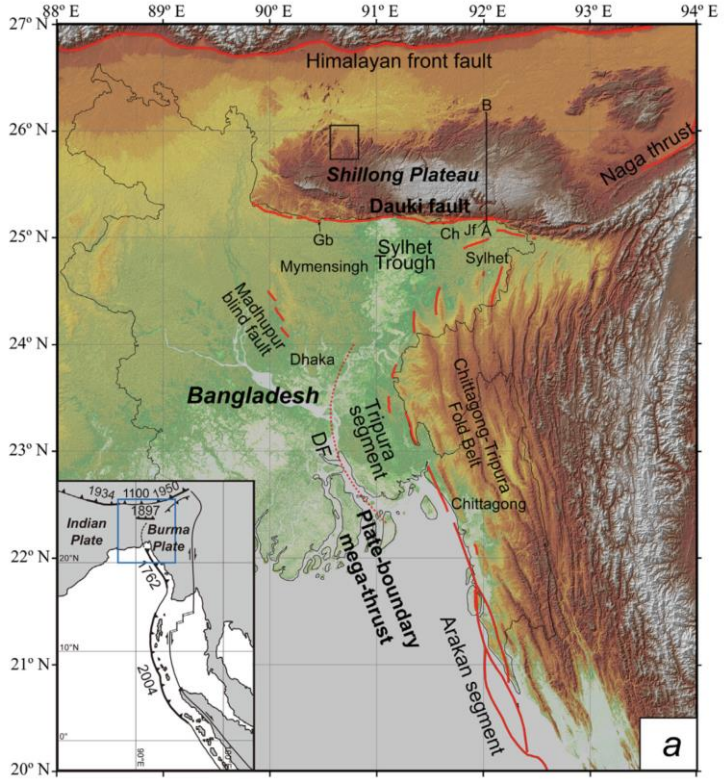
Factors which increase the susceptibility of an individual or assets to the impacts of hazards

SEISMIC HAZARD

ACTIVE FAULTS
HISTORICAL EARTHQUAKES
SEISMIC HAZARD MAPPING
SCENARIO MODELLING

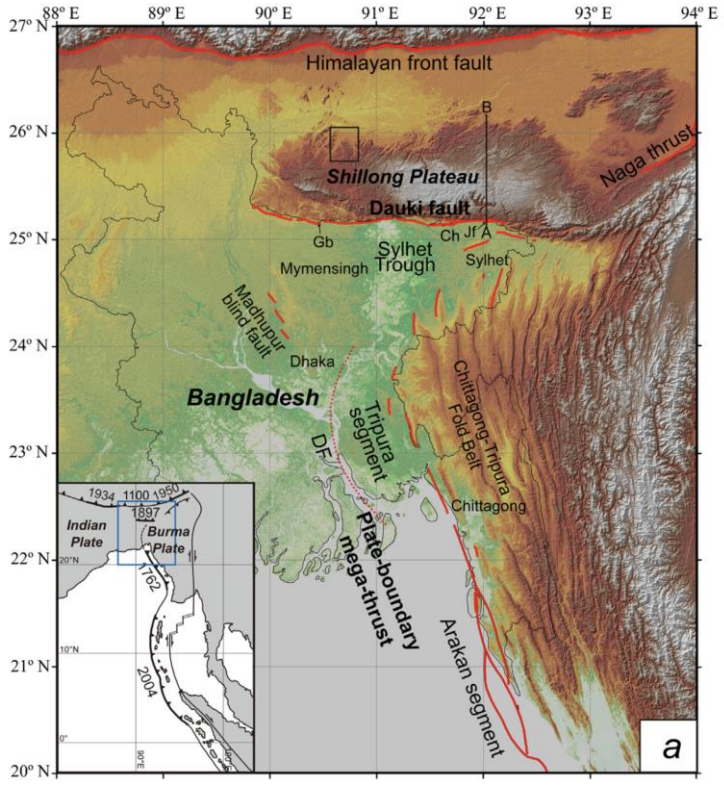


Seismic hazard assessment – Probabilistic

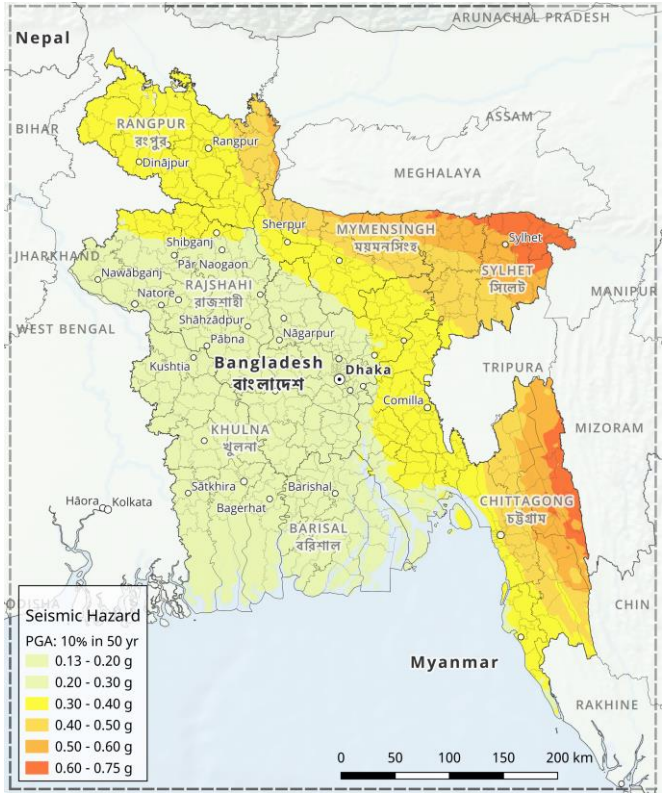


- Identification of active faults
- Tectonic region type assignments
- Historical earthquake catalogue
- Ground motion characterization
- Soil characterization
- Probabilistic seismic hazard maps

Seismic hazard assessment – Probabilistic



Active faults map



Probabilistic seismic hazard map

Seismic hazard assessment – Probabilistic

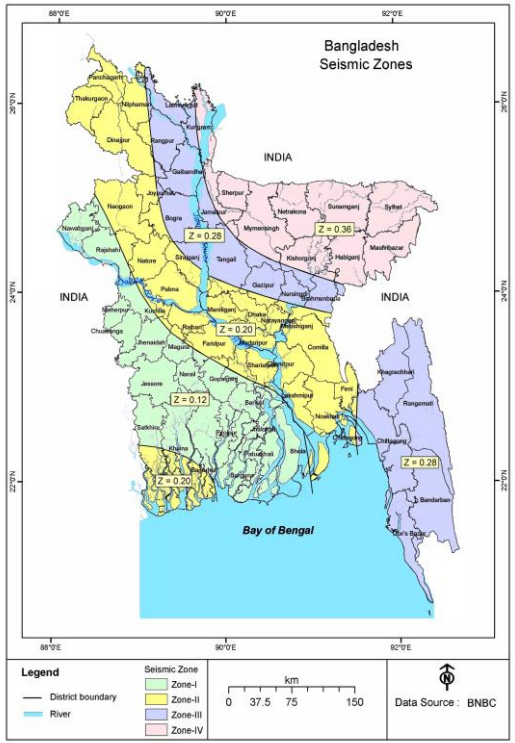
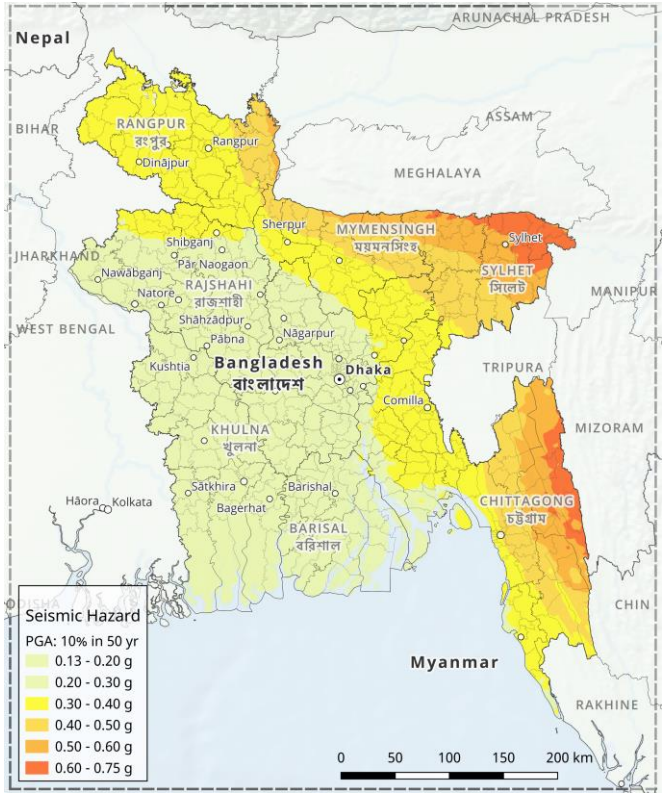


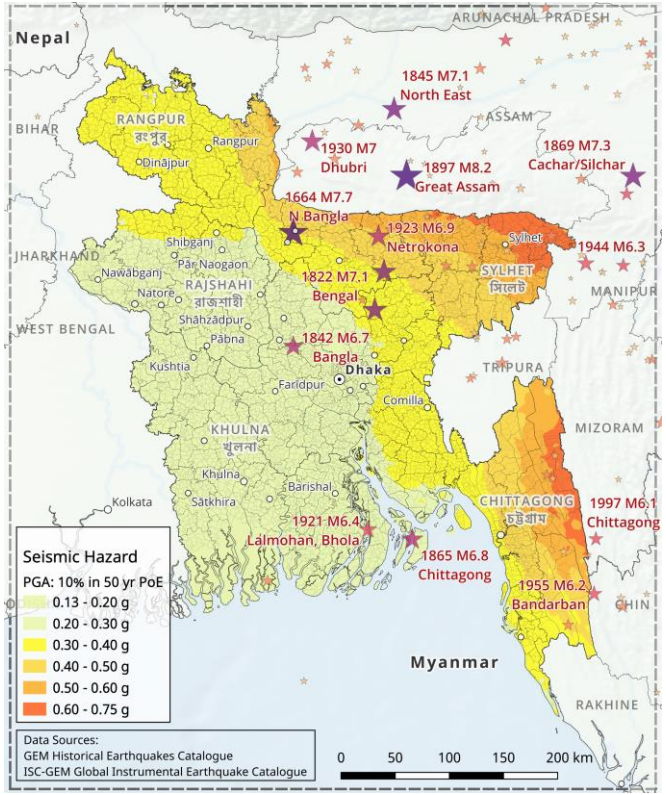
Figure 6.2.24 Seismic zoning map of Bangladesh

BNBC seismic zone map

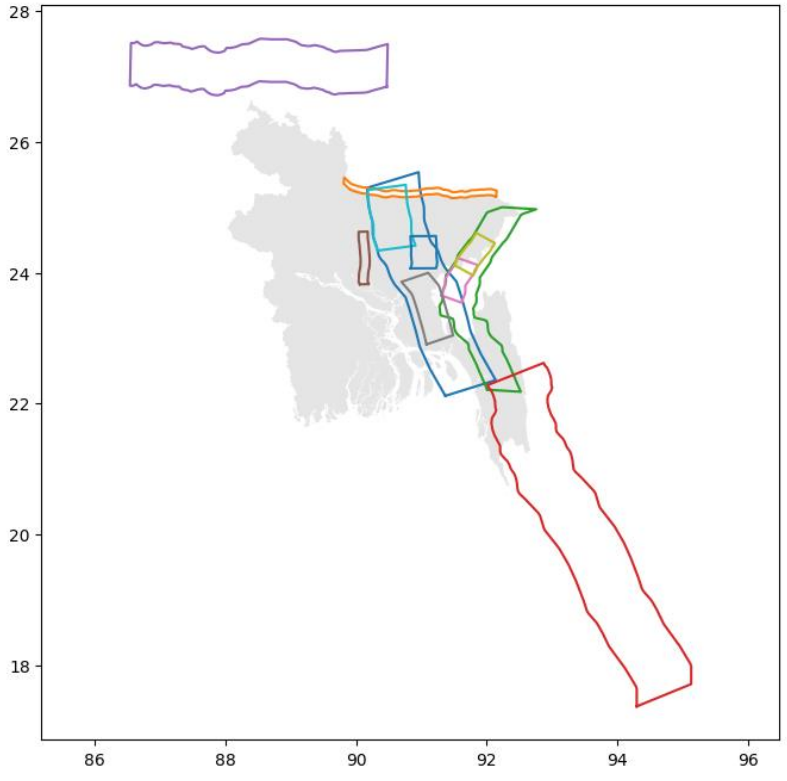


Probabilistic seismic hazard map

Seismic hazard assessment – Scenarios

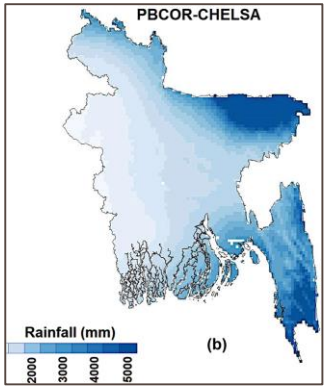


Historical earthquakes

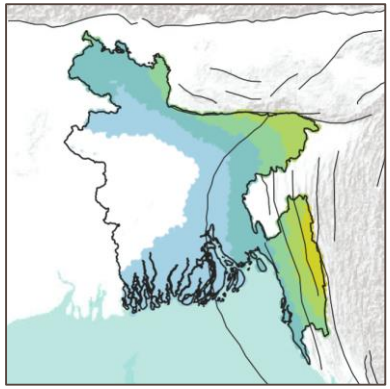


Modelled scenario ruptures

Earthquake-induced soil liquefaction



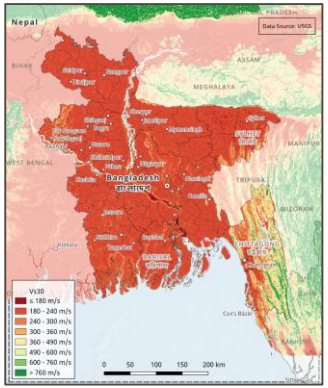
Average annual precipitation

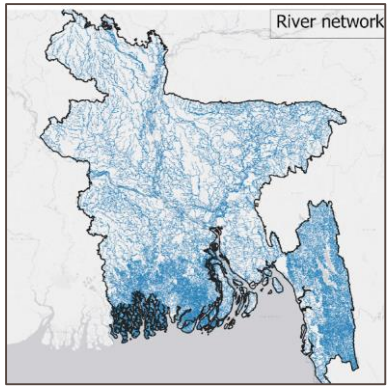


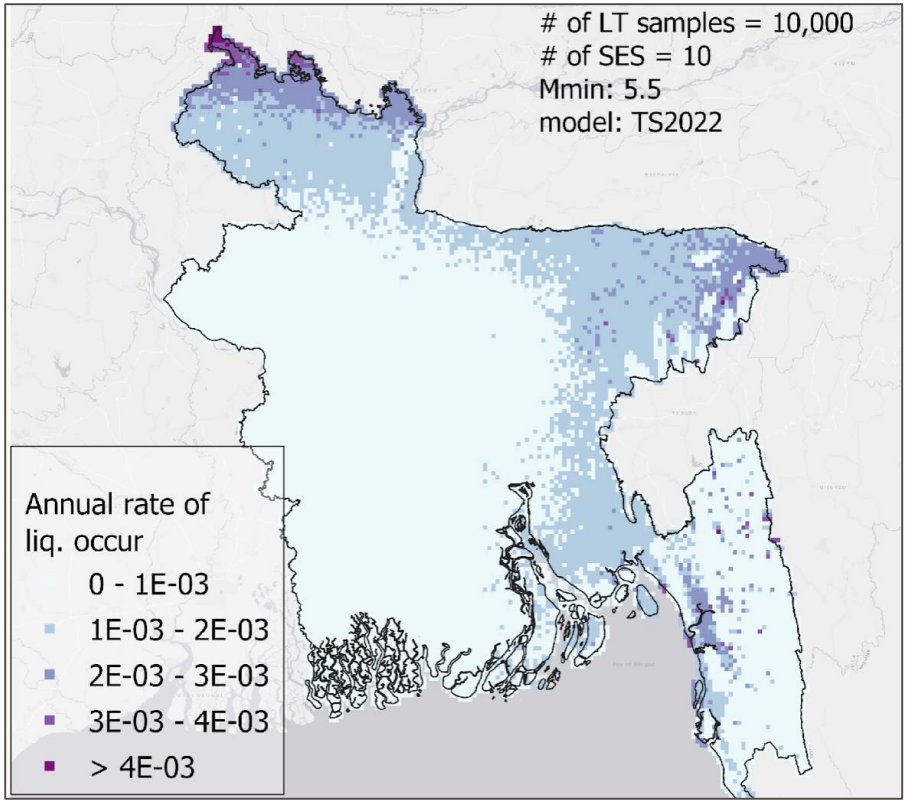
PGV, PGA

Distance to river / coast

Vs_{30}



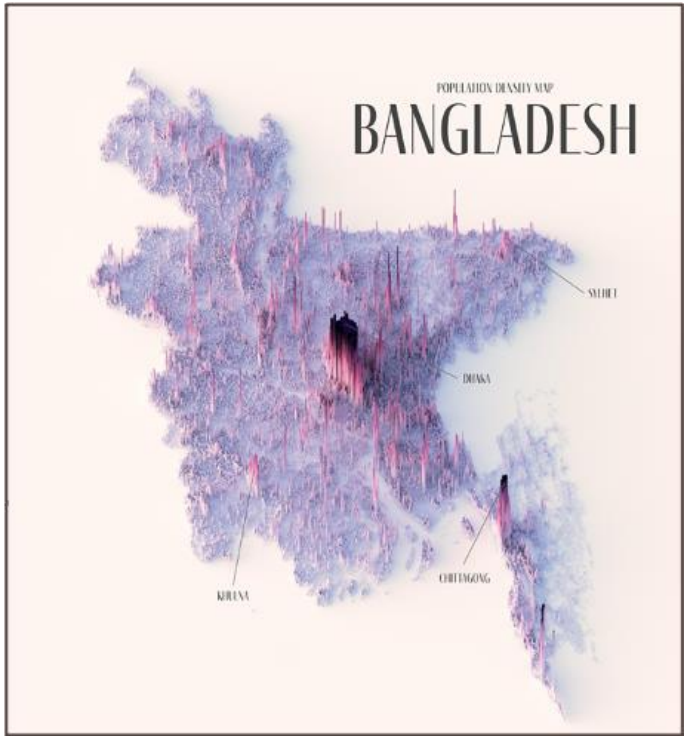




Average annual rate of liquefaction occurrence

EXPOSURE

BUILDINGS
POPULATION
INFRASTRUCTURE



Exposure – Conceptual framework

https://zagreb.gdi.net/zg3d/

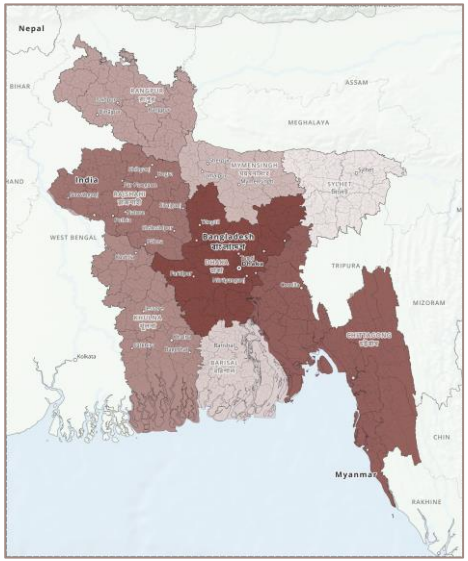
Exposure – Structural and physical attributes

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

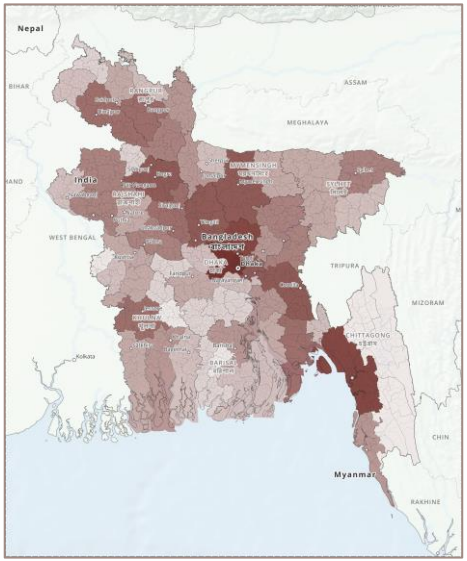



Some of the main attributes that need to be identified are:
construction material, structural system, height, and code compliance

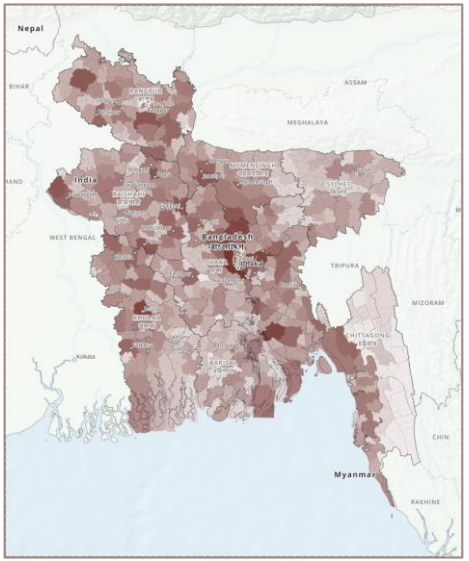
Exposure – Residential buildings



Residential Exposure (2018)
2011 Census
Admin Level 1 – Division (8)

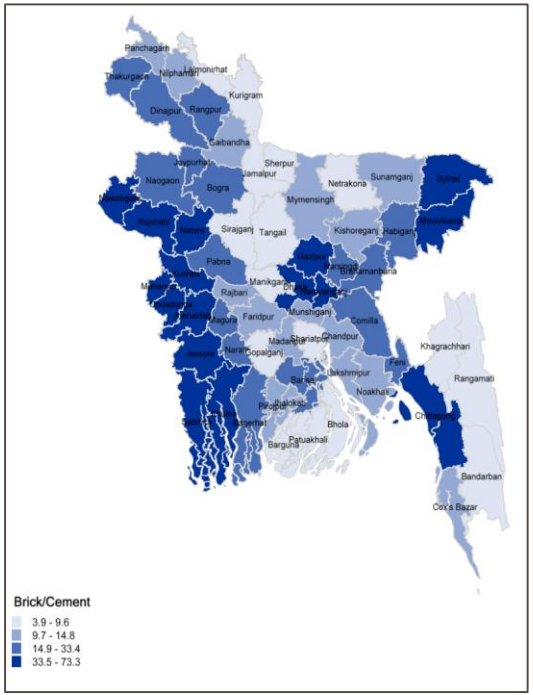


Residential Exposure (2022)
2011 Census
Admin Level 2 – Zila (64)

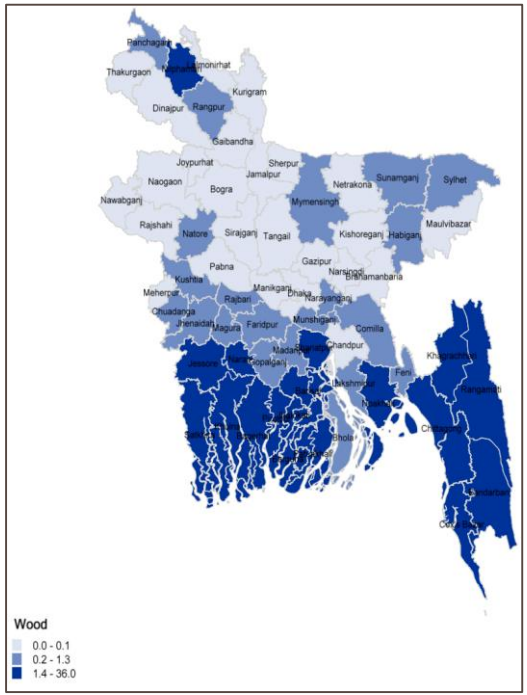


Residential Exposure (2024)
2022 Census
Admin Level 3 – Upazila / Thana

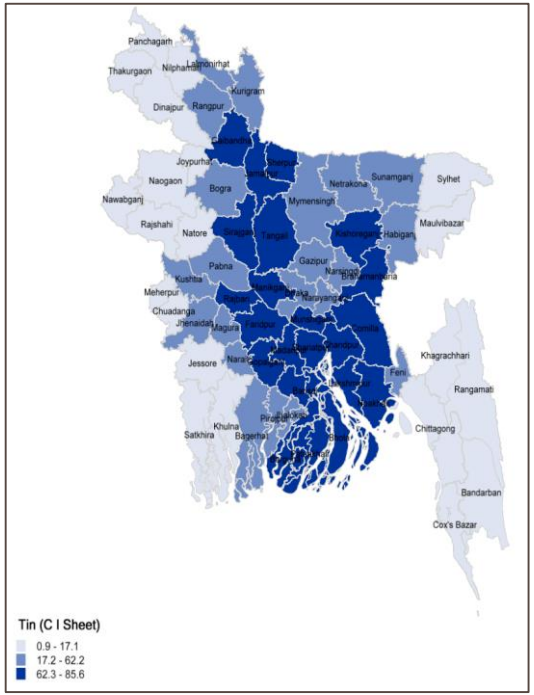
Exposure – Geographical variation of construction types



Brick / Cement
2011 Census
Zila Level

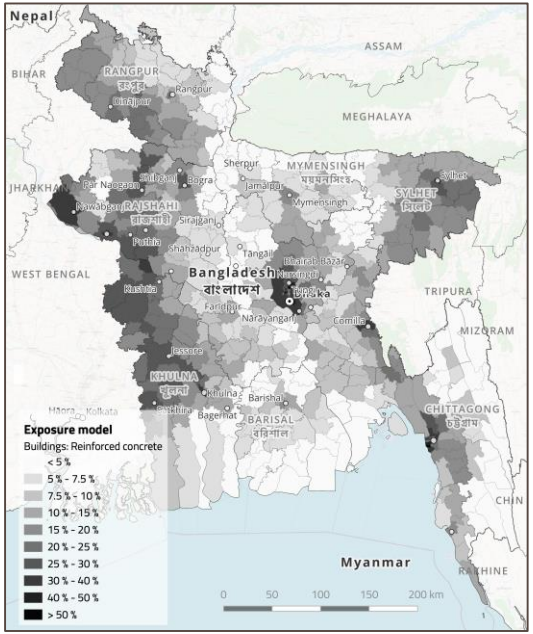


Wood / Bamboo
2011 Census
Zila Level

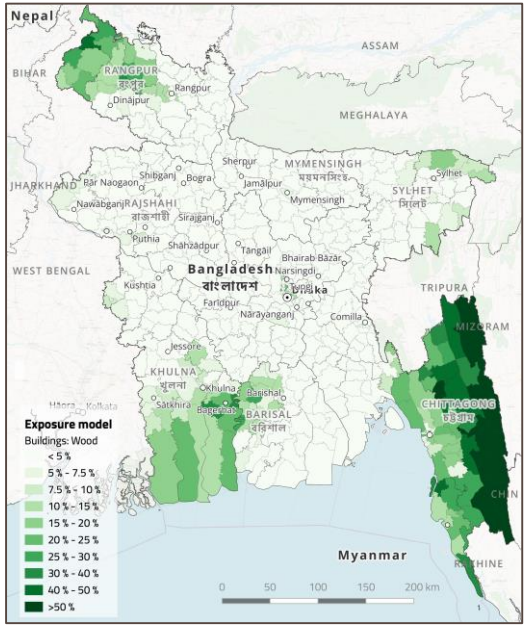


Tin / CI Sheet
2011 Census
Zila Level

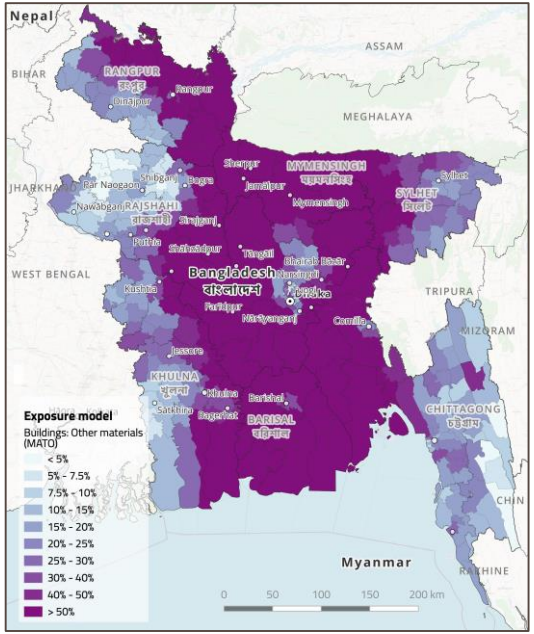
Exposure – Geographical variation of construction types



Brick / Cement
2022 Census
Upazila Level



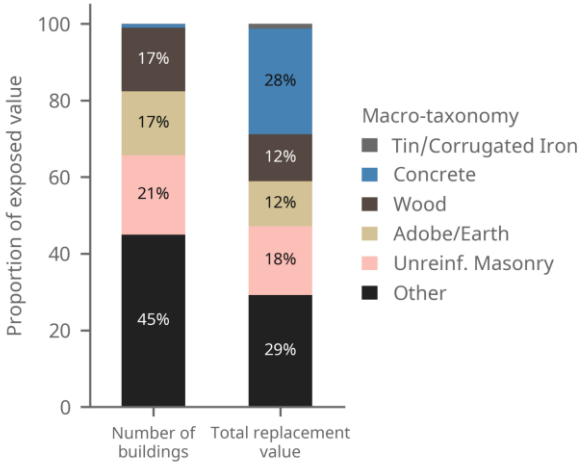
Wood / Bamboo
2022 Census
Upazila Level



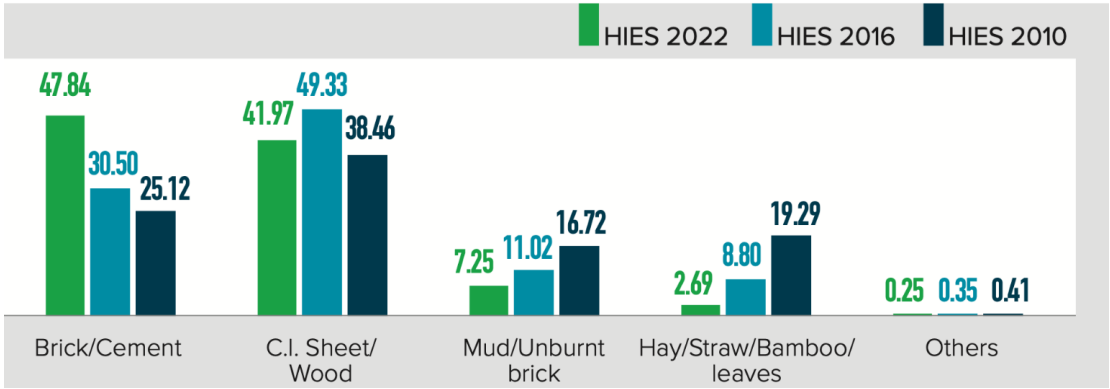
Other Materials
2022 Census
Upazila Level

Exposure – Evolution of construction types

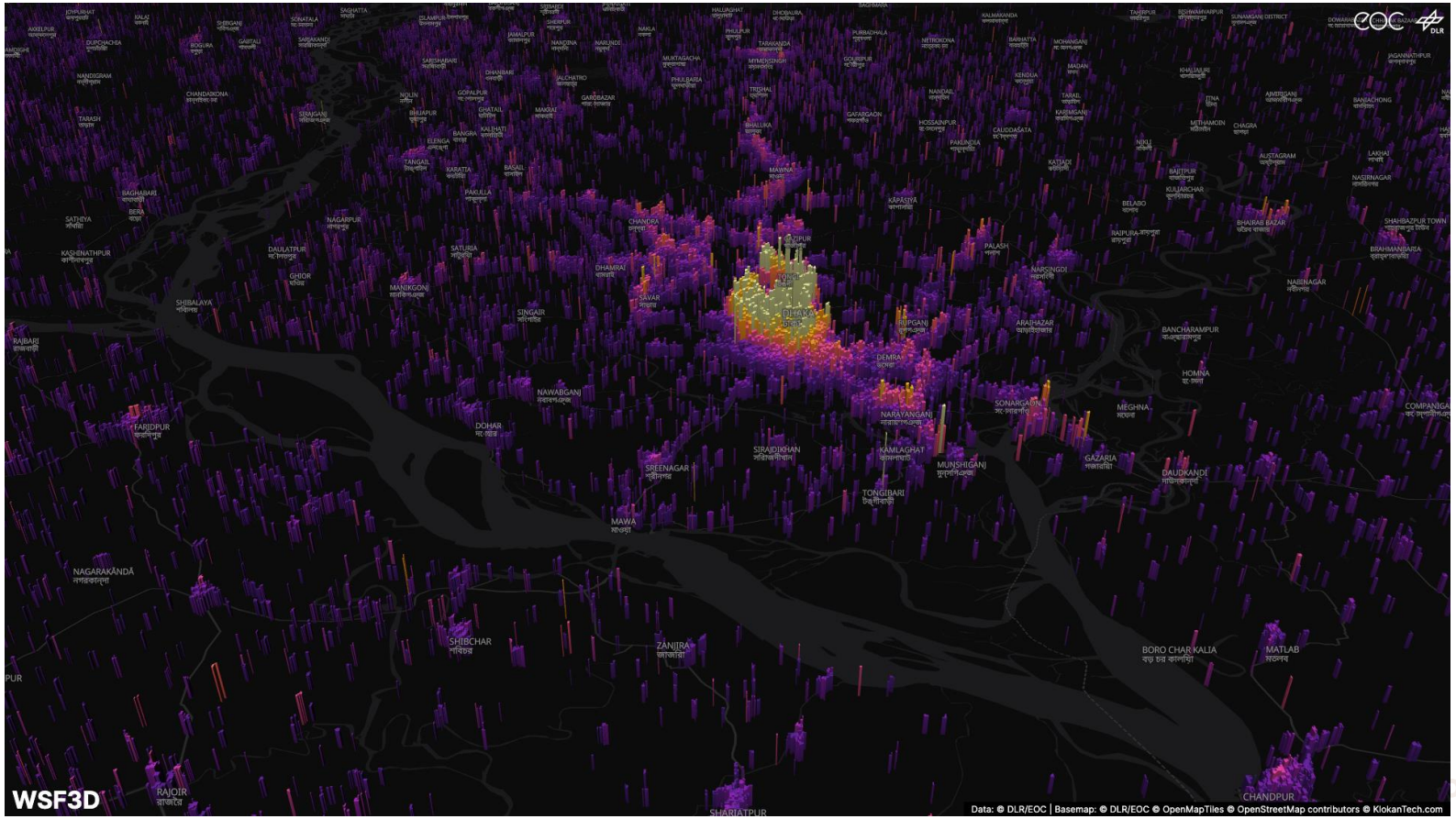


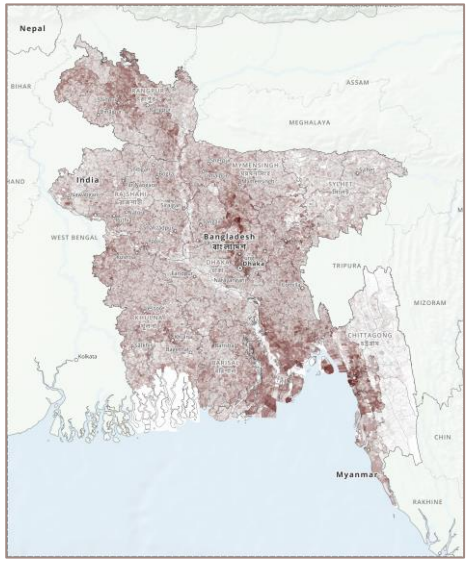
Percentage Distribution of Main Dwelling Structure by Materials of Wall and by Year



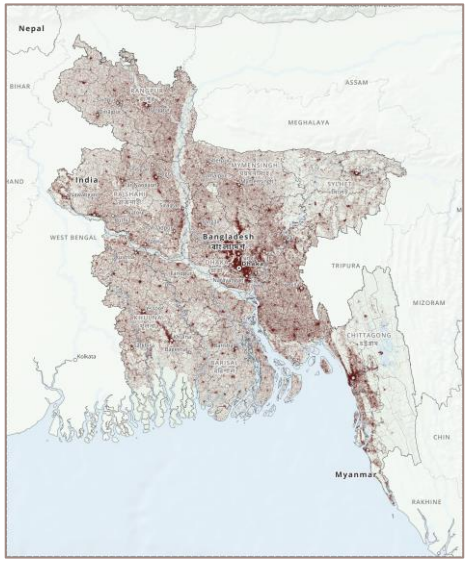
Exposure – Inferring building heights



Exposure – Enhanced spatial resolution for flood risk



Residential Exposure (2024)
2022 Census
Admin Level 5 – Villages



Residential Exposure (2024)
2022 Census
Admin Level 6 – Enumeration Areas

- **Buildings**
  - Residential
  - Commercial
  - Industrial
- **Attributes**
  - Location
  - Typology
  - Valuation
  - Height
  - Age
- **Population**
  - 2022 Census

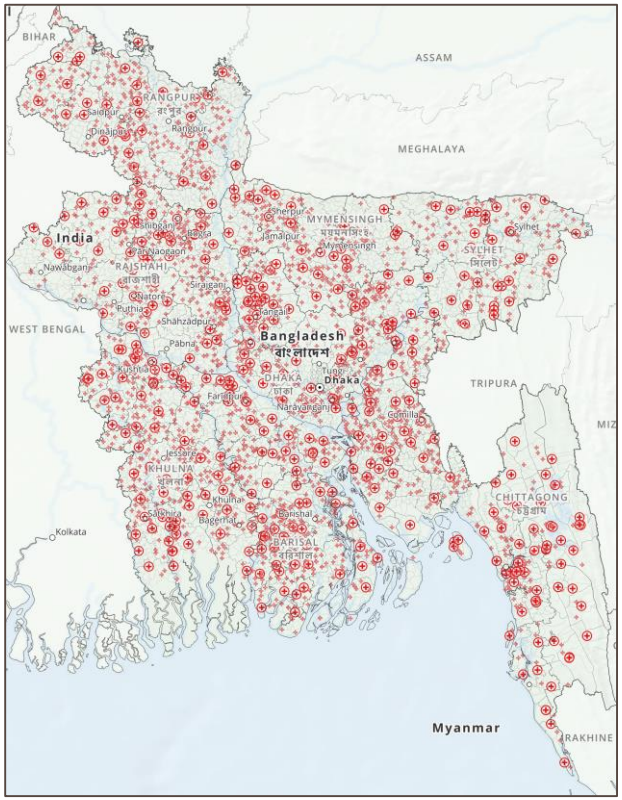
Exposure – Slum dwellings and floating population

Type of dwelling unit	Slum Census 2014		Slum Census 1997	
	Household	Percentage	Household	Percentage
Jhupri	36875	6.20	142476	42.61
Katcha/Tin	371485	62.45	178586	53.40
Semi-pucca	157243	26.43	10319	3.08
Pucca	24169	4.06	3050	0.91
Others	5089	0.86	NA	NA
National	**594861**	**100.00**	**334431**	**100.00**

NB: Tong, Chhai etc. included in katcha structure.

Source: Census of Slum Areas and Floating Population 2014, BBS

Exposure – Healthcare facilities



Primary data source:

- Hospitals & Clinics Management Section, Directorate General of Health Services (DGHS)

Exposure – Educational facilities

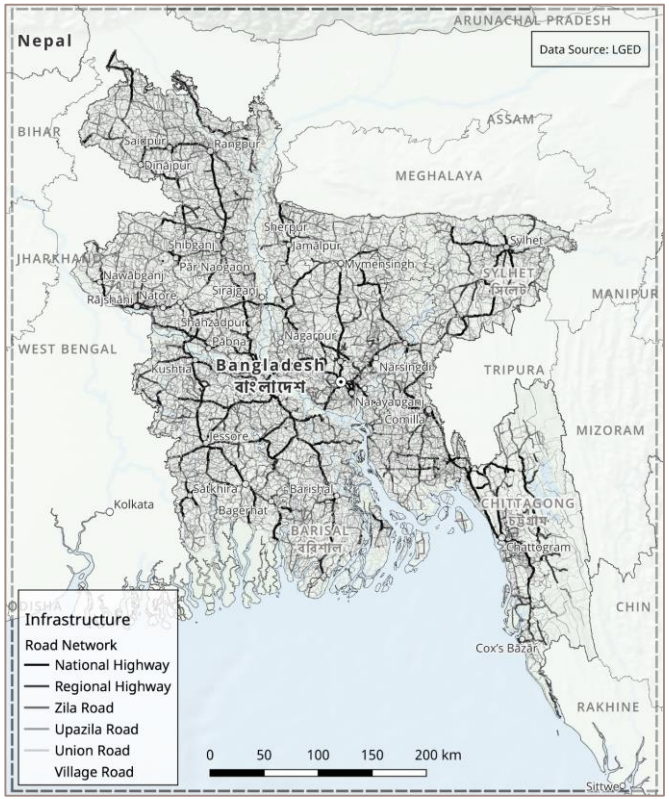
Primary data sources:

- Bangladesh Bureau of Educational Information and Statistics (BANBEIS), Ministry of Education
- Bangladesh Primary Education Statistics & Annual Primary School Census 2021, Ministry of Primary and Mass Education

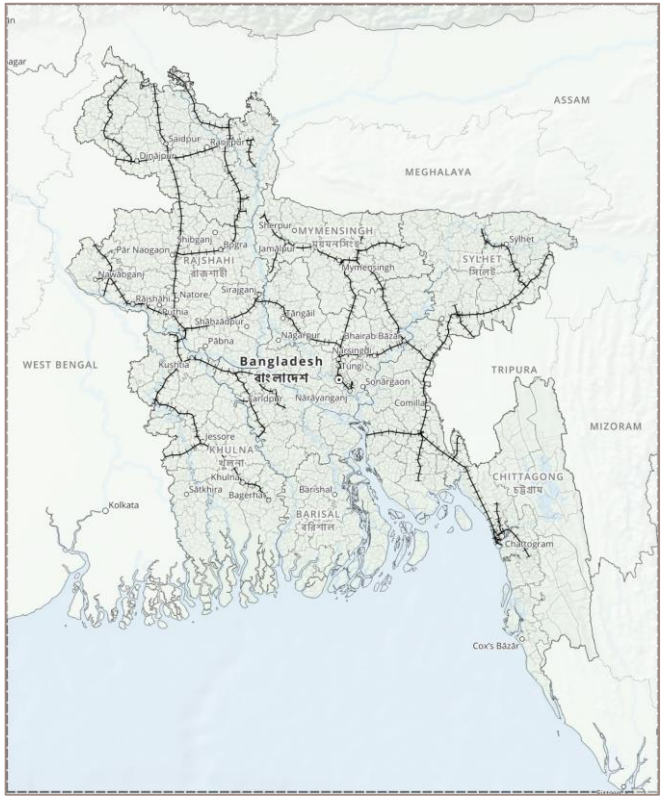
Key Statistics (public)

18,907 (627)	Secondary Education
137	English Medium School
1,446 (64)	School & College
3,301 (637)	College Education
9,268 (3)	Madrasah Education
2,547 (322)	Technical-Vocational (Independent)
826 (129)	Professional Education
209 (94)	Teacher Education
164 (53)	University Education
5,272 (369)	Attached Vocational
118,891 (65,566)	Primary Schools

Exposure – Linear infrastructure networks



Road network



Railway network

Primary data sources:

- Local Government Engineering Dept (LGED)
- OpenStreetMap (OSM)

Seismic Vulnerability Model

DAMAGE

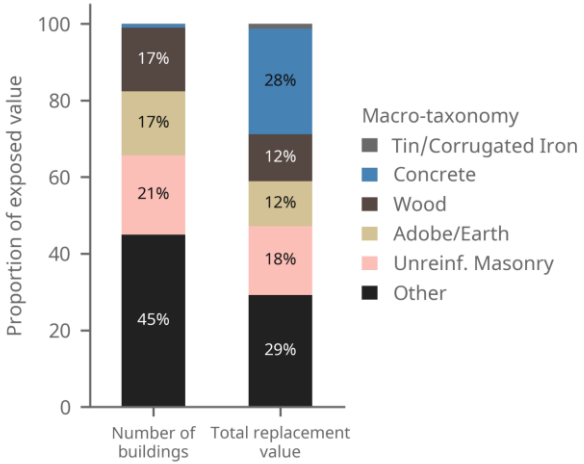
ECONOMIC LOSS

FATALITIES, INJURIES & DISPLACEMENT

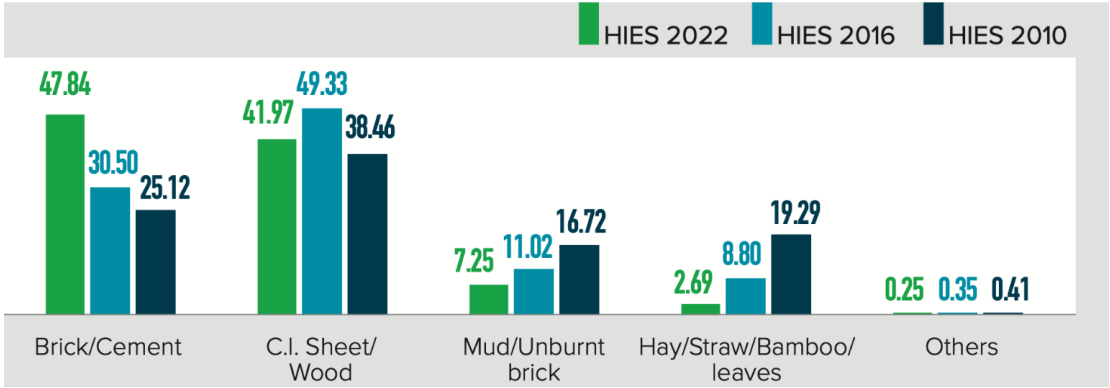
Seismic fragility and vulnerability

Seismic *fragility* represents the likelihood of an element exposed to seismic hazard to suffer *damage* due to ground shaking. Similarly, seismic *vulnerability* represents the likelihood of an element exposed to seismic hazard to suffer *losses* due to ground shaking

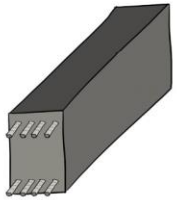
Seismic vulnerability analysis



Percentage Distribution of Main Dwelling Structure by Materials of Wall and by Year

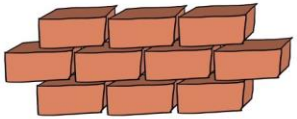


Factors affecting damage level – construction factors

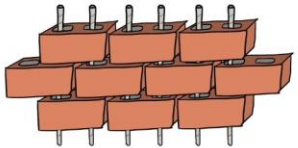


Reinforced concrete

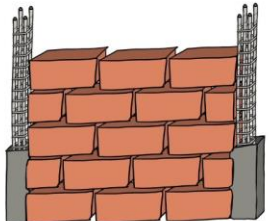
Wood



Unreinforced masonry



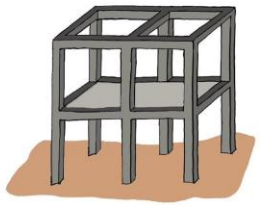
Reinforced masonry



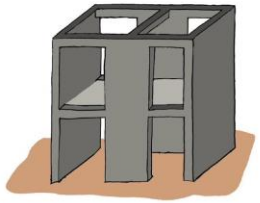
Confined masonry

Main material of construction

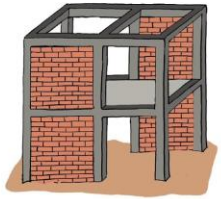
Factors affecting damage level – construction factors



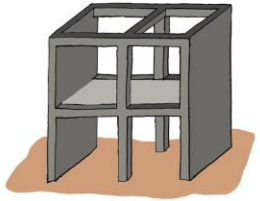
Moment frames



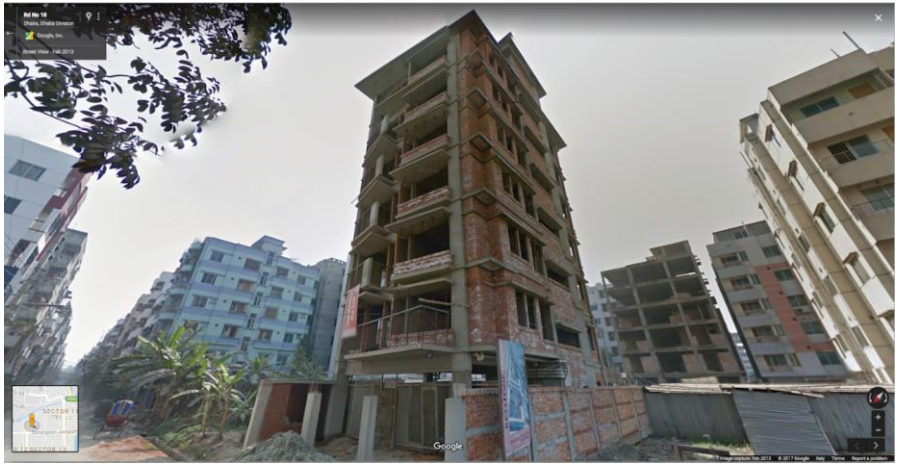
Walls



Infilled moment frames



Dual systems (Moment frames and walls)



Lateral load resisting system (LLRS)

Factors affecting damage level – construction factors

Number of stories

Height

Building code complaince

Ductility level

Structural response to ground shaking

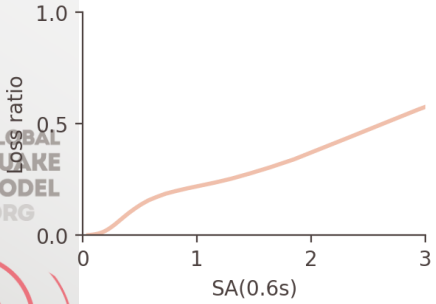
Structural response to ground shaking

DAMAGE STATE

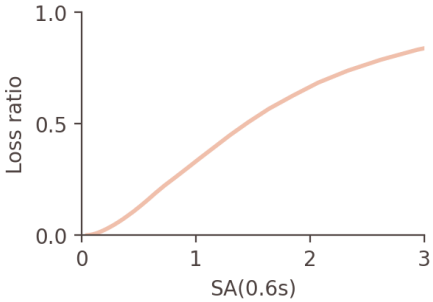
No damage | Slight | Extensive | Complete

GEM's vulnerability database → Economic losses

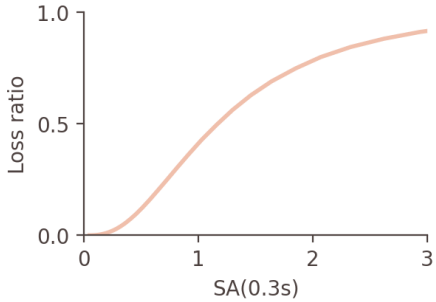
Bamboo houses



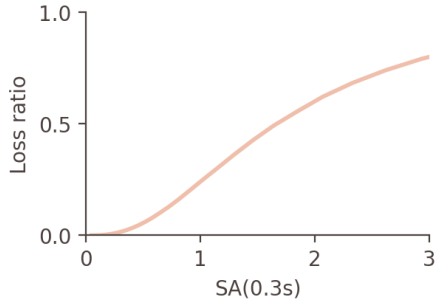
Reinforced concrete buildings



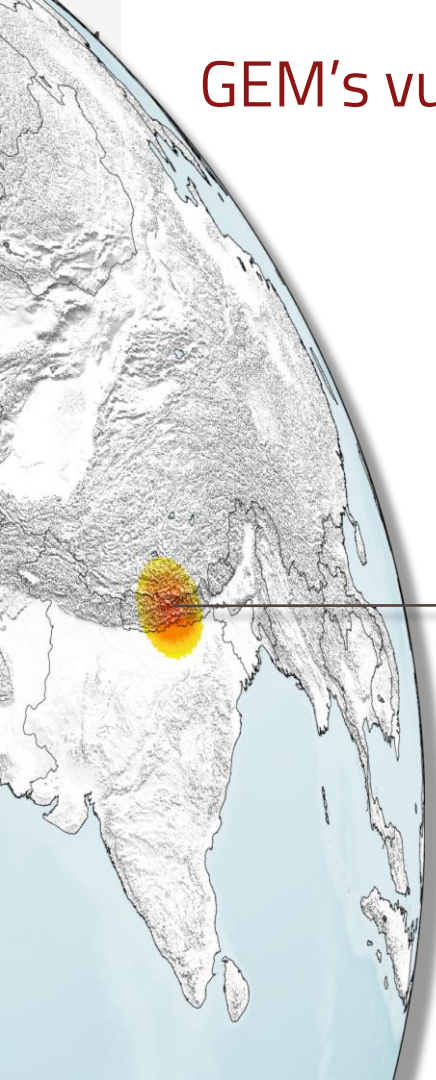
Rubble stone masonry



Clay brick masonry



GEM's vulnerability database → Human impact



High fatality rates (Concrete)

Moderate fatality rates (Masonry)

Low fatality rates (Wood)

Risk metrics covered by GEM's vulnerability database

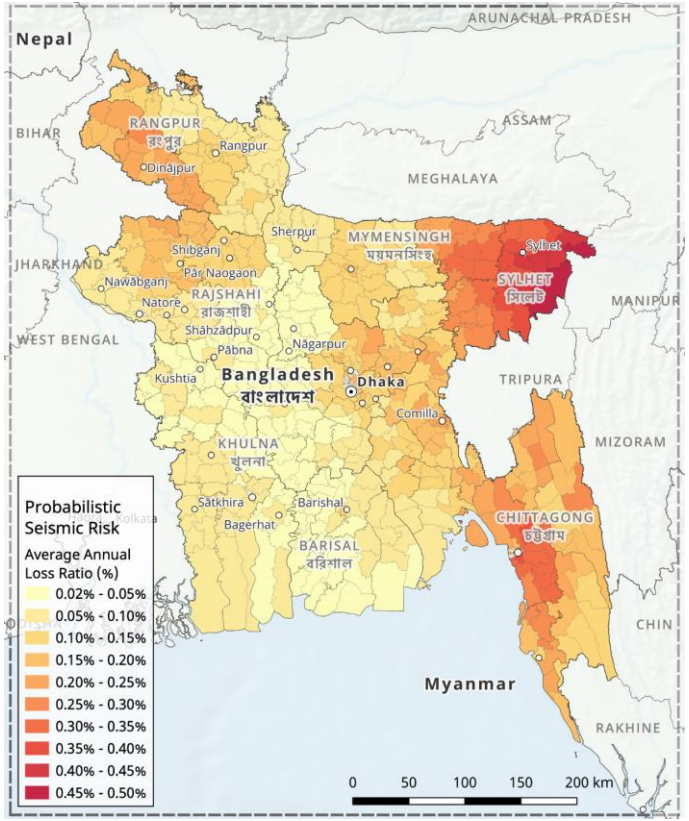
Exposure

Consequences

- Buildings lost
- Area lost (m^2)
- Economic loss (USD)
- Fatalities
- Severe injuries
- Displaced

SEISMIC RISK

SCENARIO RISK MODELLING
PROBABILISTIC SEISMIC RISK
UPAZILA LEVEL RISK MAPS



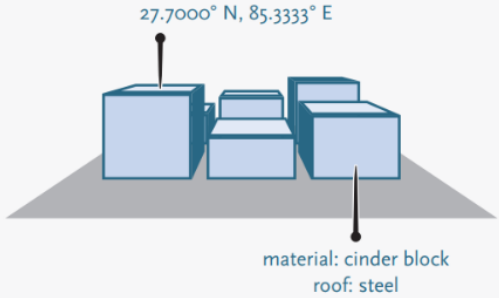
Seismic risk

HAZARD

The likelihood, probability, or chance of a potentially destructive phenomenon.

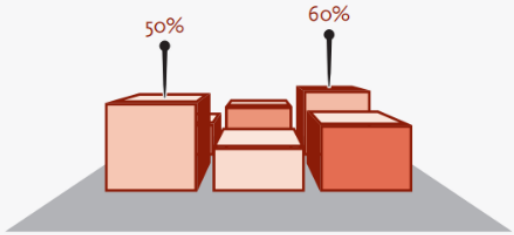
EXPOSURE

The location, attributes, and values of assets that are important to communities.



VULNERABILITY

The likelihood that assets will be damaged or destroyed when exposed to a hazard event.

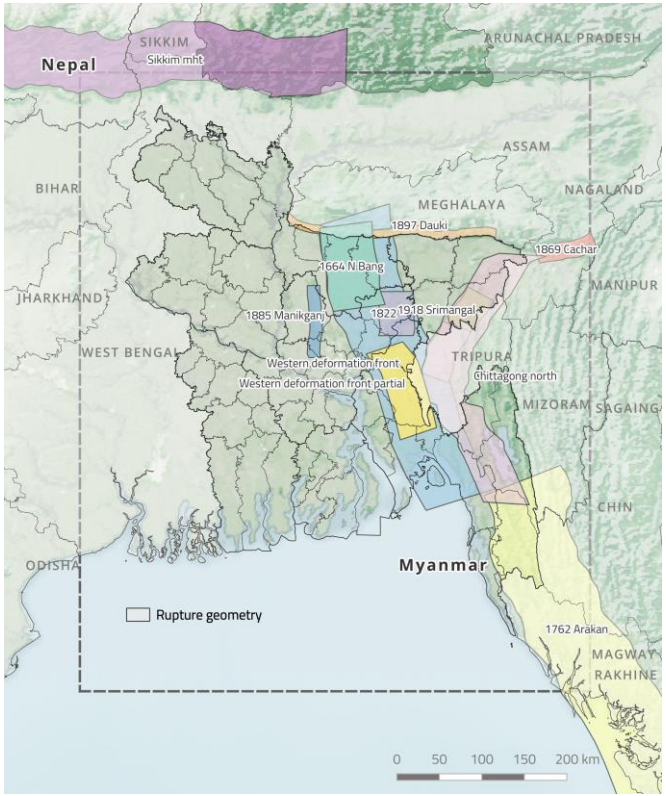


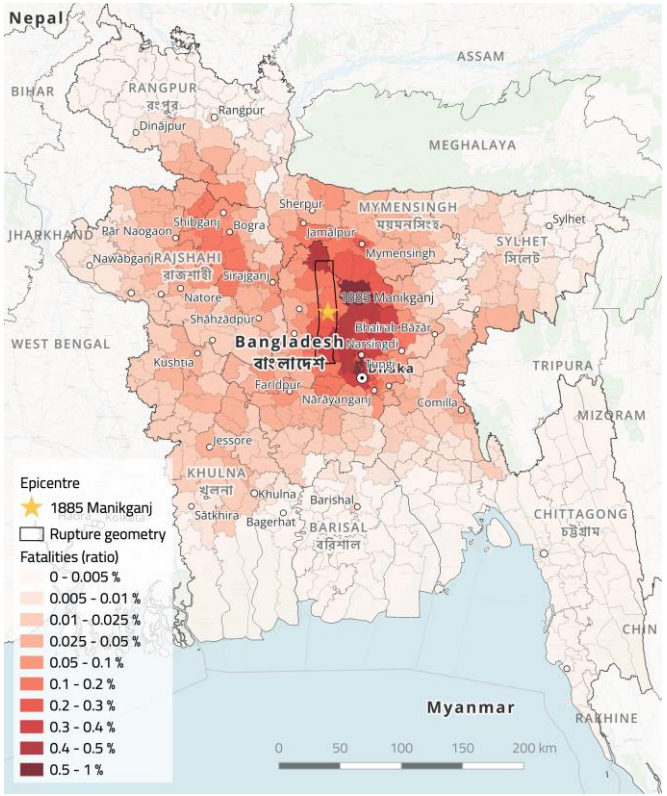
HAZARD + EXPOSURE

Risk occurs when there is a spatial and temporal overlap of these three elements

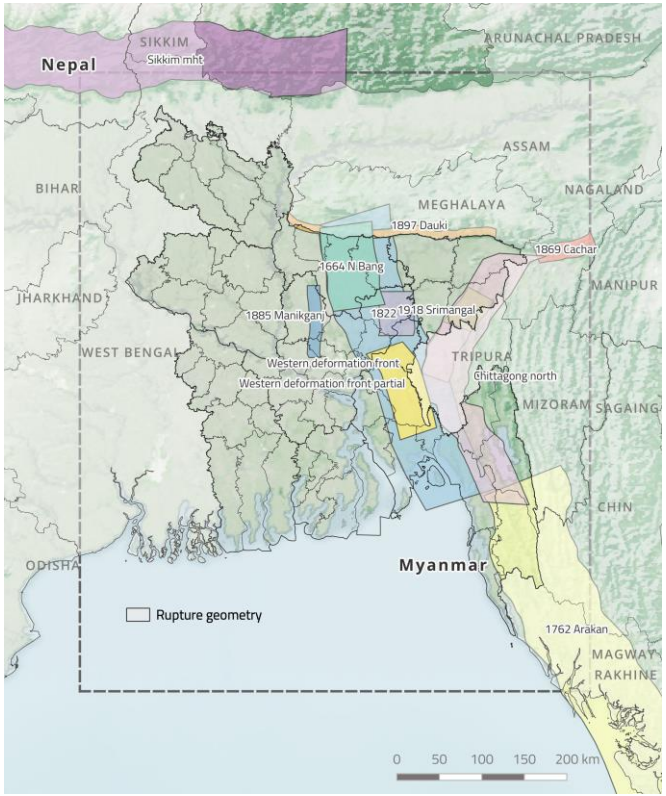
Source: gfdrr.org/sites/gfdrr/files/publication/opendri_fg_web_20140629b_0.pdf

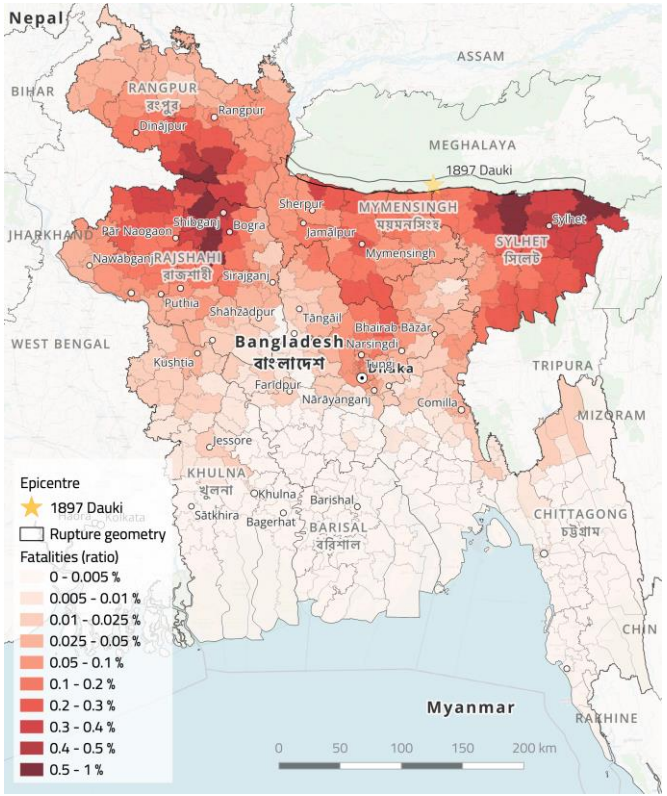
Scenario risk – 1885 M7.2 Manikganj earthquake



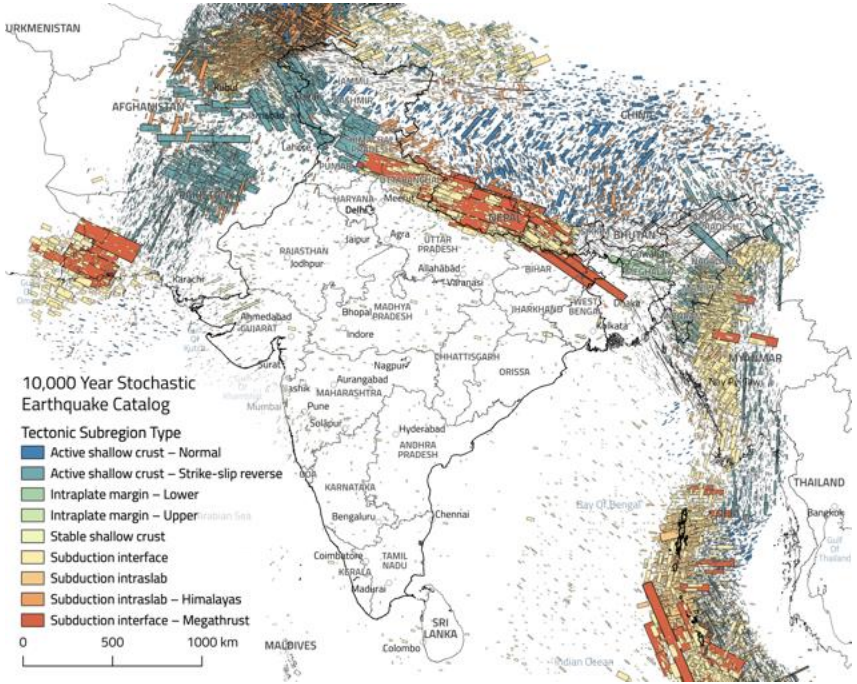


Scenario risk – 1897 M8.7 Dauki earthquake



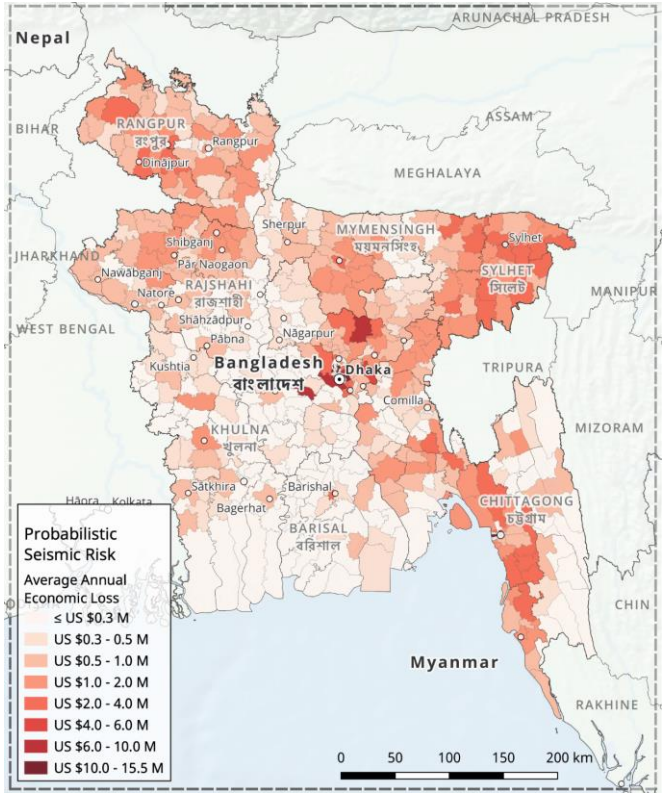


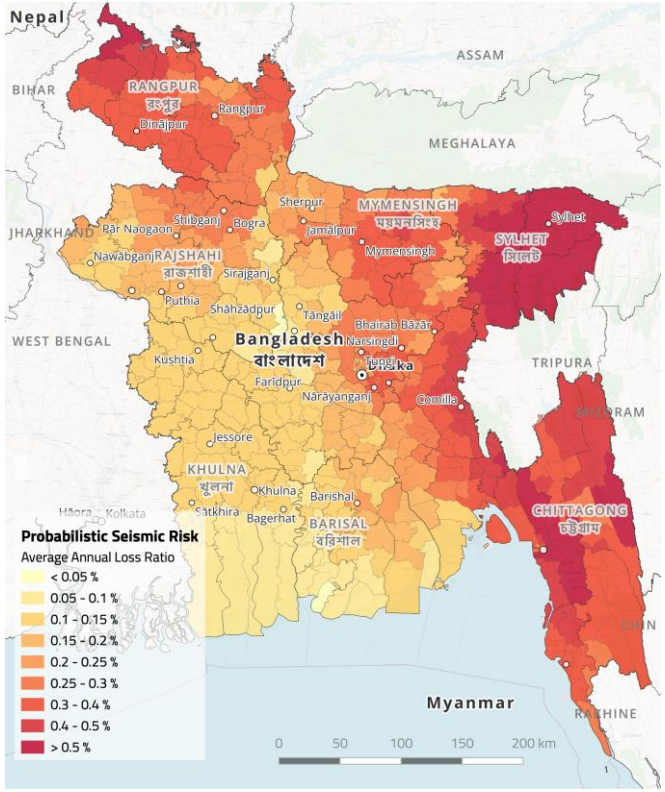
Probabilistic seismic risk assessment



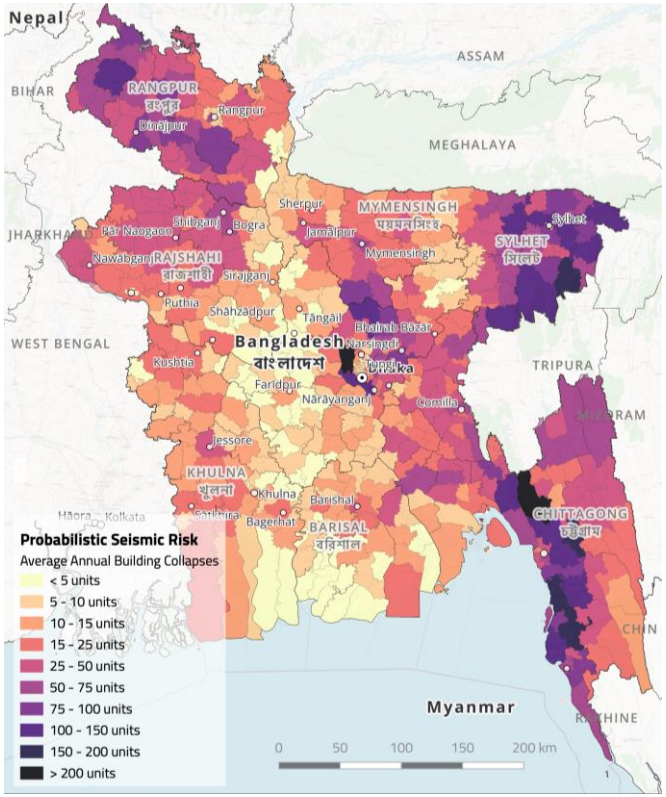
Stochastic earthquake catalog for the Indian subcontinent (10,000 years)

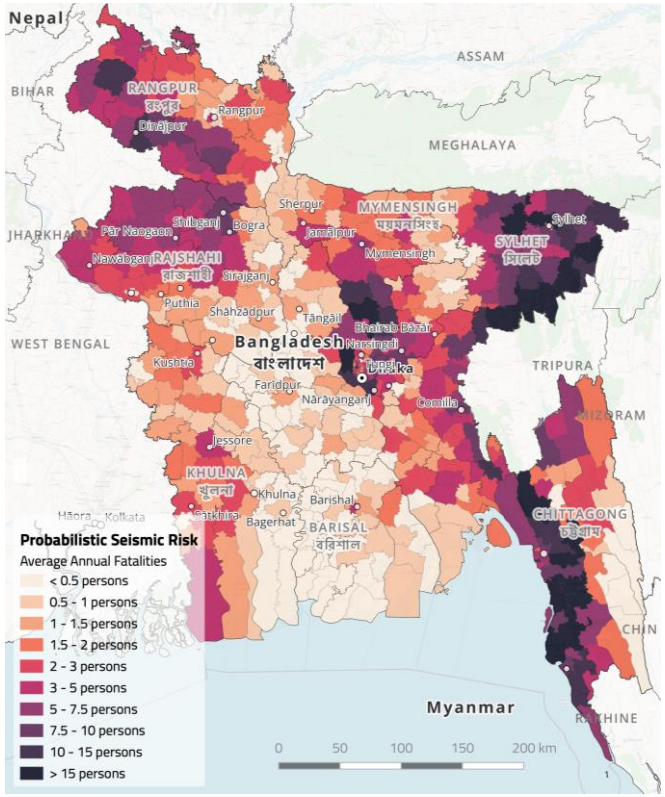
Average annual economic losses at upazila level



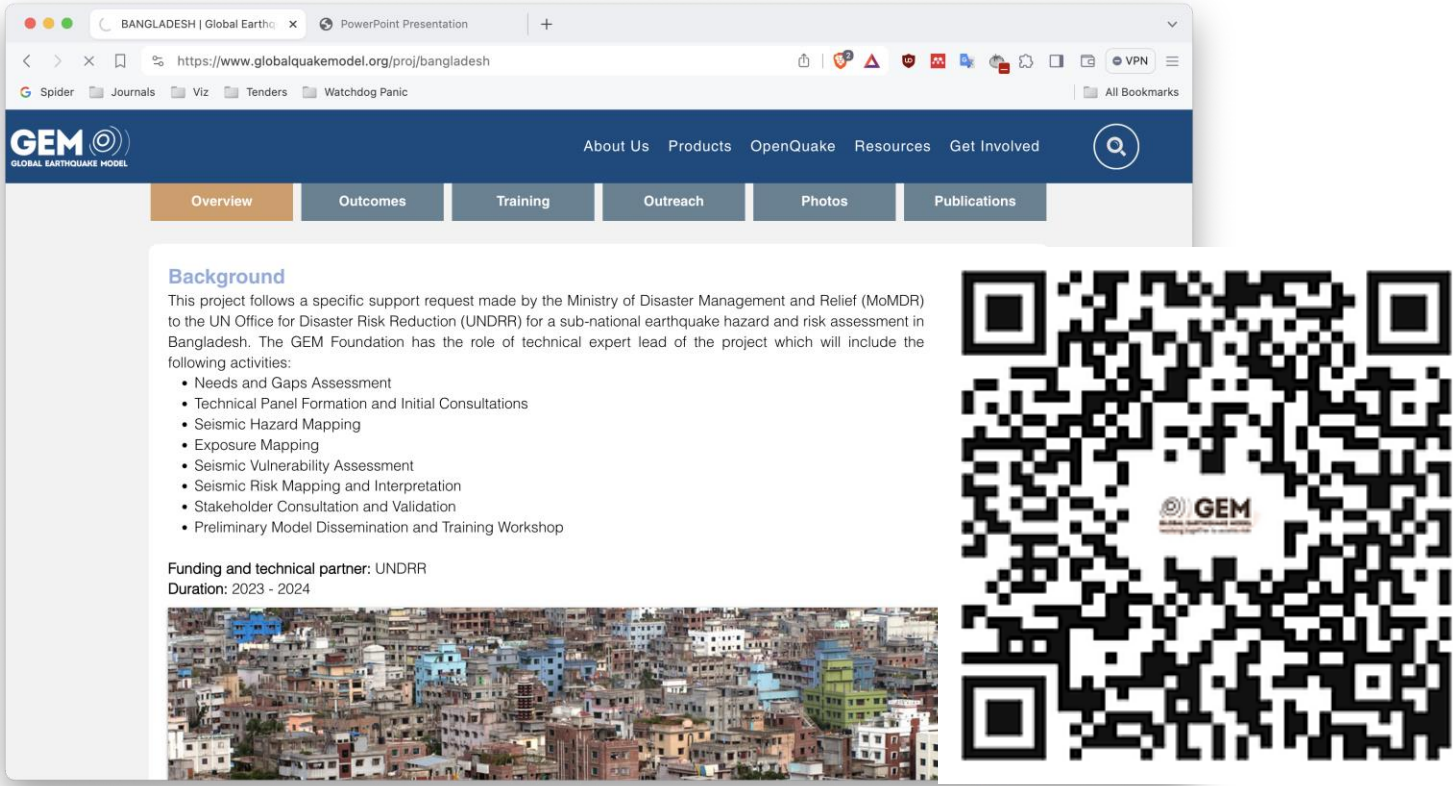


Average annual building collapses and fatalities





Project website with risk profiles and materials



GLOBAL QUAKE MODEL .ORG

Social Vulnerability Model

MOTIVATION
SOVI METHODOLOGY
SOCIO-ECONOMIC VARIABLES

Disparate impacts on different groups

WORLD NEWS

More than 90% of people killed by western Afghanistan quake were women and children, UN says

AP

6 of 7 | Afghan women sit in front of their houses that were destroyed by the earthquake in Zenda Jan district in Herat province, western of Afghanistan, Wednesday, Oct. 11, 2023. Another strong earthquake shook western Afghanistan on Wednesday morning after an earlier one killed more than 2,000 people and flattened whole villages in Herat province in what was one of the most destructive quakes in the country's recent history. (AP Photo/Ebrahim Noroozi)

BY RIAZAT BUTT

Updated 1:09 AM GMT+5:30, October 13, 2023

ISLAMABAD (AP) — More than 90% of the people killed by a 6.3-magnitude earthquake in western Afghanistan last weekend were women and children, U.N. officials reported Thursday.

...

Women and children were more likely to have been at home when the quake struck in the morning, said Siddig Ibrahim, the chief of the UNICEF field office in Herat. "When the first earthquake hit, people thought it was an explosion, and they ran into their homes," he said.

Hundreds of people, mostly women, remain missing in Zenda Jan.

Social vulnerability index

SoVI methodology established by Susan Cutter et al.

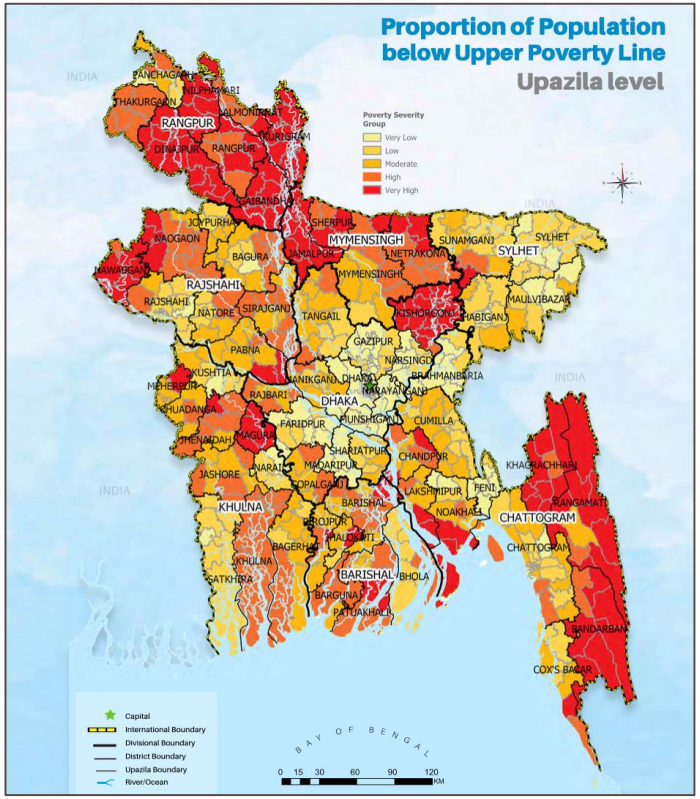
Concept	SoVI® variables
Socioeconomic status	Extreme poverty
	Overcrowded households
	No phone
Gender	% of females
	Females in work force
	Ratio F/M income
Religion and ethnicity	% by ethnicity
Age	Median age
Employment lost	Single sector reliance
Urban/Rural	% urban population
	Population density
Renters	% of renters
Occupation	Legally registered
	Not legal register
	Subsistence workers

Concept	SoVI® variables
Family structure	% Female headed households
	People per household
Education	% illiterates over 15
	Population incompleted highschool
	Complete college degree
Population change	Population change within the decade
Medical services & access	Labor force working in health
	Health coverage
Social dependency	# of Benefits granted
Special needs population	% population with disability
	% population high deficiency
Quality of the built environment	Households no water
	Households no sewer
	Households no garbage
	Households no electricity

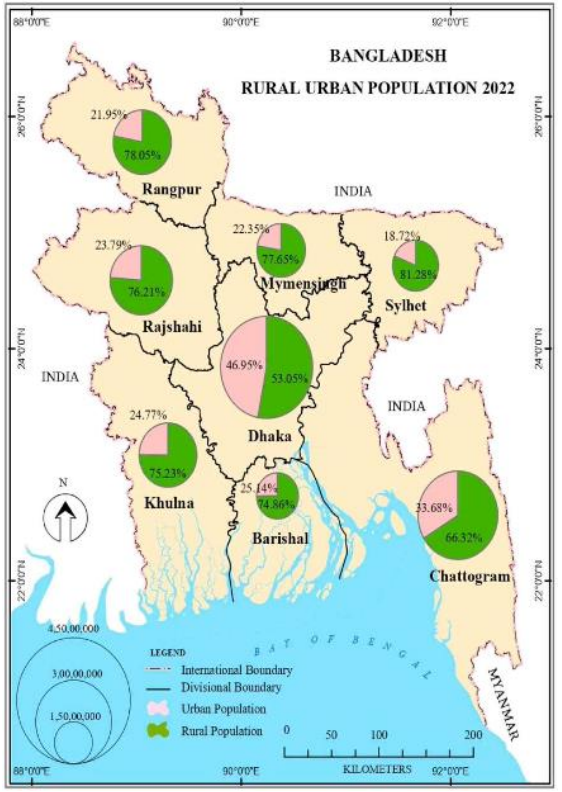
Roncancio, D. J., Cutter, S. L., & Nardocci, A. C. (2020). Social vulnerability in Colombia. *International Journal of Disaster Risk Reduction*, *50*(September), 101872. https://doi.org/10.1016/j.ijdrr.2020.101872

de Loyola Hummell, B. M., Cutter, S. L., & Emrich, C. T. (2016). Social Vulnerability to Natural Hazards in Brazil. *International Journal of Disaster Risk Science*, *7*(2), 111–122. https://doi.org/10.1007/s13753-016-0090-9

Drivers of social vulnerability: Poverty level & urban/rural



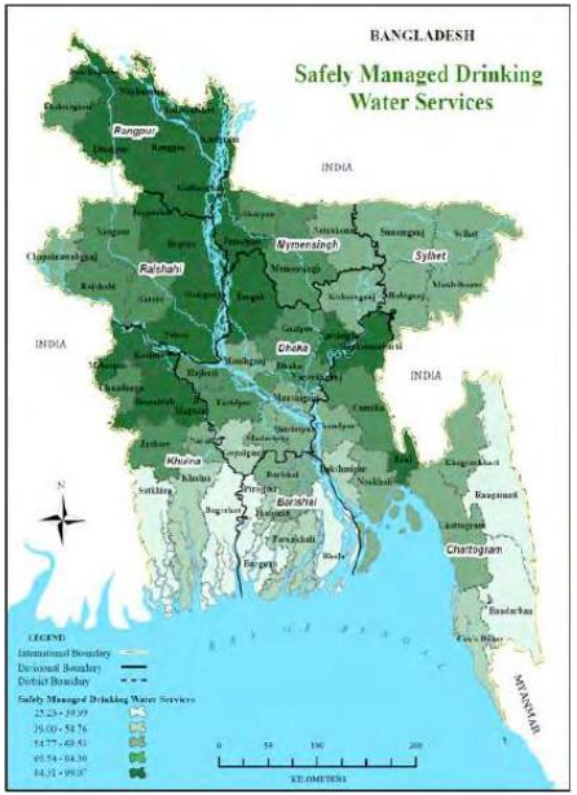
2016 Poverty Maps of Bangladesh



2022 Population & Housing Census

Drivers of social vulnerability: Sanitation and clean water

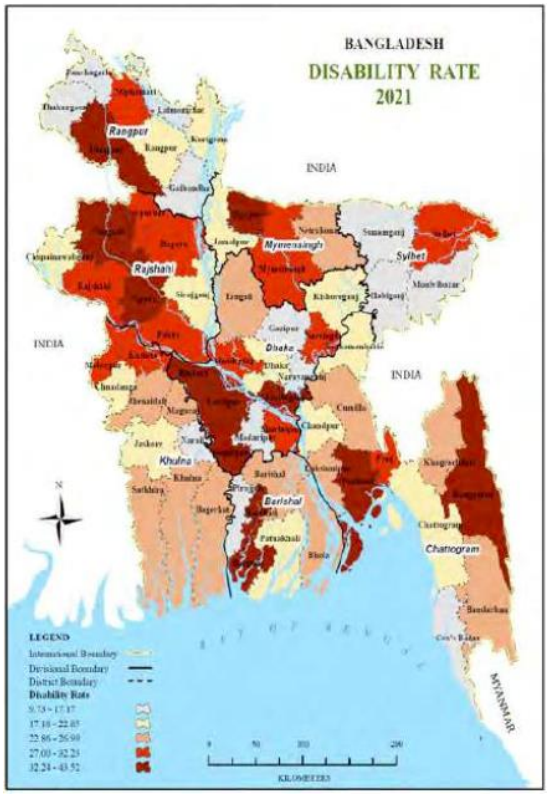
2021 Bangladesh Sample Vital Statistics



2021 Bangladesh Sample Vital Statistics

Drivers of social vulnerability: Adult literacy and disability

2021 Bangladesh Sample Vital Statistics

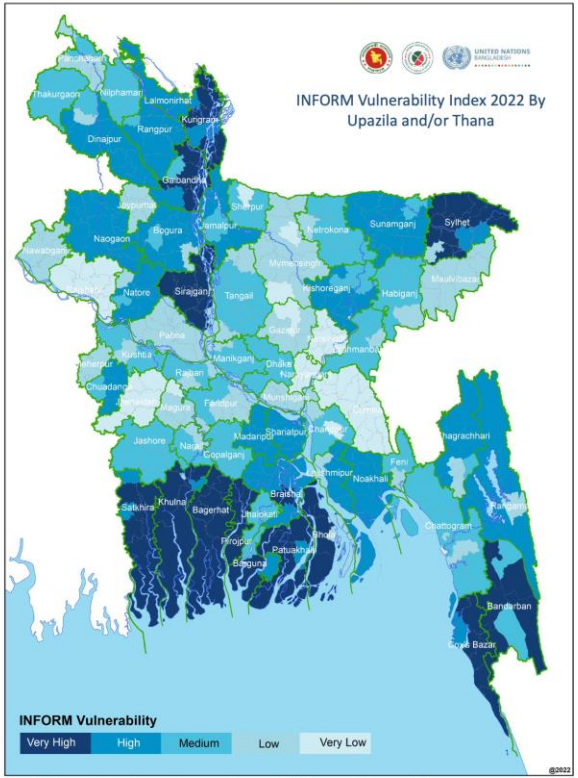


2021 Bangladesh Sample Vital Statistics

INFORM Index

INFORM INDEX FOR RISK MANAGEMENT SUBNATIONAL Bangladesh

INFORM Vulnerability: Upazila and/or Thana Map



The depiction and use of boundaries are not warranted to be error-free, nor do they necessarily imply official endorsement or acceptance by the United Nations.

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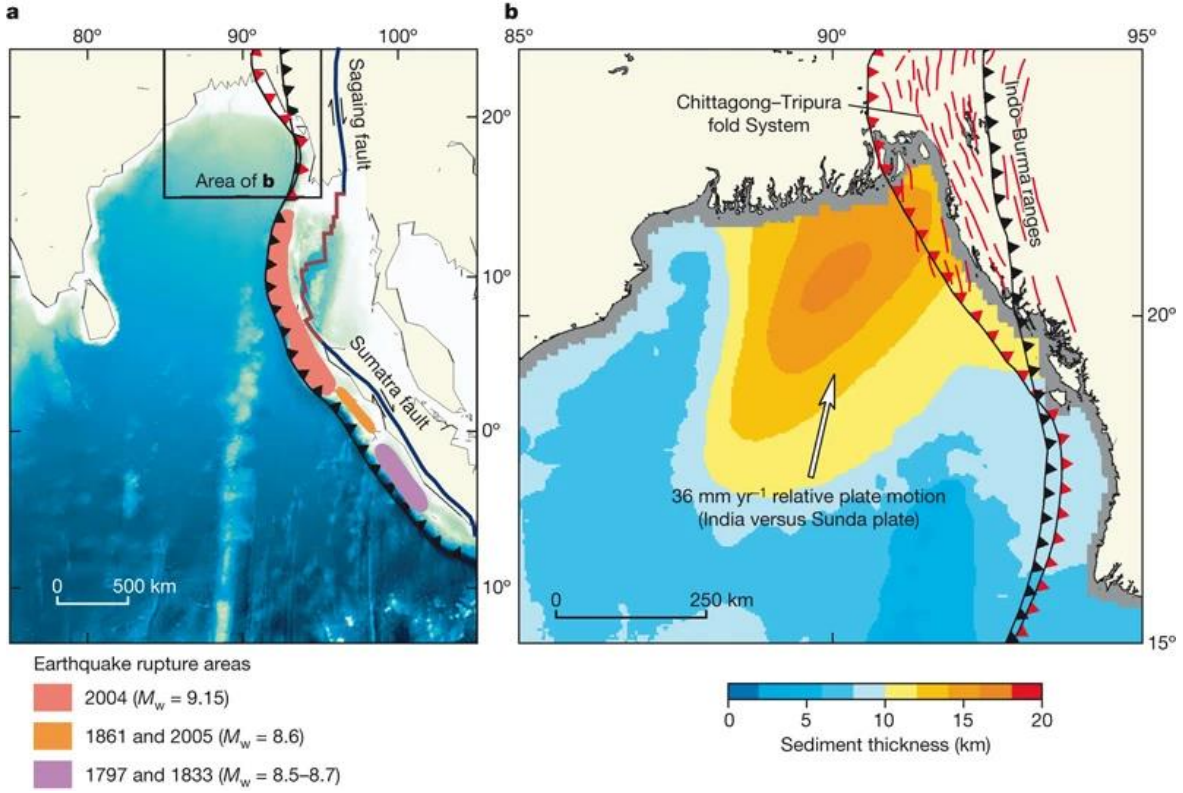
INFORM INDEX FOR RISK MANAGEMENT SUBNATIONAL Bangladesh

Vulnerability: Indicators (32)

Categories	Component	Indicators	Source
Socio-Economic	Poverty and Development (4)	• Score in Human Development Index (HDI) in 2016 • Percentage of poor households in 2017 • Percentage of extreme poor households in 2017 • Percentage of households are dependent on daily wage labour (unsustainable livelihoods)	BBS, WB
	Economic Dependence (5)	• Percentage of unemployed people in 2017 • Percentage of EGPP coverage among the poor in 2020 • Per capita public aid (in USD) in 2019 • Net ODA received as a percentage of GNI in 2020 • Volume of remittances (in USD) as a proportion of total GDP	MoDMR, BARC
	Inequality (4)	• Ratio of Gini coefficient from income distribution in 2020 • Gender parity index (GPI) for primary school adjusted net attendance ratio (NAR) in 2019 • Gender parity index (GPI) for lower secondary school adjusted net attendance ratio (NAR) in 2019 • Gender parity index (GPI) for upper secondary school adjusted net attendance ratio (NAR) in 2019	BBS, BARC
Vulnerable Group	Uprooted People (3)	• Percentage of floating population in 2020 • Number of annual average disaster induced Internal Displaced Population (IDP) per 100,000 during 2014-2020 • Number of asylum seeker/refugee in 2021	BBS, NDRCC, RRRC
	Recent Shocks (3)	• Annual average affected population (per 10,000) by flood and cyclone during 2014-2020 • Number of fully damaged houses by cyclone and flood during 2014-2020 • Number of partially damaged houses by cyclone and flood during 2014-2020	NDRCC
	Food Security (2)	• Percentage of households with poor dietary diversity (Food group <=4) in 2021 • Percentage of population in IPC level 4 (Food scarcity on terms of quality) in 2022	IPC-FAO and FPMU
	Other Vulnerable Group (7)	• Percentage of child labour (children age 5- 17) in 2019 • Percentage of women (age 15-49 years) reported domestic violence by male partner in 2017 • Percentage of women headed households in 2019 • Percentage of population with disability in 2020 • Percentage of elderly population (age >65) in 2020 • Percentage of tribal population in 2020 • Percentage of households living in jhupri and kutcha house in 2020	BBS
	Children Under 5 (2)	• Under 5 children mortality rate per 1,000 in 2020 • Underweight prevalence (severe) <-3 SD in 2019 • Stunting prevalence (severe)<-3 SD in 2019 • Insufficient early child development index (% of 36-59 months child) in 2019	BBS

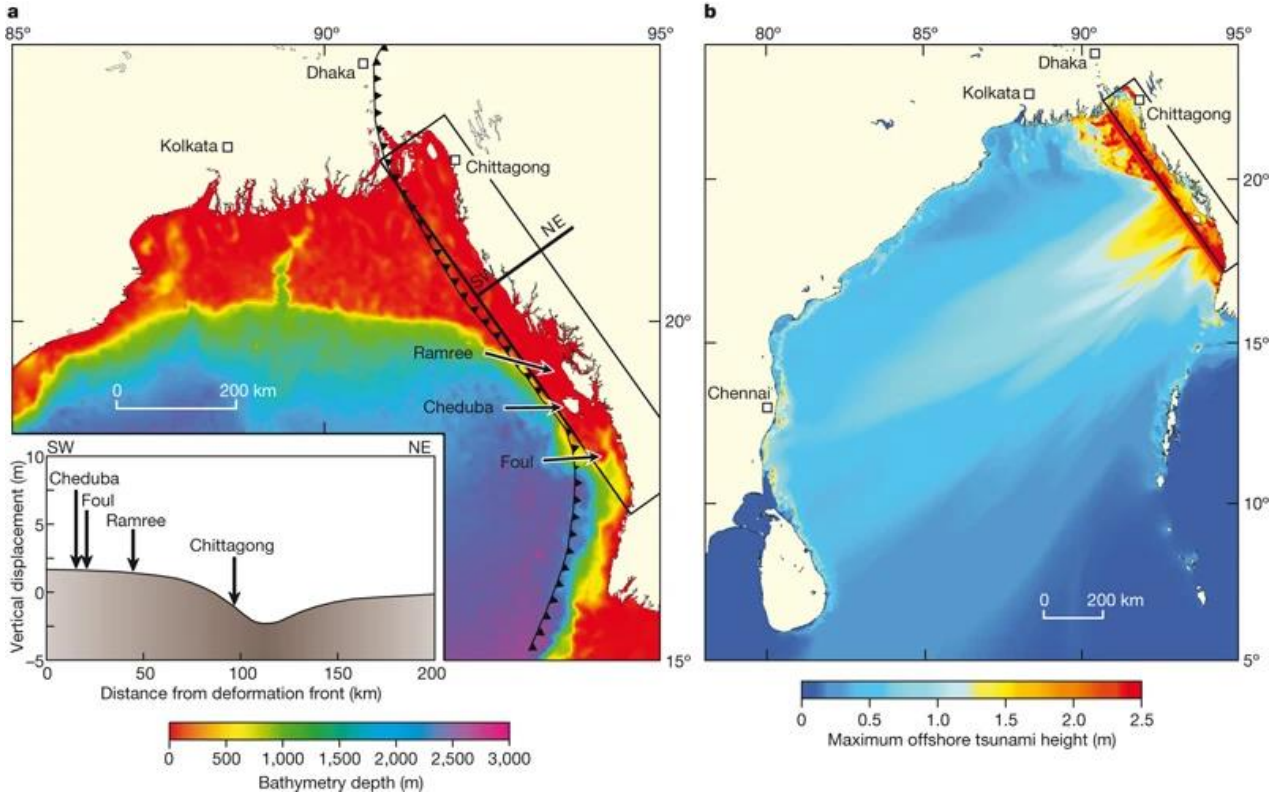
17

Tectonic setting of the Bay of Bengal



Cummins, P. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature 449, 75–78 (2007). https://doi.org/10.1038/nature06088

Models for the 1762 Arakan earthquake and tsunami



Cummins, P. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature 449, 75–78 (2007). https://doi.org/10.1038/nature06088

Thank you!

Please attribute to the GEM Foundation with a link to:
https://www.globalquakemodel.org

Contact

Anirudh Rao <anirudh.rao@globalquakemodel.org>