First Level Seismic Microzonation Map of Chennai City – A GIS Approach

Ganapathy, G. P. (2011)

Natural Hazards and Earth System Sciences, 11(2)

Presenter : Ciao-Huei Yang

Advisor: Prof. Jia-Jyun Dong, Dr. Jia-Cian Gao

Date : 2025/05/02

Outline

1 **Introduction**
- What is Seismic Microzonation?
- Study Area
- Objectives of this Study

2 **Methods**
- Data Collecting
- Analytic Hierarchy Process
- GIS Integration

3 **Results and Discussion**
- Seismic Microzonation Map
- High-Risk Zones

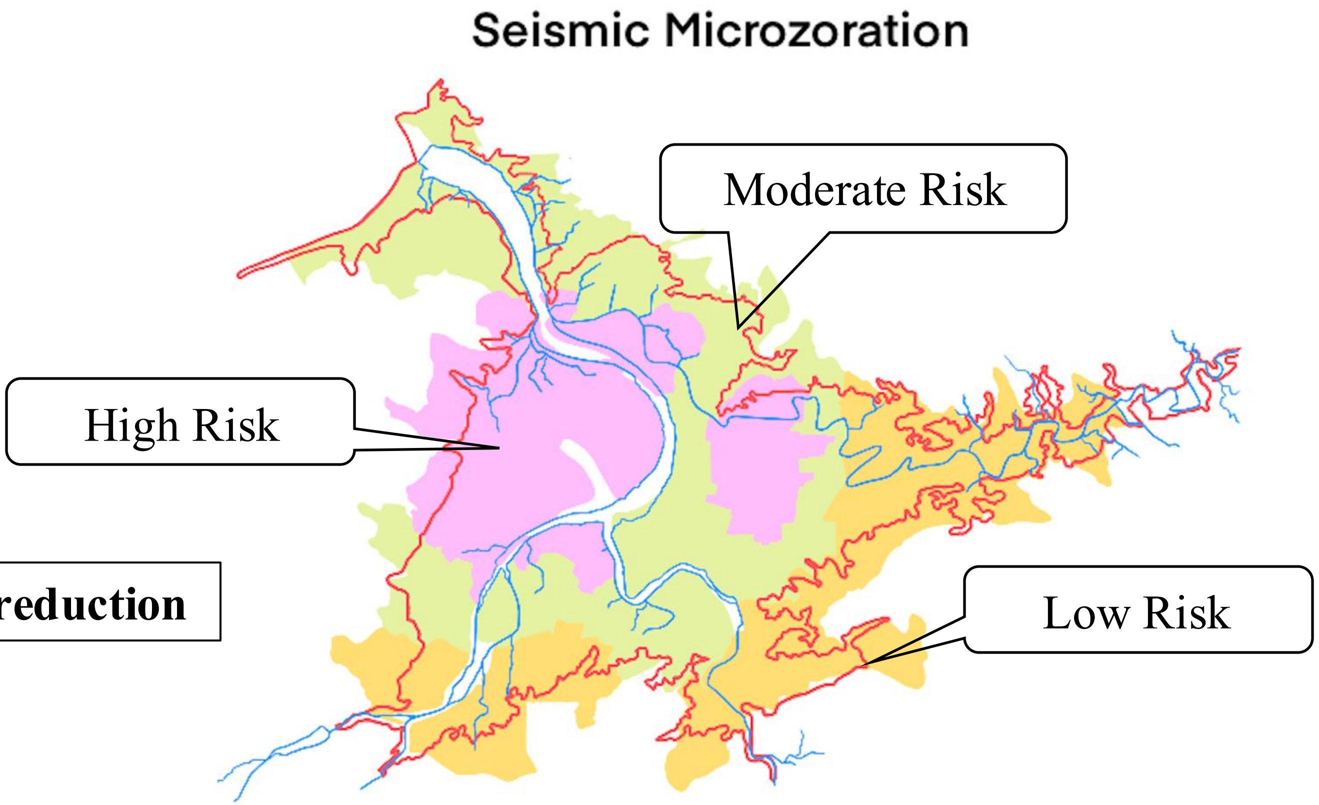
4 **Conclusions**

Introduction

Seismic Microzonation

- **Dividing a city or region into several small blocks based on the differences in the impact of seismic waves.**

- To identify the potential for different levels of damage in different areas when an earthquake occurs.
- To support better building design and disaster preparedness.



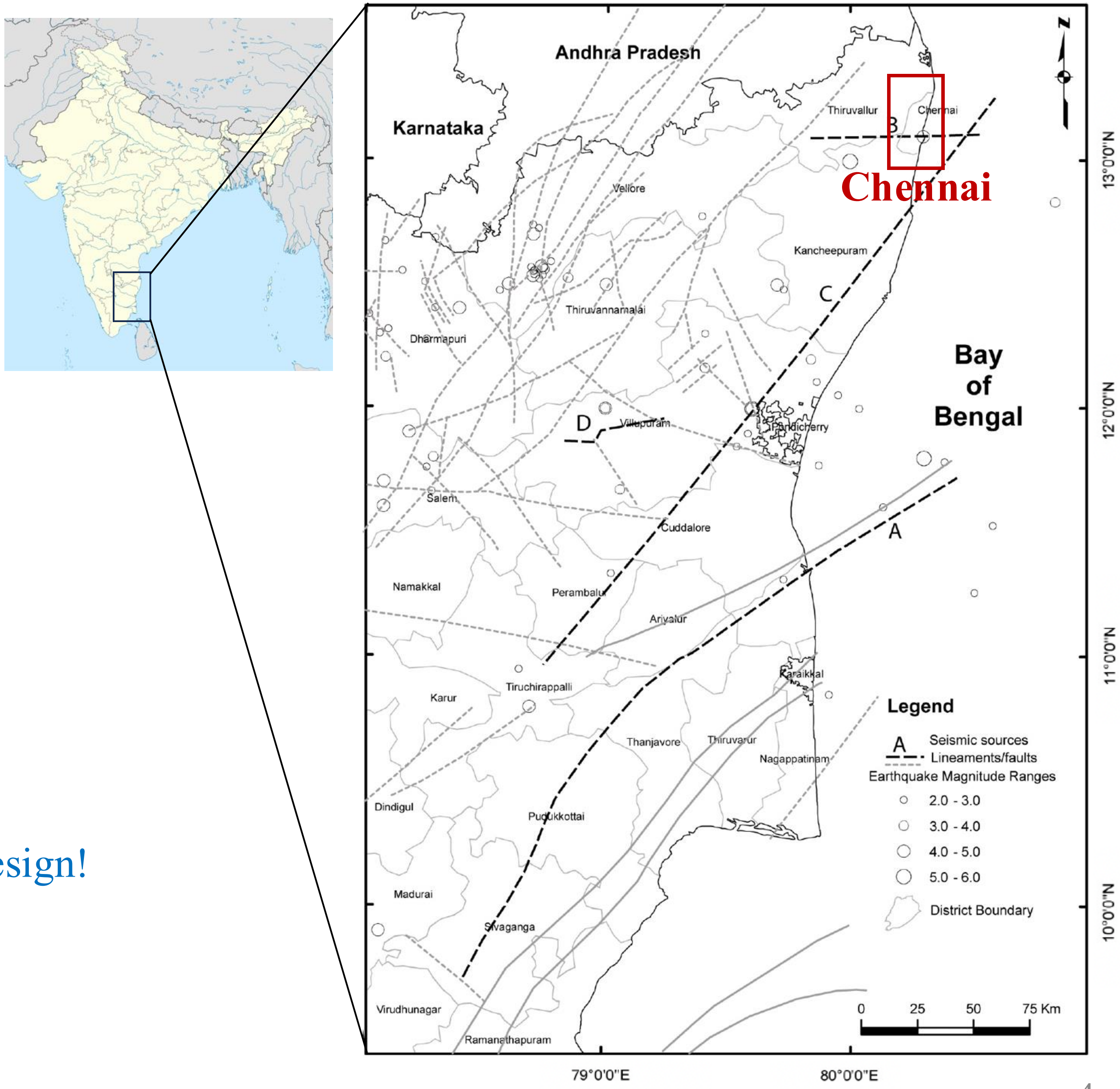
The first and most important step in seismic risk reduction

Introduction

Study Area – Chennai

- The fourth largest metropolis in India.
- A number of water bodies (lakes and ponds), which existed in Chennai have been **filled up with sand and clay**.
- Building types :
  - The earthen walls (9.59%)
  - Stone walls (3.1%)
  - Burned brick walls (80.79%)
  - Others (6.54%)

Over 93% of buildings lack earthquake-resistant design!



Introduction

- **Objectives of this study**

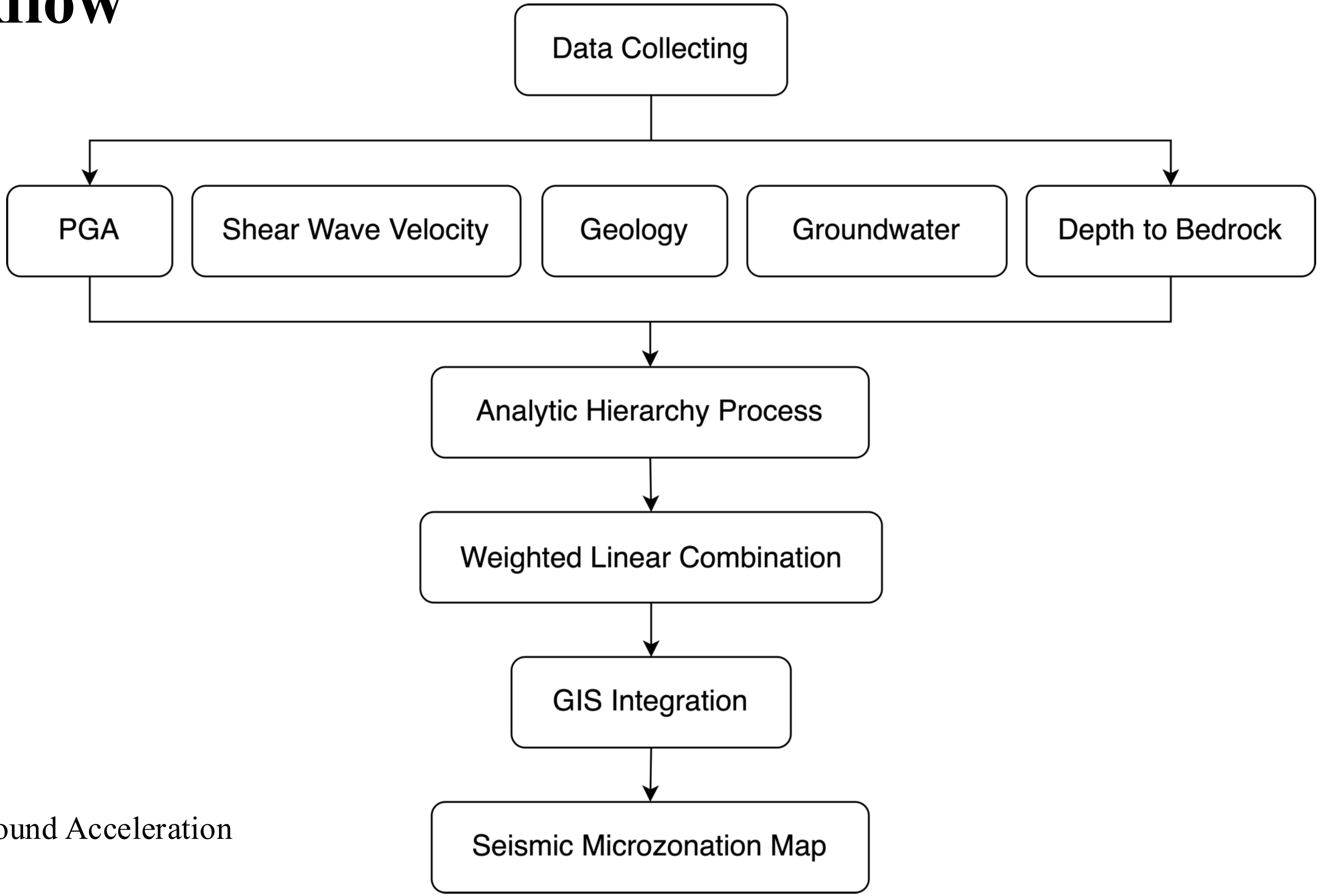
- **Integrate** diverse spatial datasets (PGA, shear wave velocity, geology, ground water, bedrock) using **GIS and Analytic Hierarchy Process**.
- Develop a seismic microzonation map.
- Provide scientific support for **urban planning**, **earthquake-resistant construction**, and **disaster mitigation strategies**.

→ Reduce seismic hazard in Chennai city.

- **Why to choose this paper ?**

- Current building code only rely on ground motion records for microzonation.
- This paper **incorporate geological conditions** by assigning weights to different datasets.

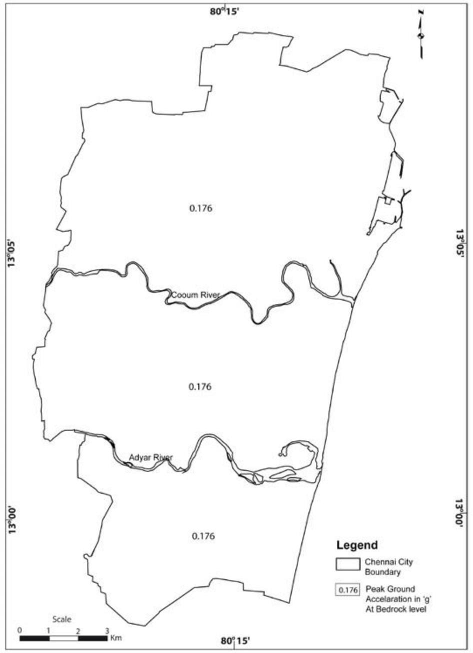
Workflow



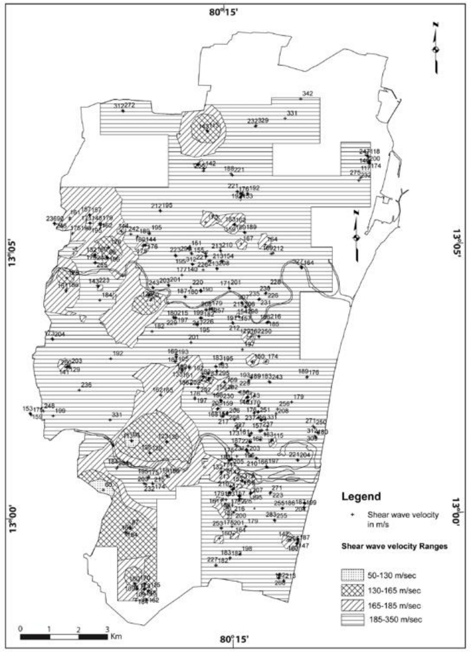
*PGA : Peak Ground Acceleration

Method – Data Collecting

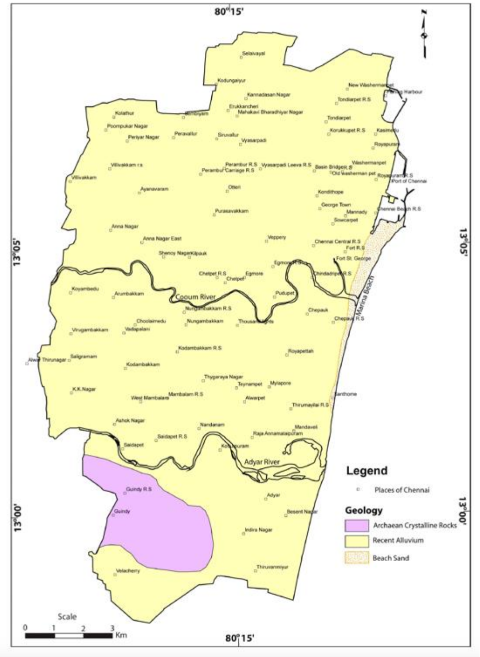
- Five types of data used in this study:



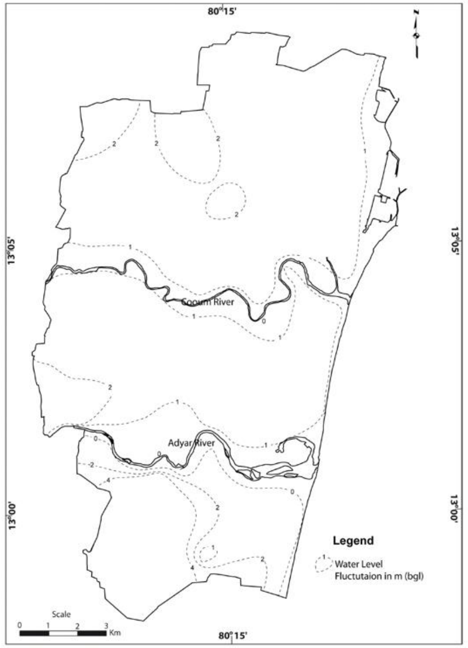
PGA



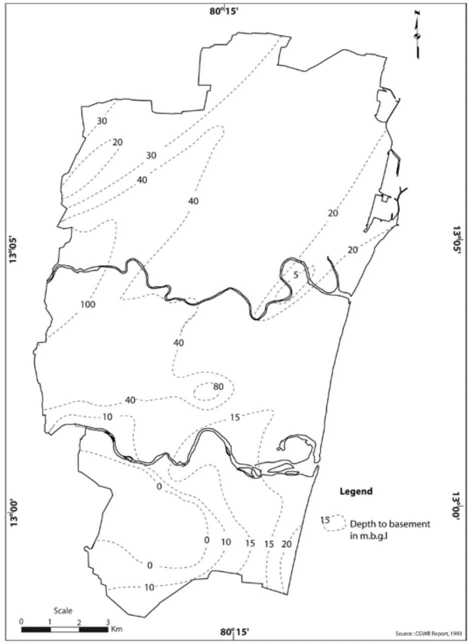
Shear Wave Velocity



Geology



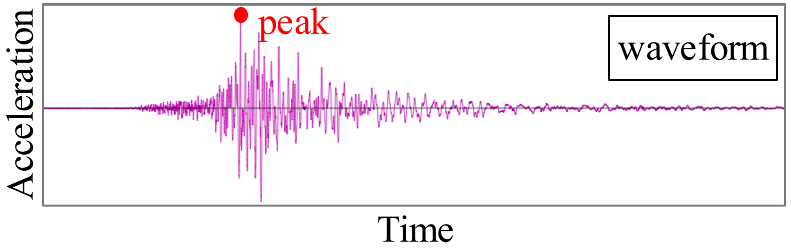
Groundwater

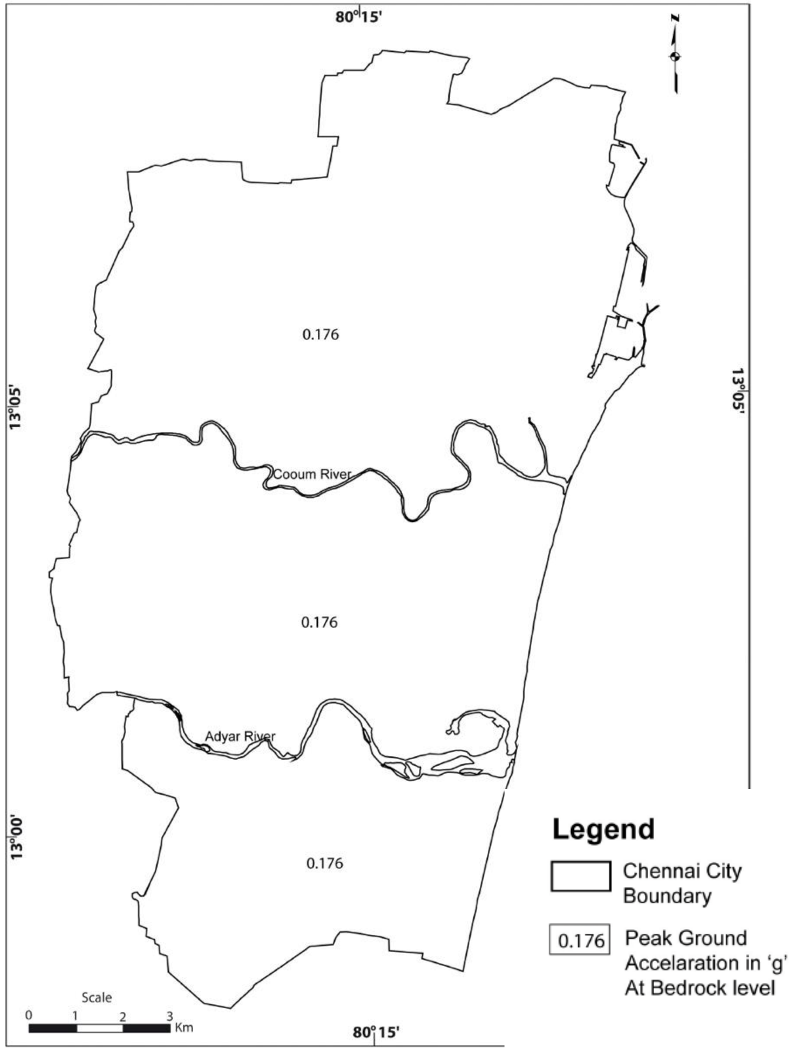


Bedrock

*PGA : Peak Ground Acceleration

Method – Data Collecting





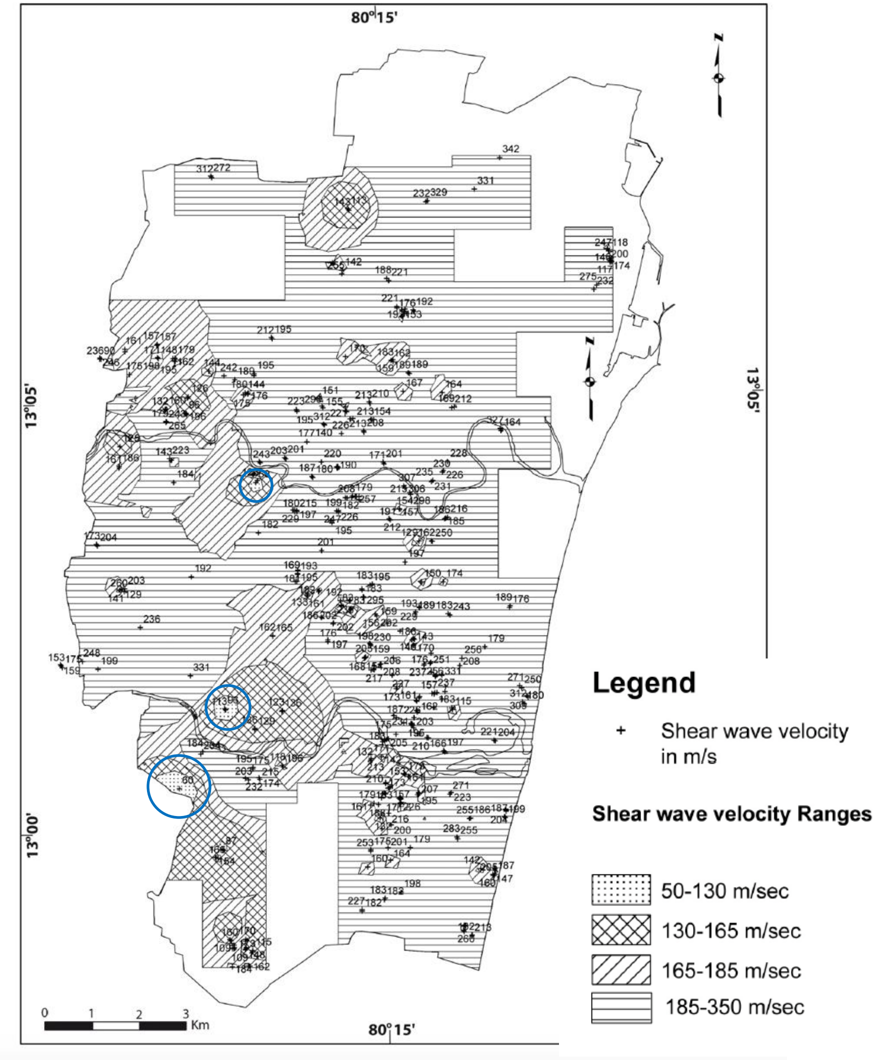
Peak Ground Acceleration (PGA)

- The **maximum ground shaking** during an earthquake.
- Higher values indicate stronger shaking and higher potential damage to buildings.

Seismic Sources	Cumulative Earthquakes	Maximum Magnitude	Epicentral Distance from Chennai	Estimated Peak Ground Acceleration
A	5	5.6	156	0.176
B	1	5.3	10	0.107
C	3	5.0	155	0.078
D	3	5.0	174	0.078

- The maximum PGA estimated for Chennai is about **0.176 g**, equivalent to intensity IV+ in Taiwan.

Method – Data Collecting

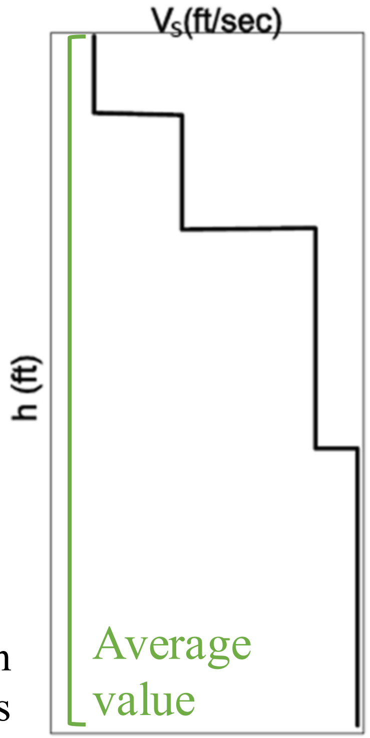


Shear Wave Velocity (Vs3)

- An indicator of **how soft or hard the soil is**.
- Softer and weaker soils have lower Vs and tend to amplify the ground motion.
- The slowest Vs3 values range between **50–130 m/s**,

⟶ soft soil layers that may cause stronger seismic shaking

*Vs3 : average shear wave velocity within the top 3 meters



(Toro, 2022)

Method – AHP

Analytic Hierarchy Process (AHP) (Mohanty et al., 2007 and Moustafa et al., 2022)

- A multi-criteria decision-making method.
- Determines **relative weights** of factors through **pairwise comparisons**.
- This study used AHP to evaluate the relative influence of five factors on seismic hazard.

Criteria	A	B	C
A	1	5/1	2/1
B	1/5	1	1
C	1/2	1	1

(Score) 1 → 5

Equally important → One is more important

Themes	PGA	Soil	Geology	Ground Water	Bedrock
PGA	1	5/4	5/3	5/2	5/1
Shear Wave Velocity	4/5	1	4/3	4/2	4/1
Geology	3/5	3/4	1	3/2	3/1
Ground Water	2/5	2/4	2/3	1	2/1
Bedrock	1/5	1/4	1/3	1/2	1

PGA and Shear Wave Velocity : The two most important factors

- Weighting can be obtained by:

$$Weighting = \frac{S_F}{S_{AF}}$$

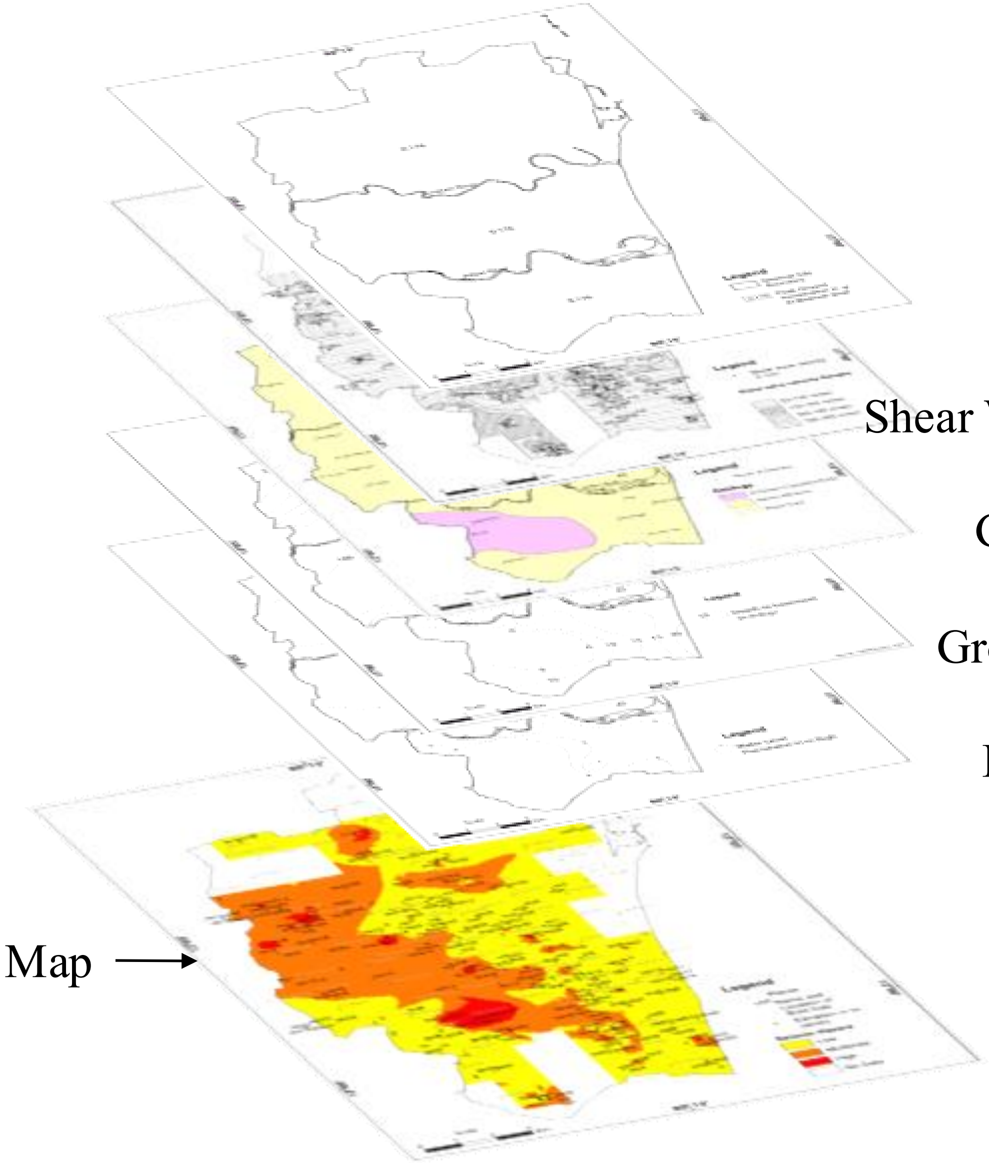
S_F : sum of relative score in each factor

S_{AF} : sum of relative score in all factors

Method – GIS

GIS Integration

- 5 factor layers
- Union and overlay operation



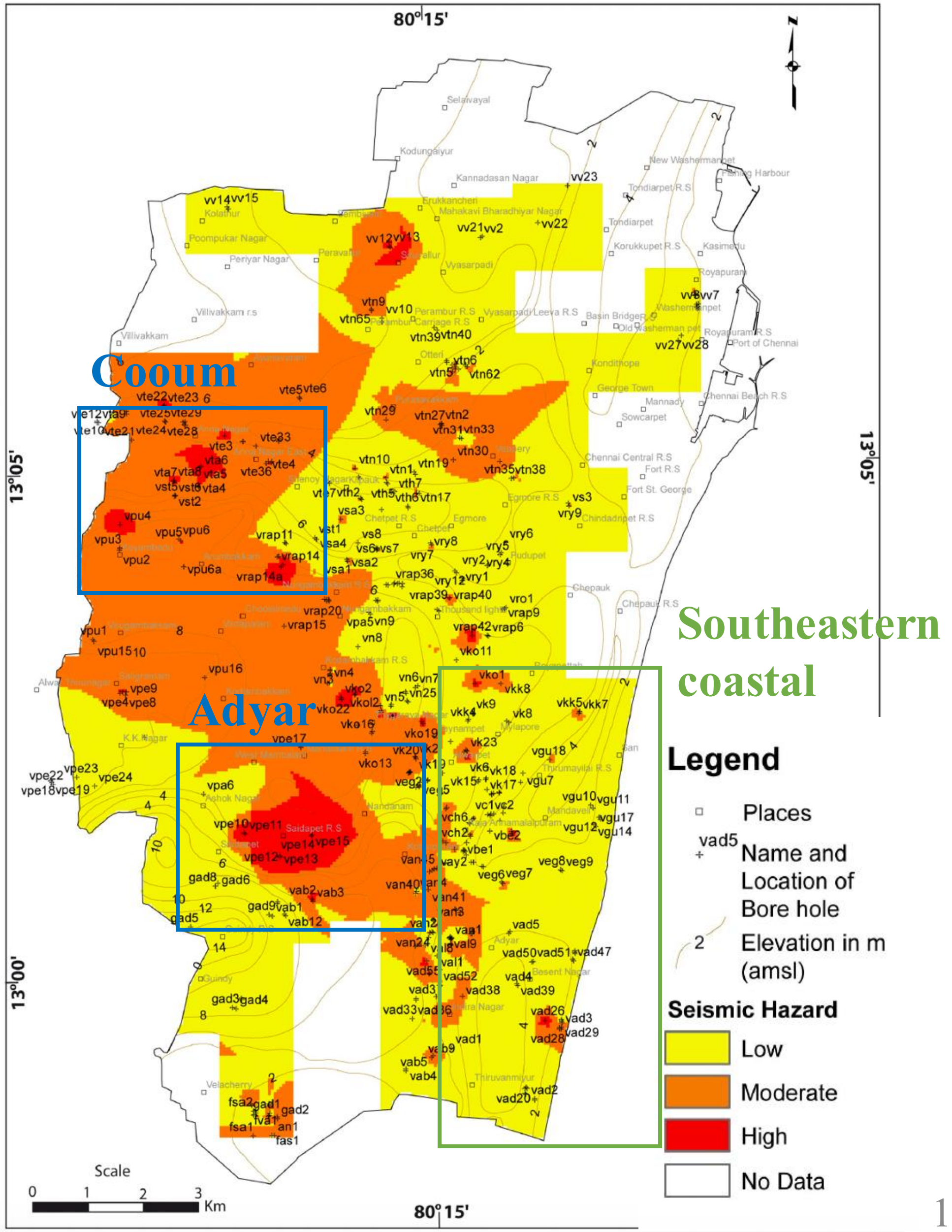
Final Map →

Factor	Weighting
PGA	0.3333
	+
Shear Wave Velocity	0.2666
	+
Geology	0.2000
	+
Groundwater	0.1333
	+
Bedrock	0.0666
	=
	1.0000

Results and Discussion

Seismic Microzonation Map

- Three zones (High, Moderate, Low)
- High-risk zones : The southwestern part of the city, particularly around the Adyar and Cooum river basins.
- Low-risk zones : The southeastern coastal areas.

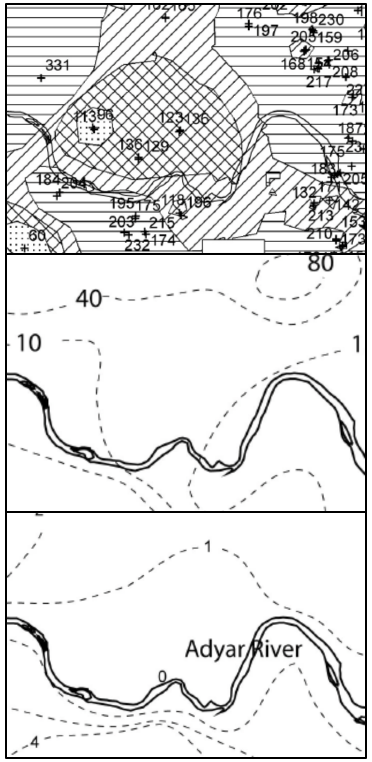


Results and Discussion

Distribution and Causes of High-Risk Zones

(Adyar river basin)

Mainly related to local soil conditions:



Soft soil layers

- Vs3 between 50-165 m/s

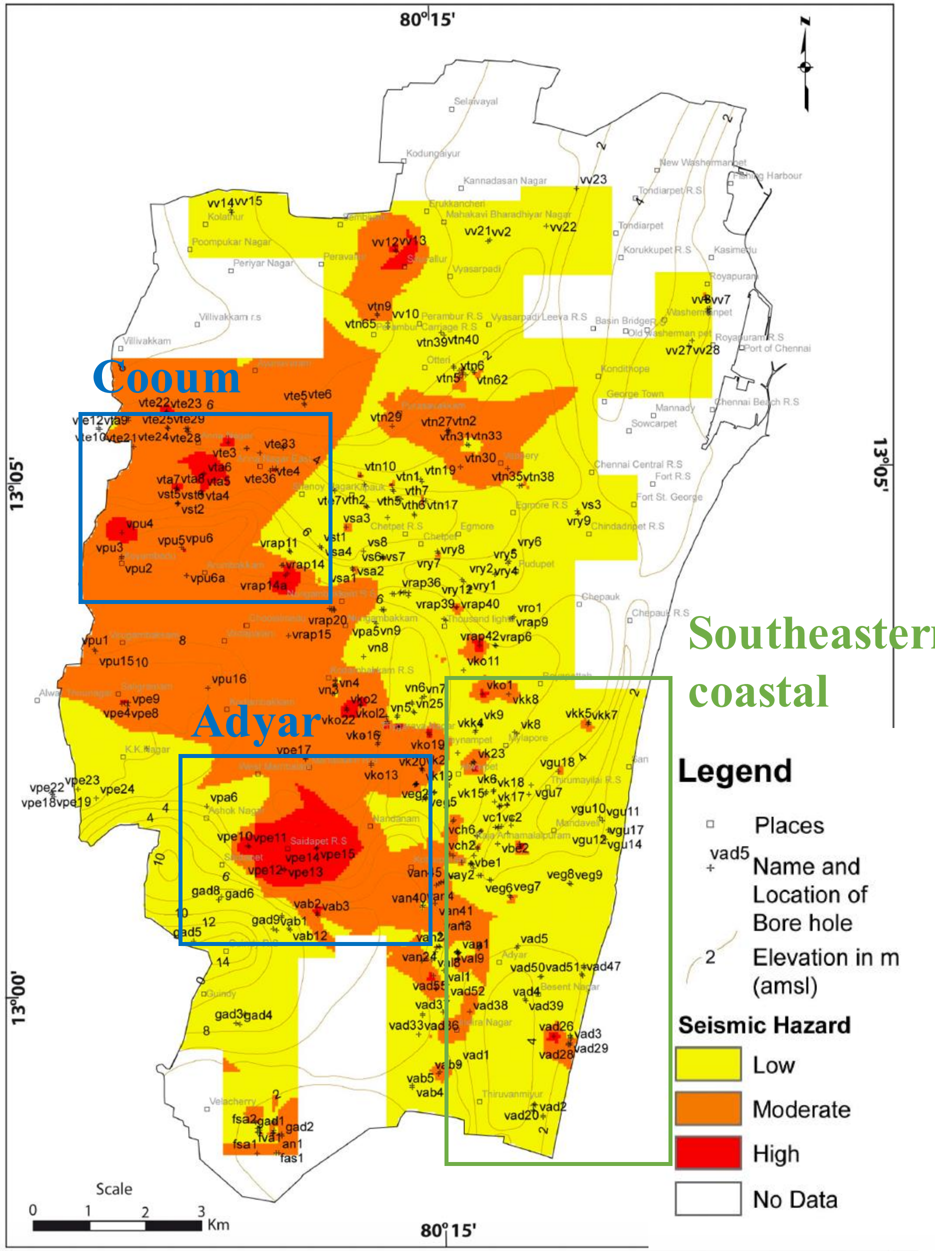
Deep bedrock

- Up to 40-80 meters

Shallow and fluctuating groundwater levels

- Between 0-1.5 m below the ground level

Reduce soil strength and amplify seismic waves



Conclusions

- Successfully developed the seismic microzonation map of Chennai using GIS and AHP methods.
- About half of Chennai falls under moderate to high seismic hazard zones.
- **High-risk** areas are concentrated in the **southwestern river basin zone**, mainly due to soft soil, deep bedrock, and shallow groundwater.
- This methodology can also **be applied to other rapidly growing cities** as a valuable reference for disaster planning and land management.

Future Work

- Collect geological and seismic data.
- Apply weighting methods and GIS approach.
- Update seismic microzonation in Taipei basin.

Reference

- Mohanty, W. K., Walling, M. Y., Nath, S. K., & Pal, I. (2007). First order seismic microzonation of Delhi, India using geographic information system (GIS). *Natural Hazards*, *40*, 245-260.
- Moustafa, S. S., Abdalzaher, M. S., Naeem, M., & Fouda, M. M. (2022). Seismic hazard and site suitability evaluation based on multicriteria decision analysis. *IEEE Access, 10*, 69511-69530.
- Toro, G. R. (2022). Uncertainty in shear-wave velocity profiles. *Journal of Seismology, 26(4),* 713-730.

Thanks for your attention

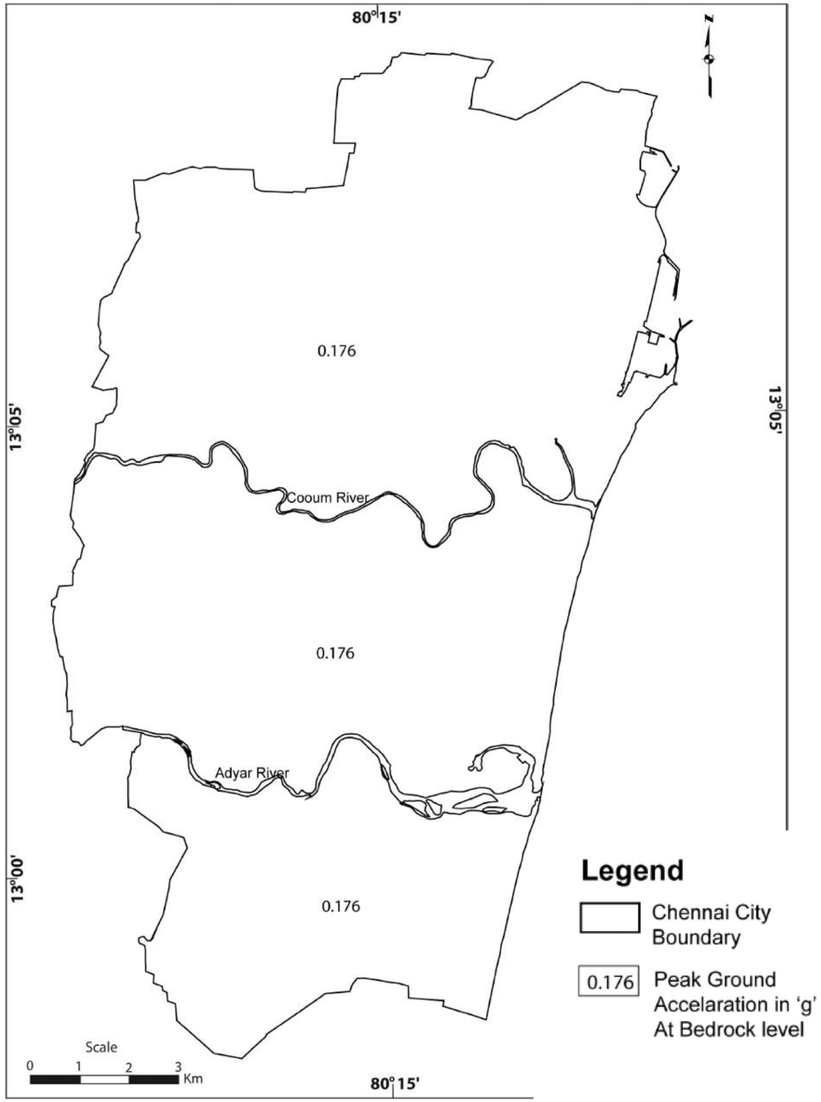
Method – Data Collecting

- **Peak Ground Acceleration (PGA)**

PGA estimated by:

$$\ln y = c1 + c2(M-6) + c3(M-6)^2 - \ln R - c4R$$

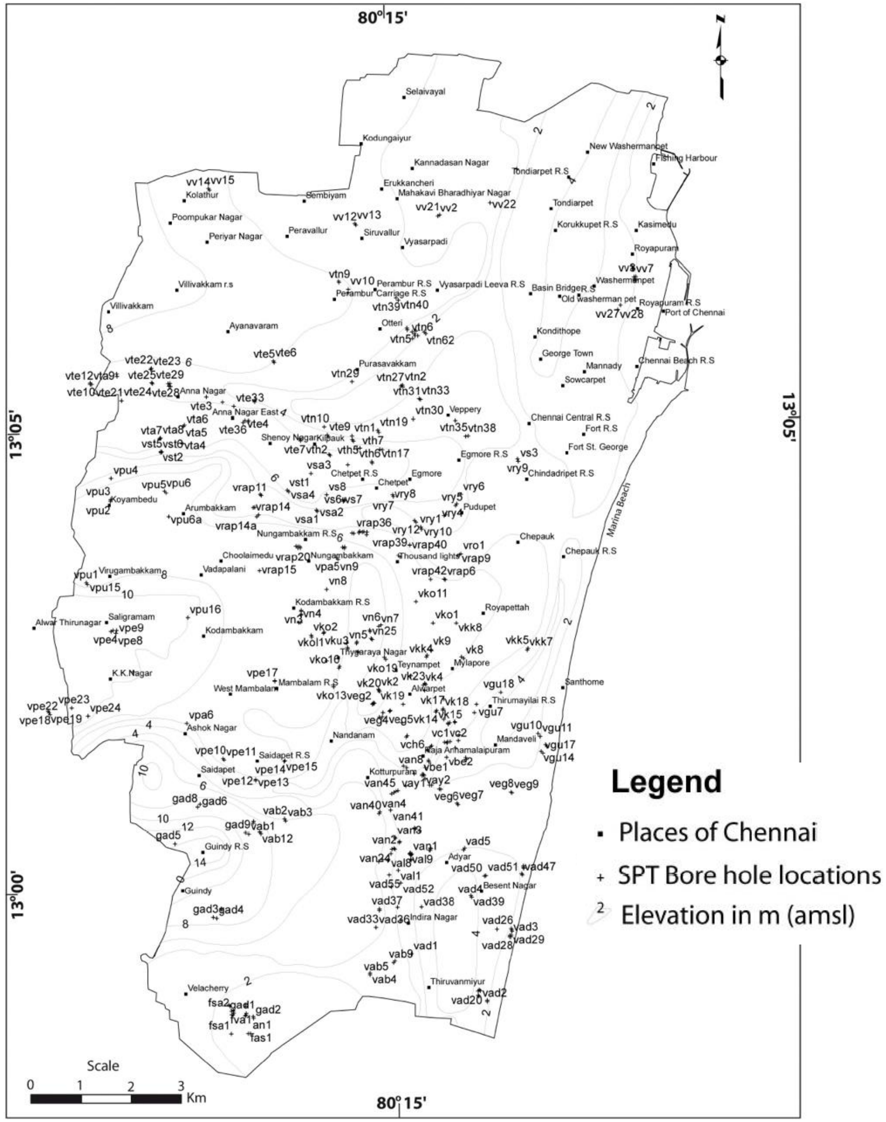
y : PGA (in g) , M : magnitude, R : hypocentral distance



Method – Data Collecting

Shear Wave Velocity

- Collecting data from **503 boreholes**, and most of those only went down to a few meters — not deep enough for vs30.
- Instead of trying to estimate deeper layers and introduce error, they focused on the **shallow layers they could measure directly**.



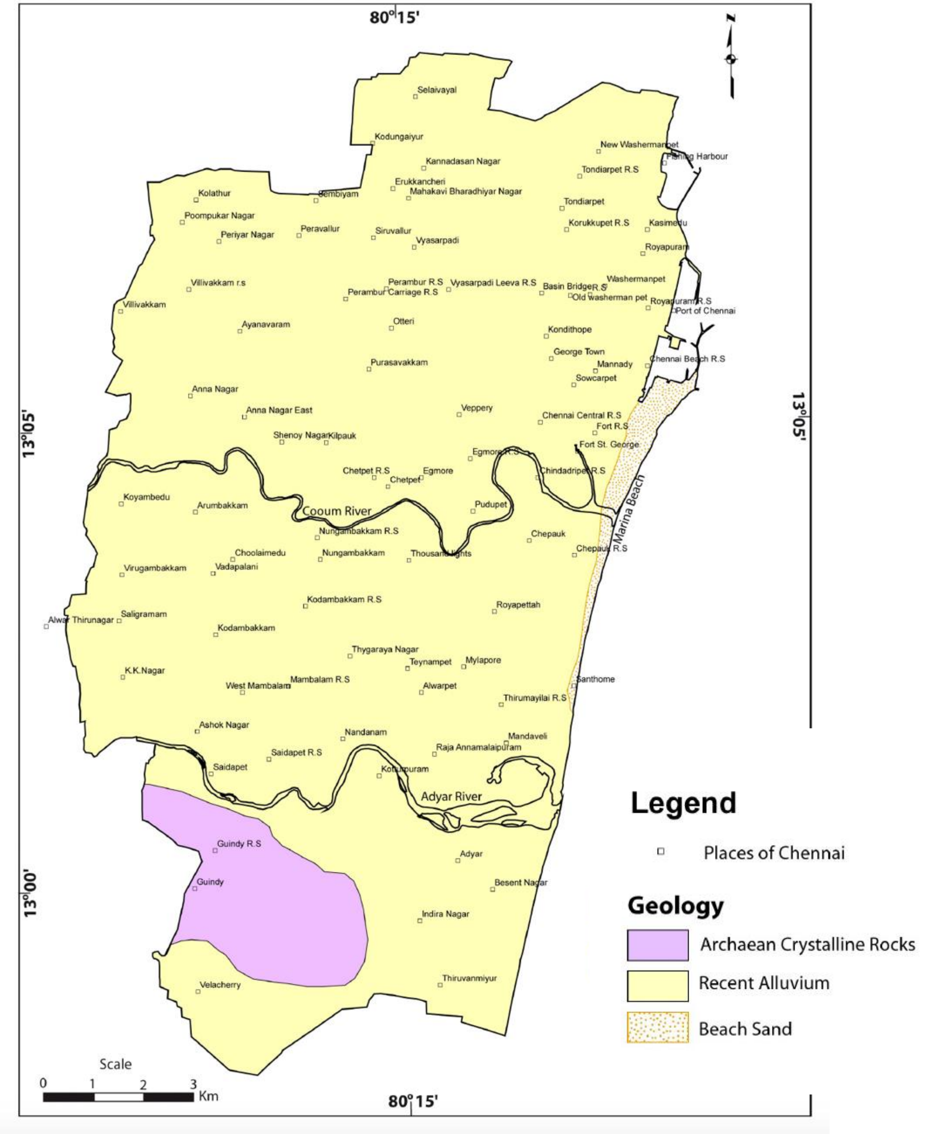
Method – Data Collecting

Geology

- **Archaean crystalline rocks (charnockite and gneiss)**：
- Southwestern part & Hard and dense
- Don’t shake much ⟶ Low Risk

- **The alluvium**：
- Almost across all city & soft soil made up of sand, silt, and clay
- Amplifies seismic waves and stronger shaking ⟶ High-Risk

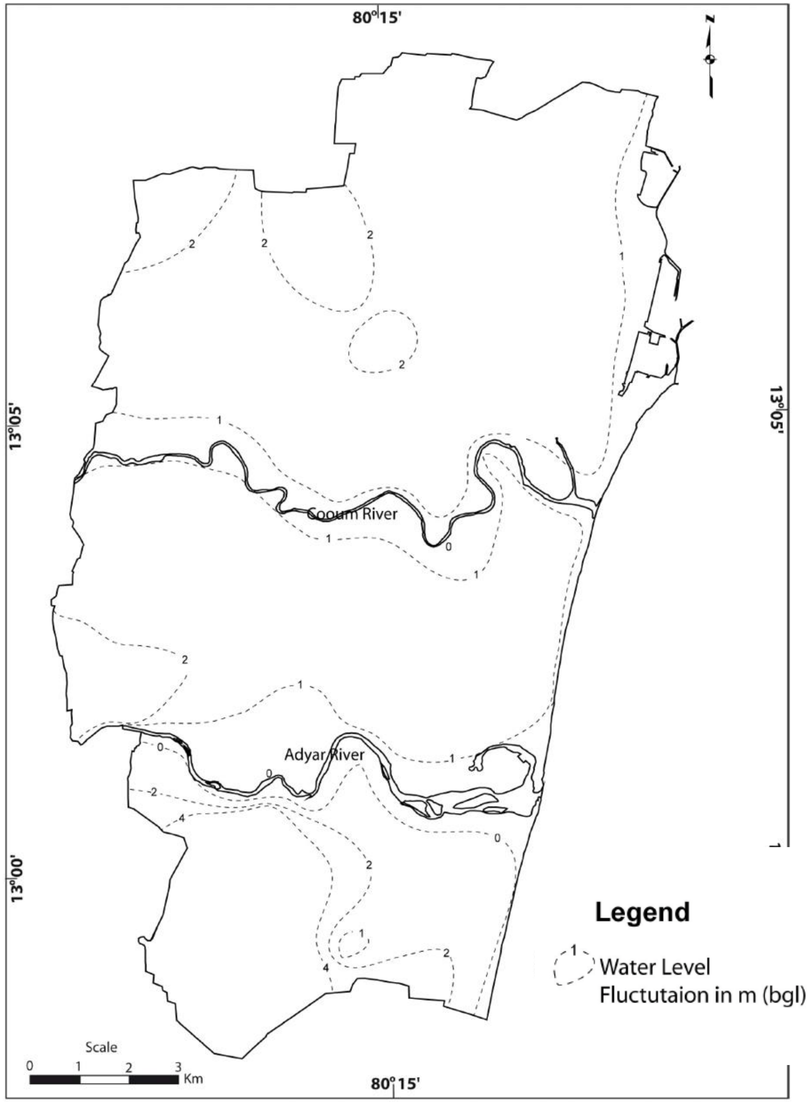
- **Gondwana shale**：
- Adyar river basin or northwestern part, more fractured and layered
- Not as soft as alluvium, but not as stable as crystalline rock either.



Method – Data Collecting

Water Table and Water Level Fluctuation

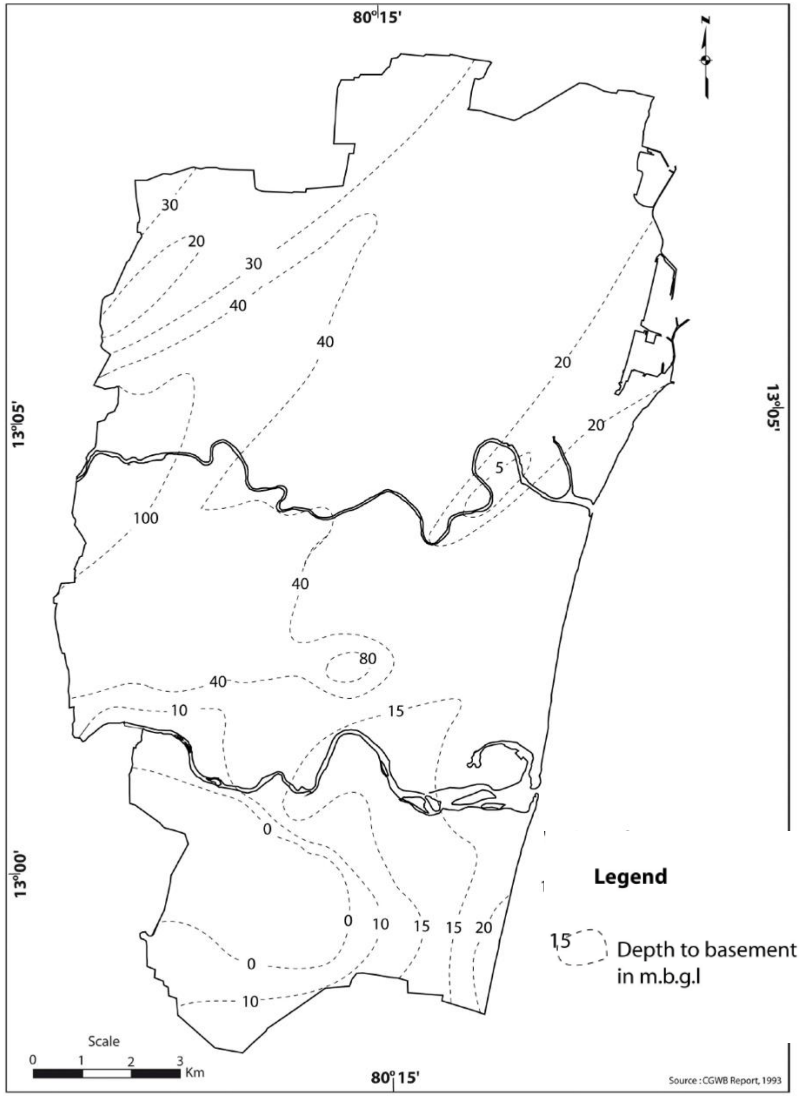
- Areas with greater groundwater level are considered to have higher liquefaction potential.
- The high-hazard zones are not located in areas with the highest fluctuation, but rather in places where the groundwater table remains shallow year-round.
- Long-term saturated conditions reduce effective stress and lower the shear wave velocity.



Method – Data Collecting

Depth to Bedrock

- The depth to bedrock means **how thick the soil layer** is before hitting the hard rock underneath.
- If the bedrock is **very deep**, that means there's a thick layer of soft soil on top — and soft soil tends to **trap and amplify seismic waves**.
- It's kind of like shaking a bowl of jelly versus shaking a bowl of concrete — the jelly is going to wiggle way more.



Why AHP ?

- Simple but powerful
- Clear structure and without complex calculation
- More flexible

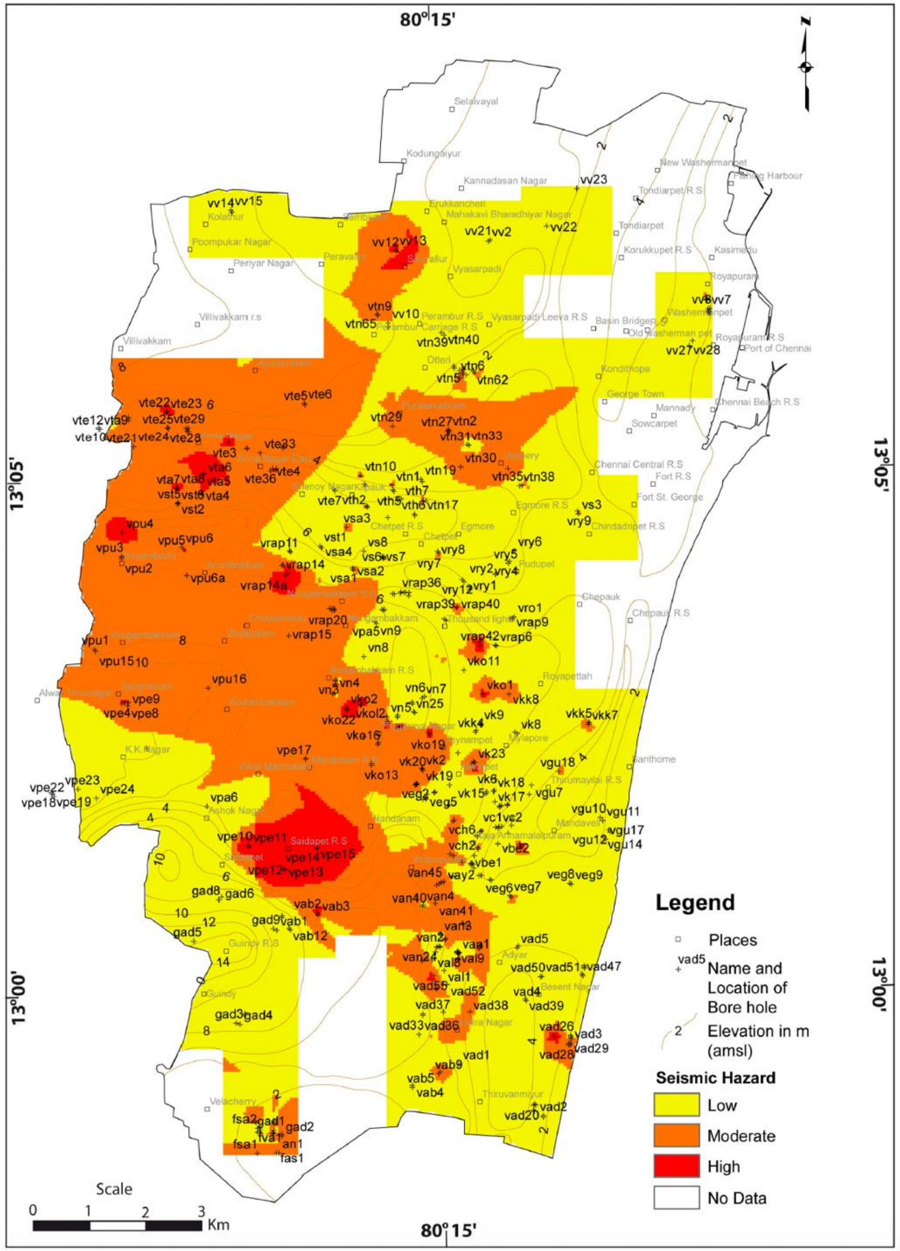
Themes	PGA	Soil	Geology	Ground Water	Bedrock
PGA	1	5/4	5/3	5/2	5/1
Shear Wave Velocity	4/5	1	4/3	4/2	4/1
Geology	3/5	3/4	1	3/2	3/1
Ground Water	2/5	2/4	2/3	1	2/1
Bedrock	1/5	1/4	1/3	1/2	1

About weighting score…

- Earlier experience with similar processes
- Discussion and consensus reached after discussions
- Expert opinion

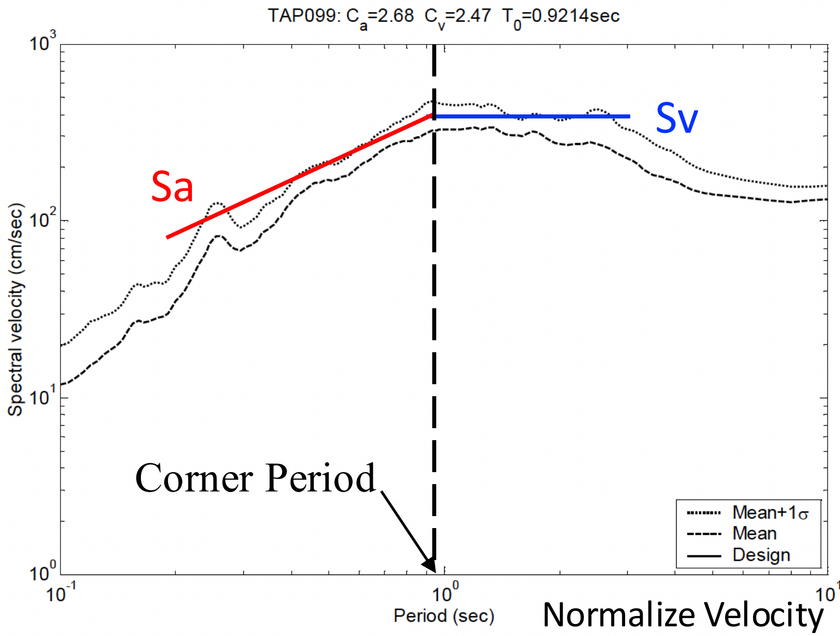
Themes	PGA	Soil	Geology	Ground Water	Bedrock
PGA	1	5/4	5/3	5/2	5/1
Shear Wave Velocity	4/5	1	4/3	4/2	4/1
Geology	3/5	3/4	1	3/2	3/1
Ground Water	2/5	2/4	2/3	1	2/1
Bedrock	1/5	1/4	1/3	1/2	1

Themes	Weightage	Normalised Values			
		4	3	2	1
PGA (in g)	0.3333	–	0.176	–	–
Shear Wave Velocity ($m\,s^{-1}$)	0.2666	50–130	130–165	165–185	185–350
Geology	0.2000	–	Alluvium	Beach Sand	Rock
Ground Water Fluctuation (m)	0.1333	0–2	2–4	–	–
Bedrock (m)	0.0666	> 40	20–40	10–20	0–5

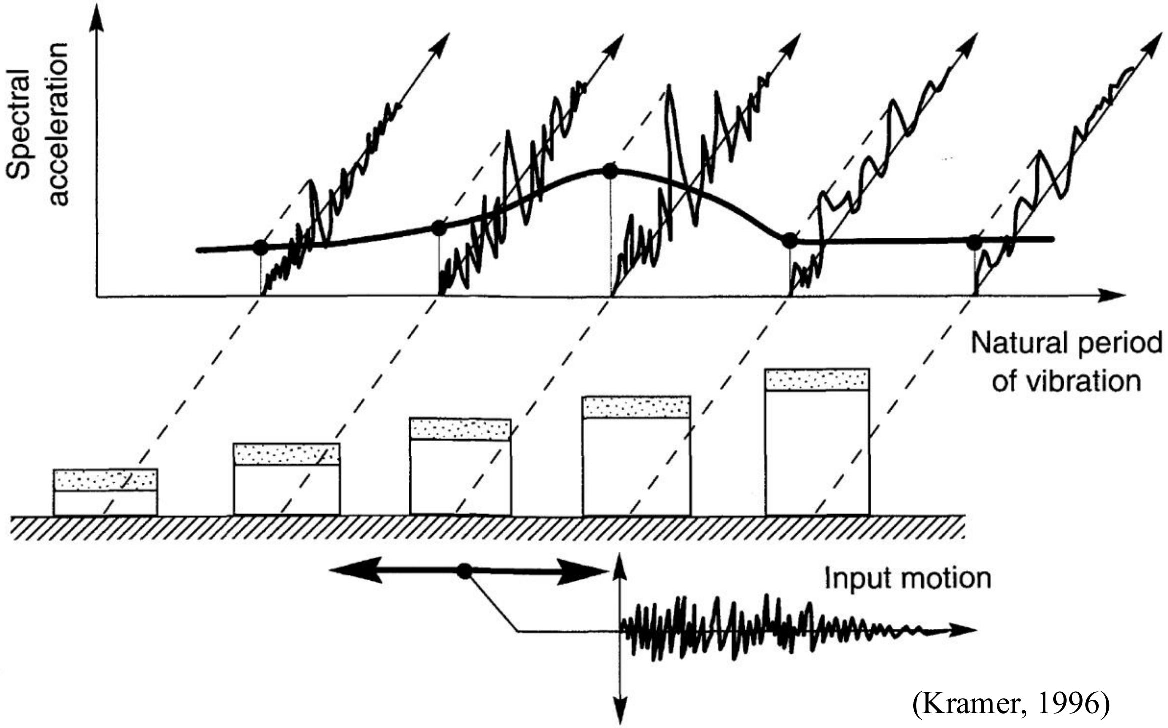


Current building code

- Corner Period



Normalize Velocity Response Spectra



(Kramer, 1996)