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"7th Workshop on Three-Dimensional Modelling of Seismic Waves Generation and their Propagation"

25 October - 5 November 2004

Towards a Dialogue between the Seismologist and Earthquake Engineer

Part 2: Challenges to the Scientists

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Toward a Dialogue Between Seismologist and Earthquake Engineers Part 2

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The Abdus Salam International Center for Theoretical Physics
7th Workshop on Three-Dimensional Modeling of Seismic Waves Generation, Propagation and Their Inversion

25 October – 5 November 2004
Trieste-Italy

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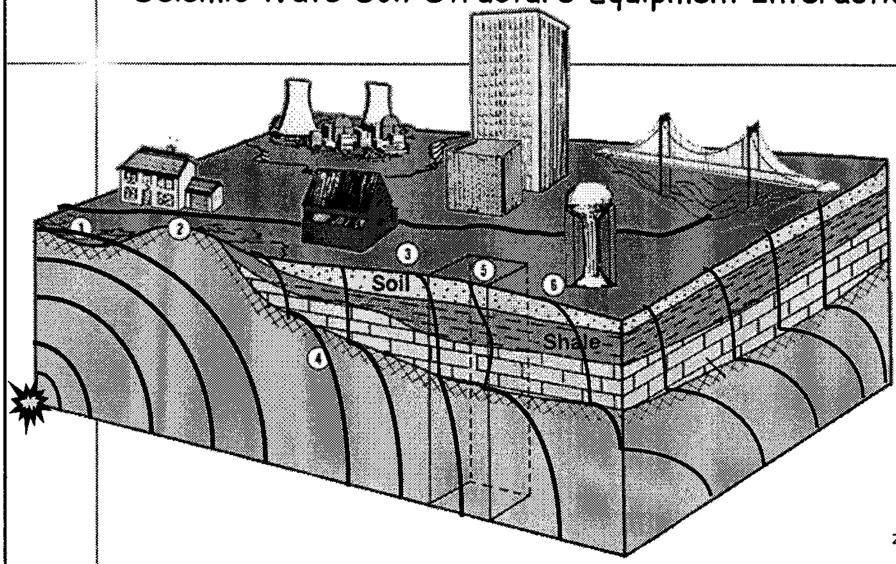
Earthquake Cause and Effect:

Seismic Wave-Soil-Structure-Equipment Interaction



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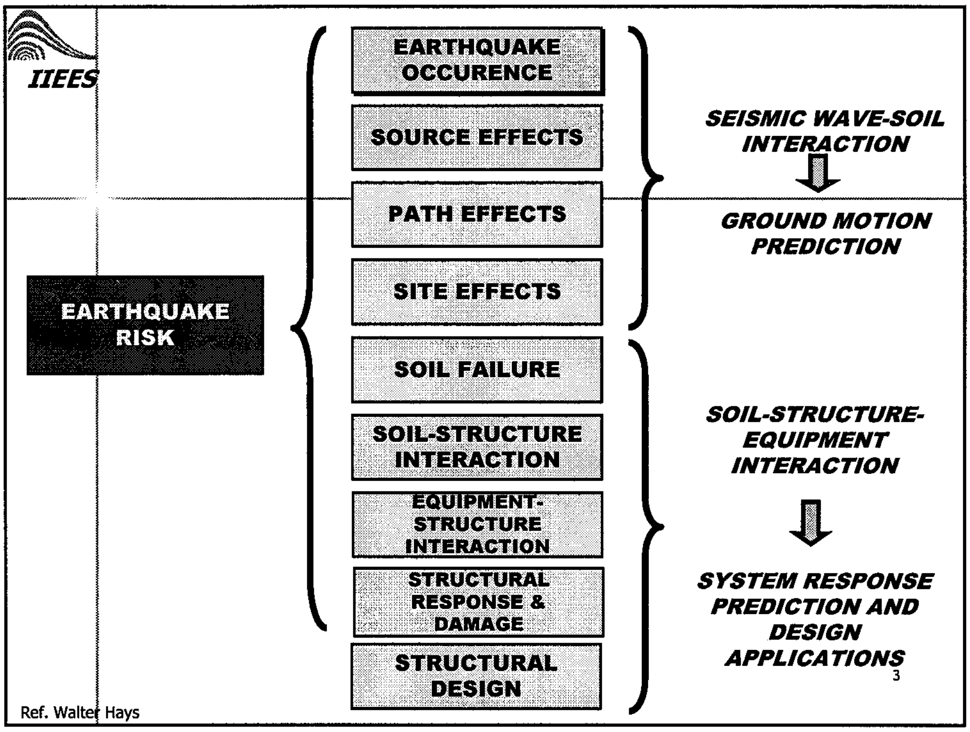
Ref. Walter Hays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EARTHQUAKE RISK
EARTHQUAKE OCCURENCE
SOURCE EFFECTS
PATH EFFECTS
SITE EFFECTS
SOIL FAILURE
SOIL-STRUCTURE INTERACTION
EQUIPMENT-STRUCTURE INTERACTION
STRUCTURAL RESPONSE & DAMAGE
STRUCTURAL DESIGN
SEISMIC WAVE-SOIL INTERACTION
GROUND MOTION PREDICTION
SOIL-STRUCTURE-EQUIPMENT INTERACTION
SYSTEM RESPONSE PREDICTION AND DESIGN APPLICATIONS
3
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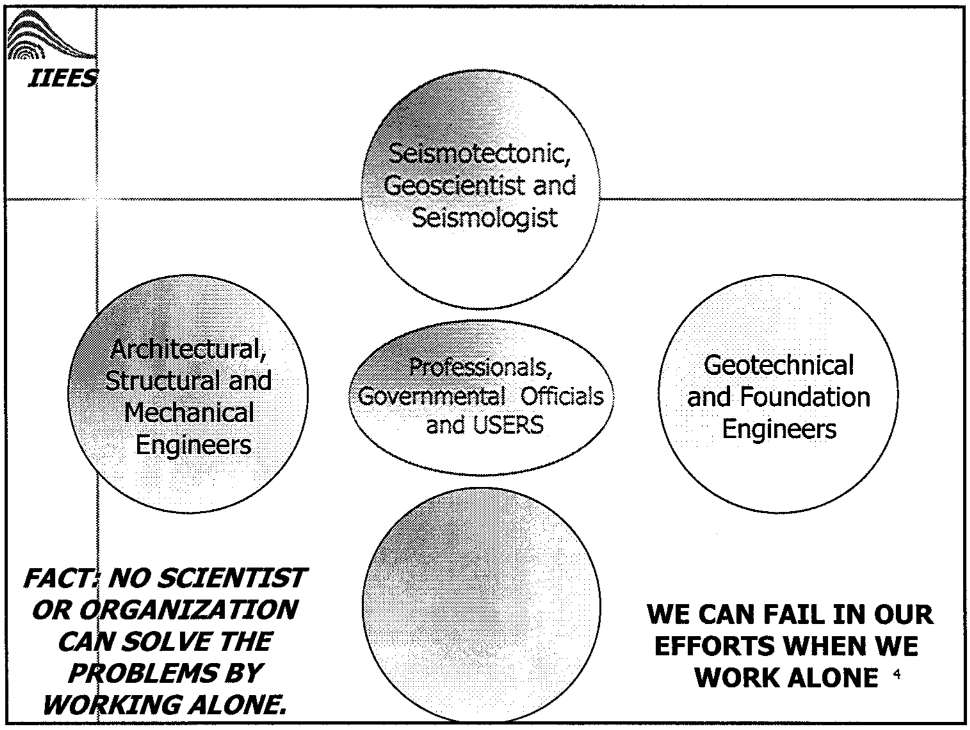
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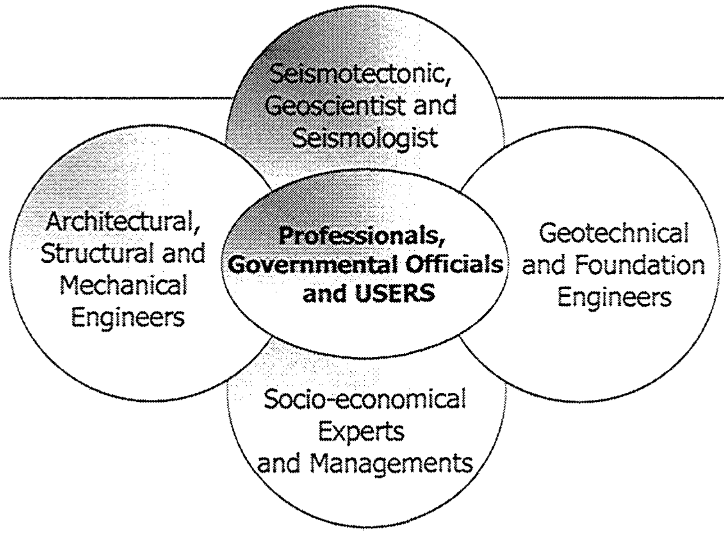
Seismotectonic, Geoscientist and Seismologist
Architectural, Structural and Mechanical Engineers
Professionals, Governmental Officials and USERS
Geotechnical and Foundation Engineers
FACT: NO SCIENTIST OR ORGANIZATION CAN SOLVE THE PROBLEMS BY WORKING ALONE.
WE CAN FAIL IN OUR EFFORTS WHEN WE WORK ALONE
4

STRATEGIC GOALS:

WORKING TOGETHER TO ACHIEVE THE RISK REDUCTION OBJECTIVES



RESULTS: SUCCESS IN REDUCING THE VULNERABILITIES & RISK

What and How Should Be Done?

1. Multi-disciplinary groups of researchers, practicing professionals, users, government officials, etc. SHOULD work together and to develop a DOABLE PLAN and ensure its implementation by reliable and suitable policies and strategies which would help to reduce and control seismic risks to acceptable and manageable levels for the a community or government.

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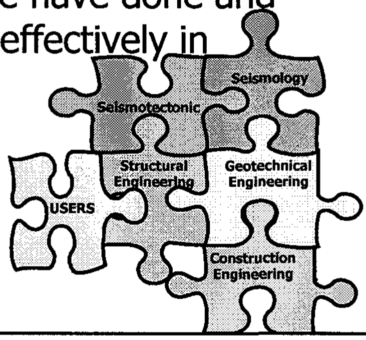
What and How Should Be Done?

2. We need to see the total picture of earthquake from its source to its effects and impacts.
3. We need to see what we have done and what needs to be done effectively in order to solve the Earthquake Puzzle.



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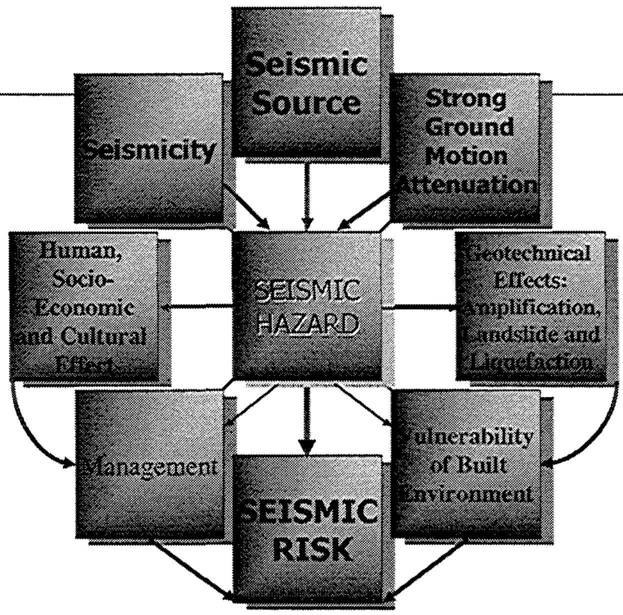
Earthquake Cause and Effect



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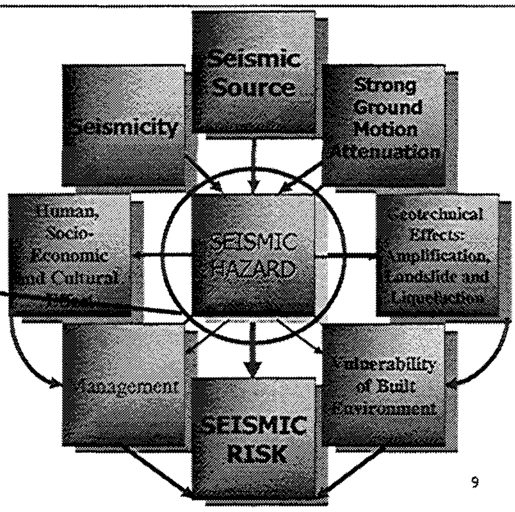
Earthquake Cause and Effect

Seismic Hazard is the Link Between the Earth Scientist and Engineers in the Risk Reduction Program.

The Objective of the Seismological Studies Should Be:
Reliable Assessment of Seismic Hazard



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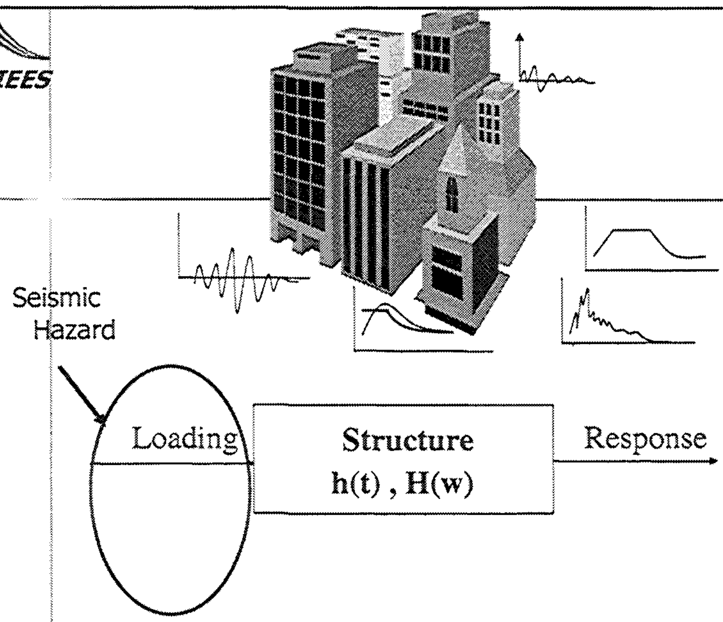

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SEISMIC HAZARD ASSESSMENT

- Seismic Hazard: Any effect of an earthquake with the potential to lead to adverse consequences and effect on human activities at a particular location.

Methods of Analysis:

- **Probabilistic SHA:** Introduced by Cornell in 1968 is most widely used approach for Determining the Ground Motion Characteristics.
- **Deterministic SHA:** Introduced by Reiter in 1990 is time independent and judgmental approach for Determining the Ground Motion Characteristics.

None of the methods have been fully successful in the assessment of future earthquake ground motion characteristics !!

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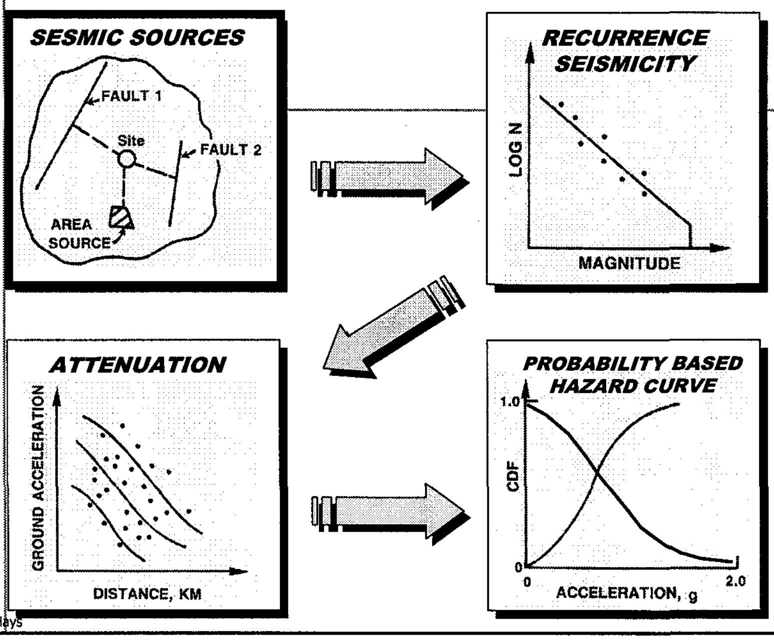
SEISMIC HAZARD ASSESSMENT



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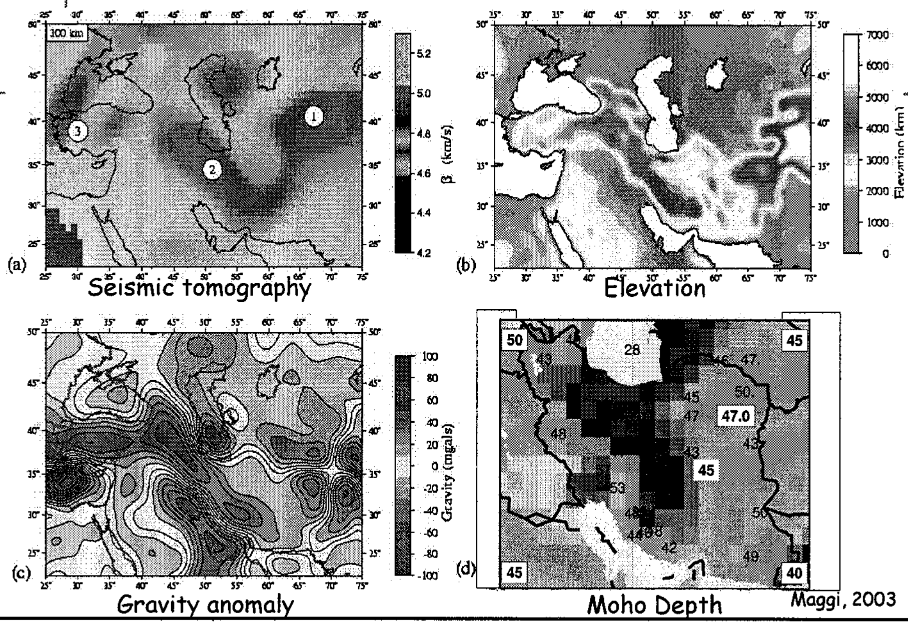
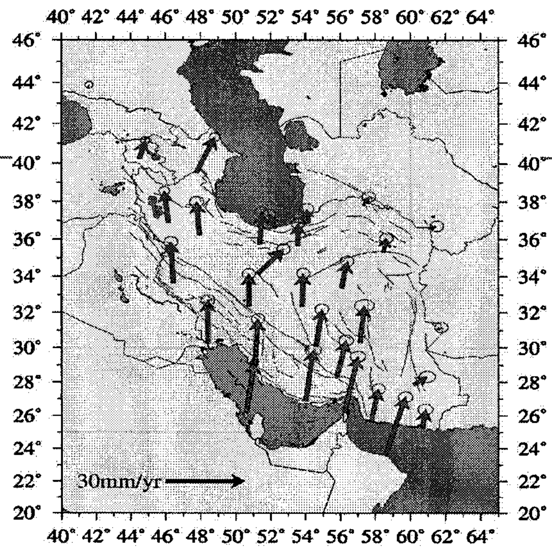
Iran: Tectonic Facts





not really rigid blocks...

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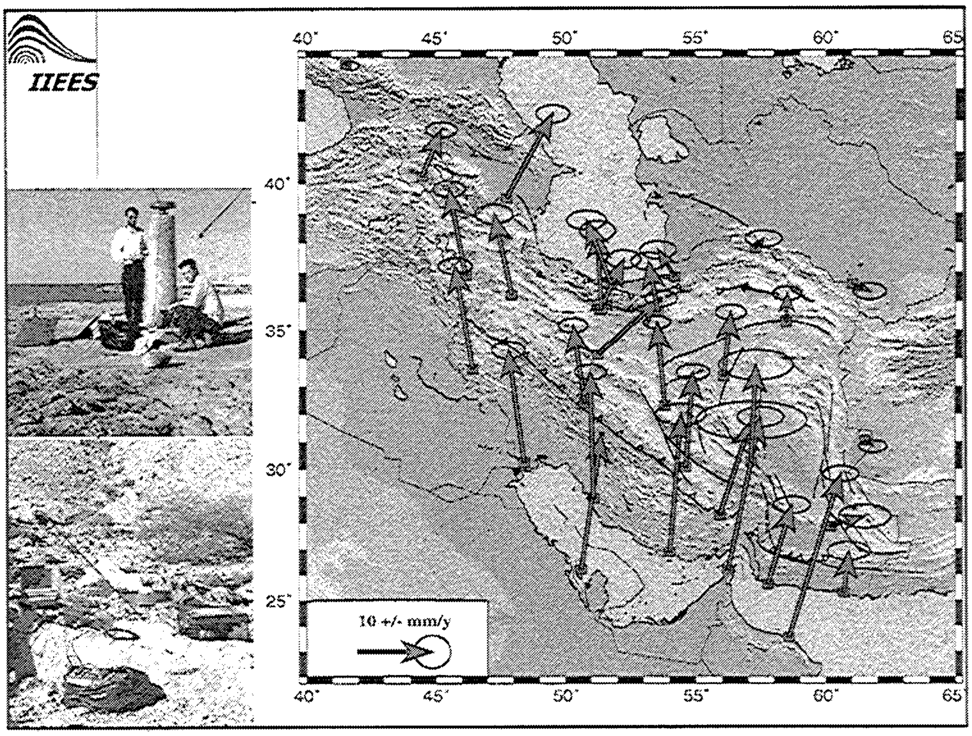

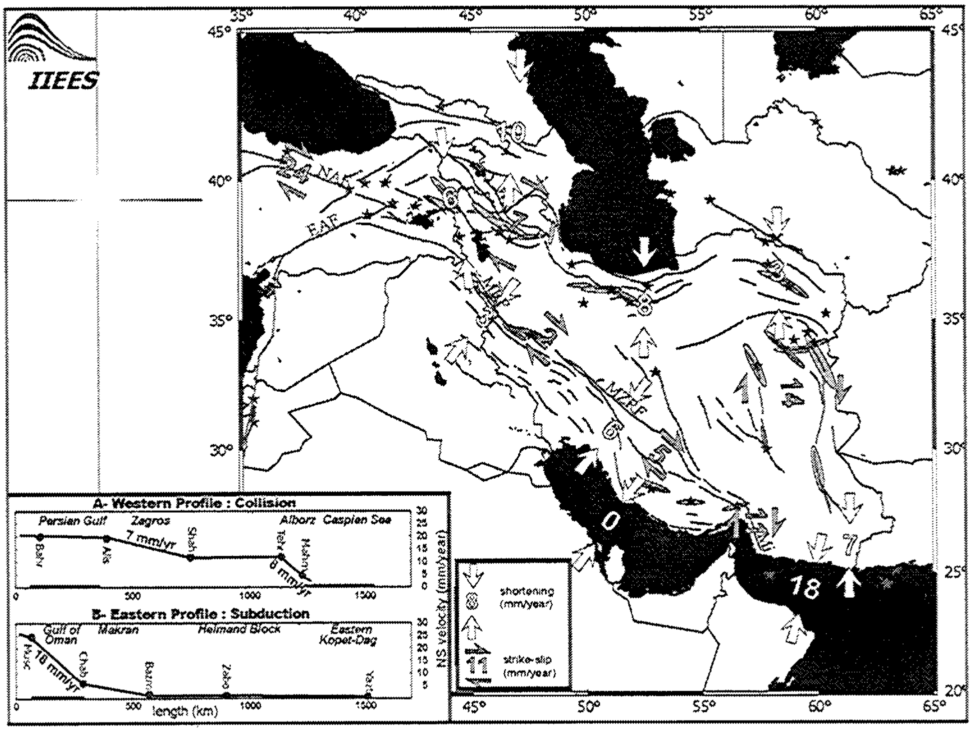

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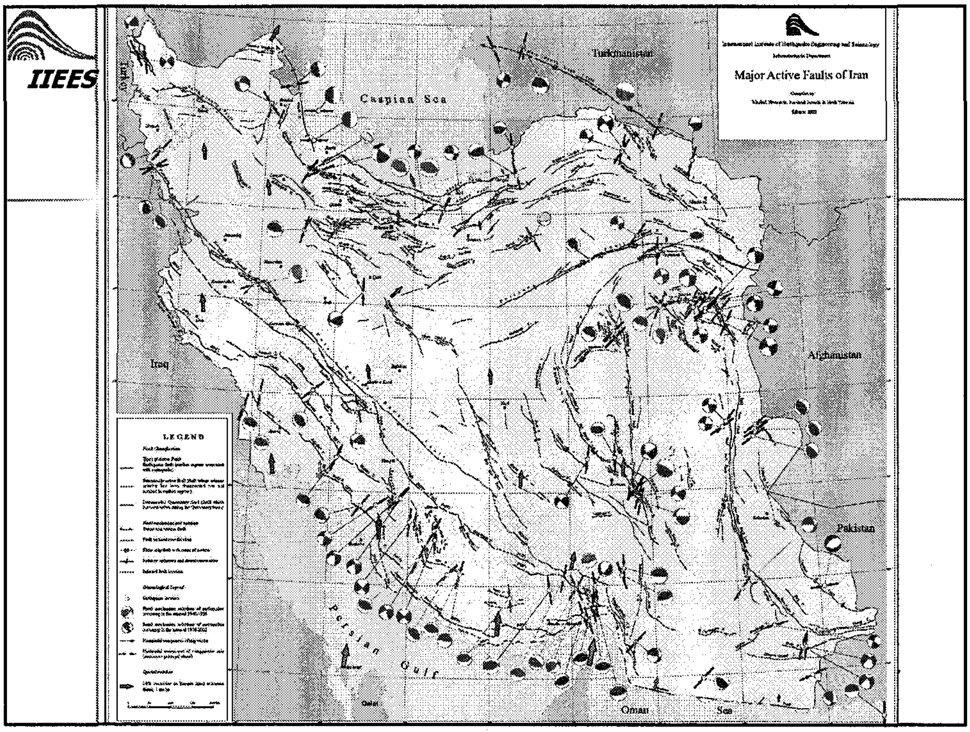

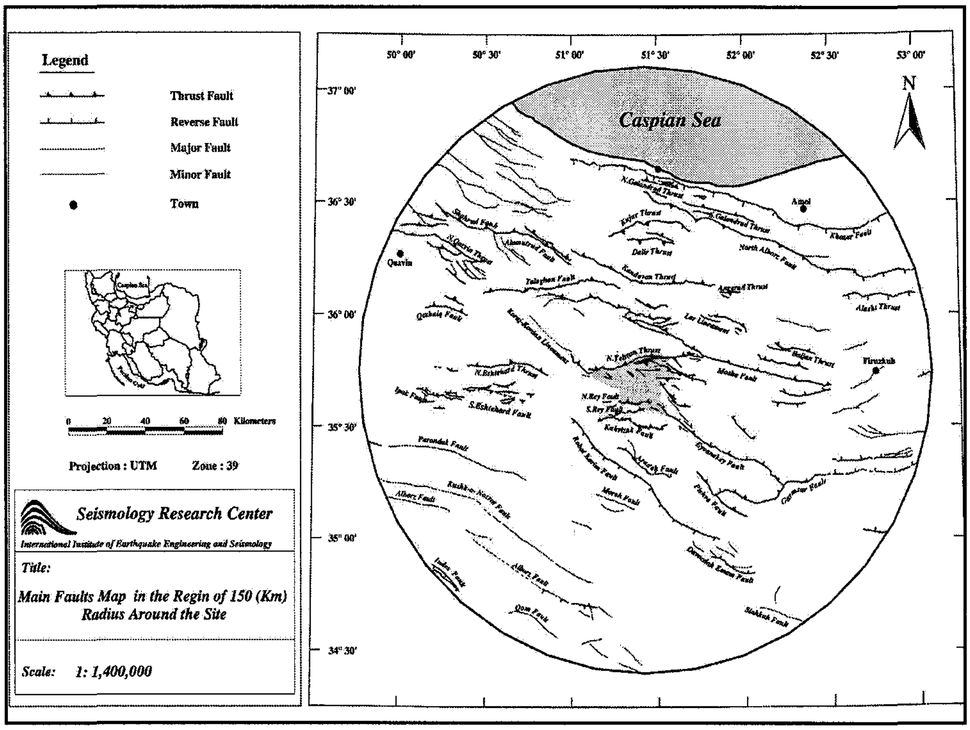

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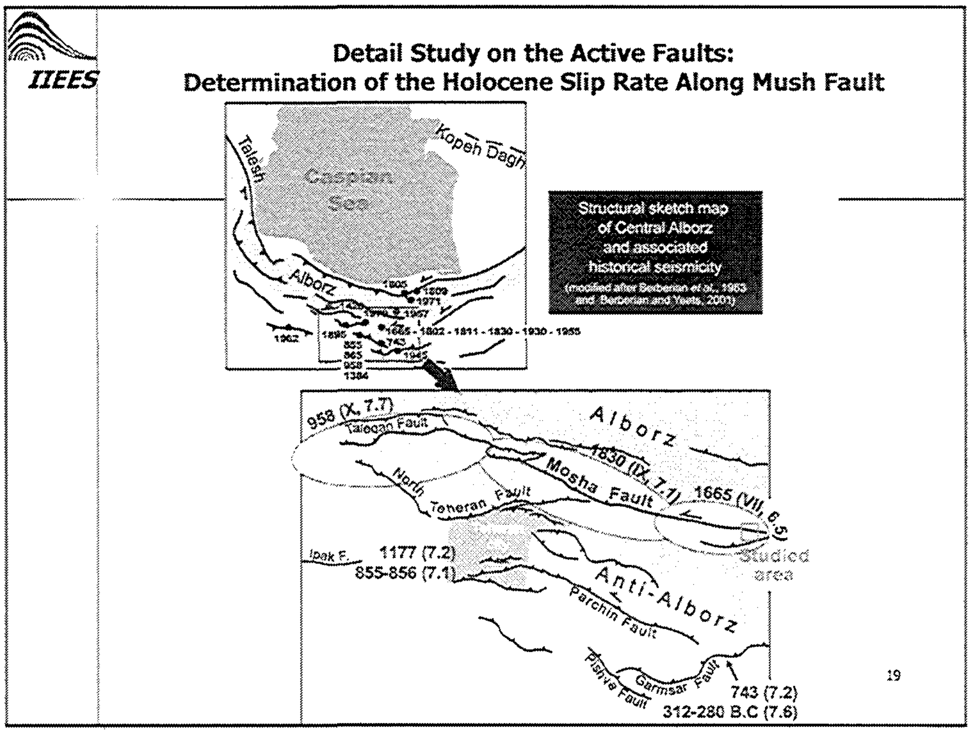

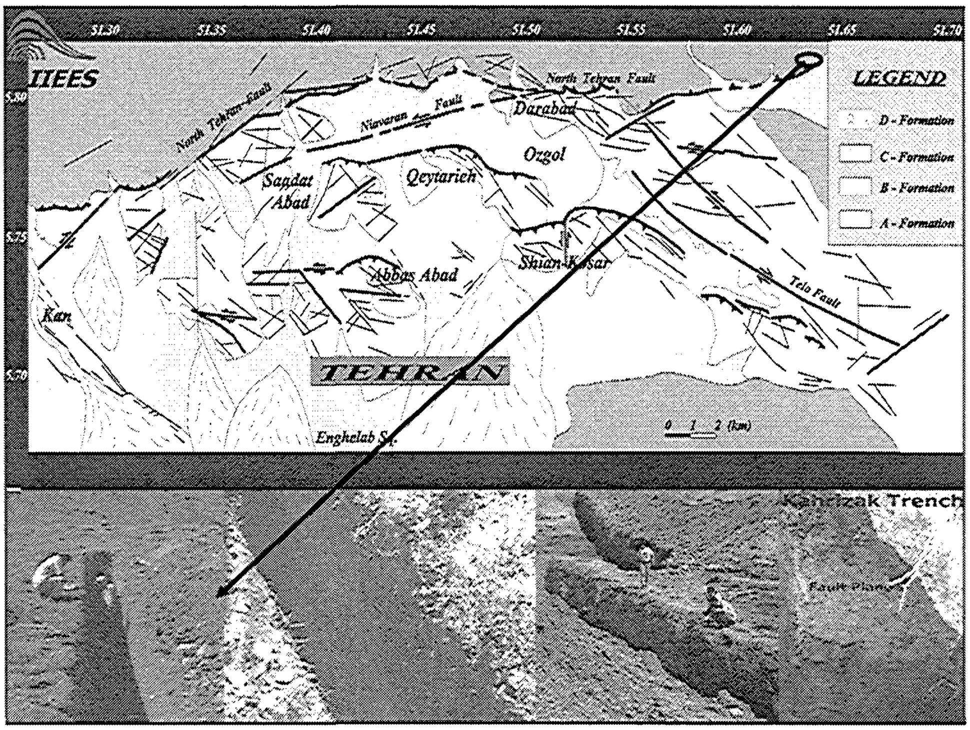

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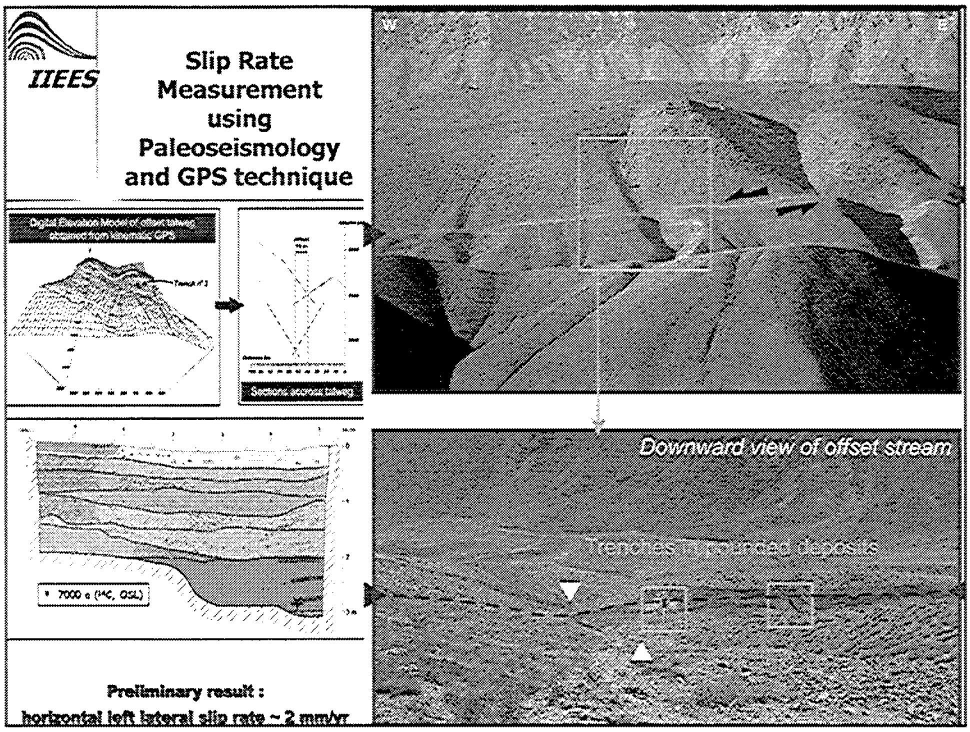

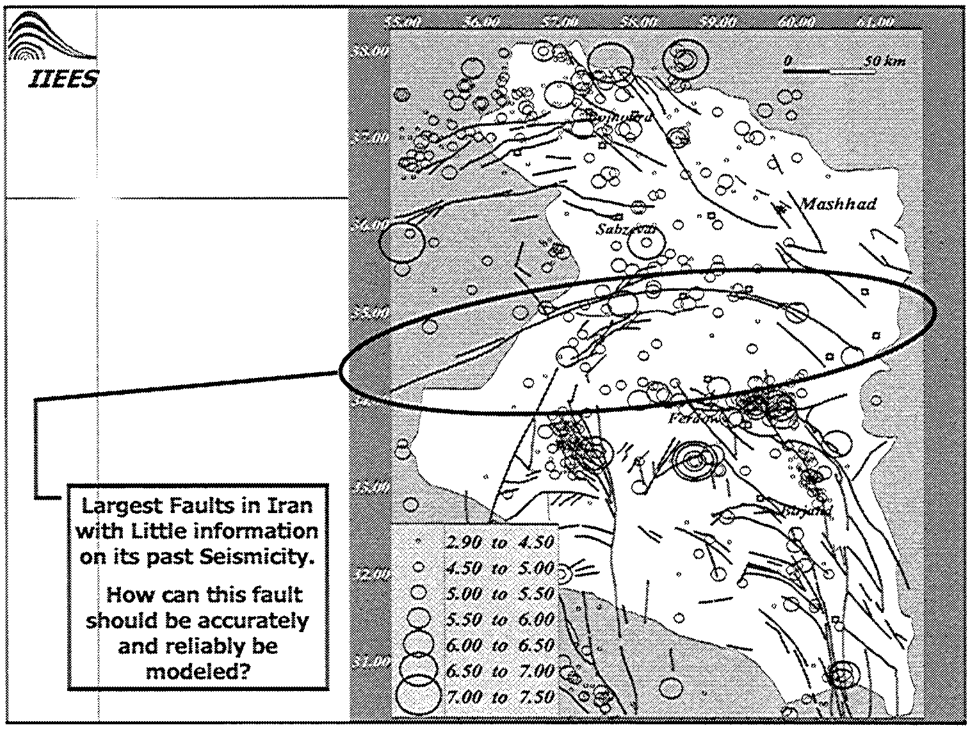

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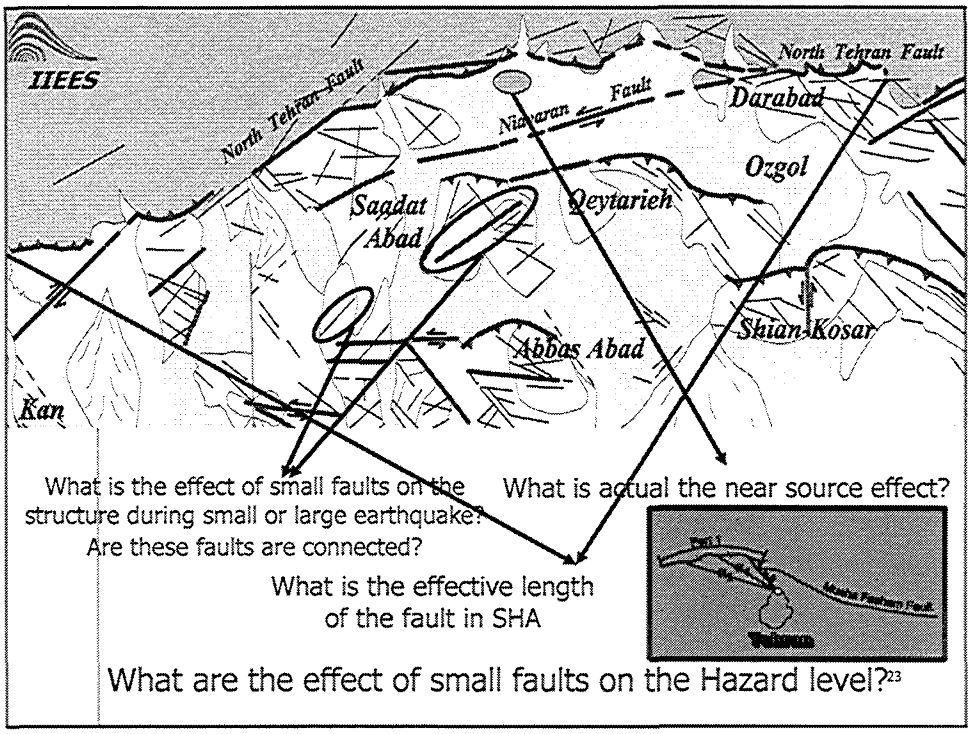

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Practical Questions in Seismic Source Identifications and Studies:

1. What should be the appropriate level of accuracy or scaling in various tectonic studies?
2. What should be the reliability level of the fault maps?
3. What is the effective length of the faults that need to be considered in SHA?
4. What is the effect of surface fault rupture on SHA?
5. What is the effect of small faults on SHA?
6. What is the effect of large faults movement on small faults?
7. What is the importance of the small faults under the structure?
8. Many more.....

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Issues need to addressed in Tectonic Studies:

1. Defining the active region or fault by neotectonic studies using seismic measurement
2. Determination and mapping of the quaternary active faults for reliable assessment of seismic source in SHA.
3. Determination of active seismic zone where there is no recorded seismological data.
4. Trends of active faults.
5. Defining the blind faults or blind portions of the faults
6. Defining the contemporary stress direction
7. Defining the relation between small faults and big faults using deep seismic profile.
8. Defining the relation between fault mechanism with the seismic wave directivity, and their effect on the energy.

IS THERE ANY OTHER WAY TO MODEL THE SEISMIC SOURCE?

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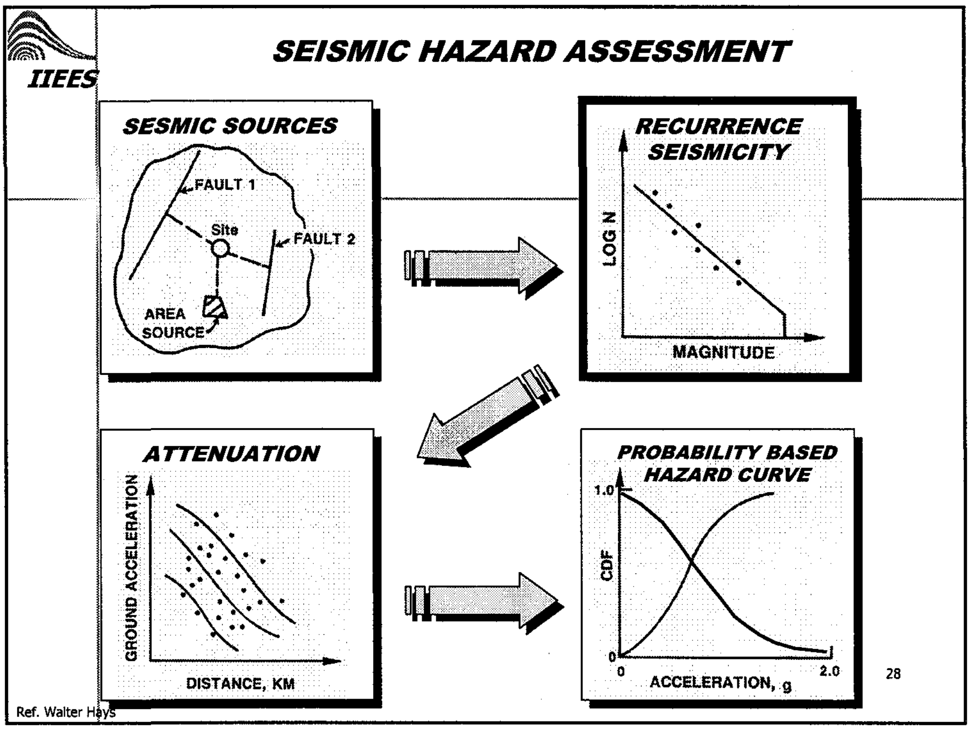

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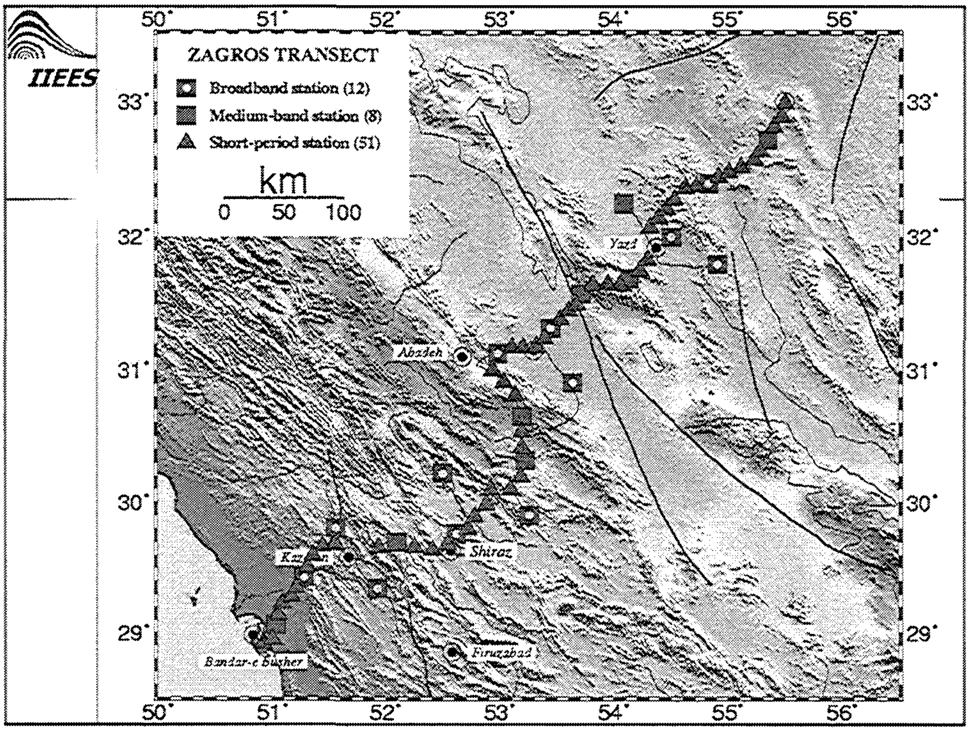

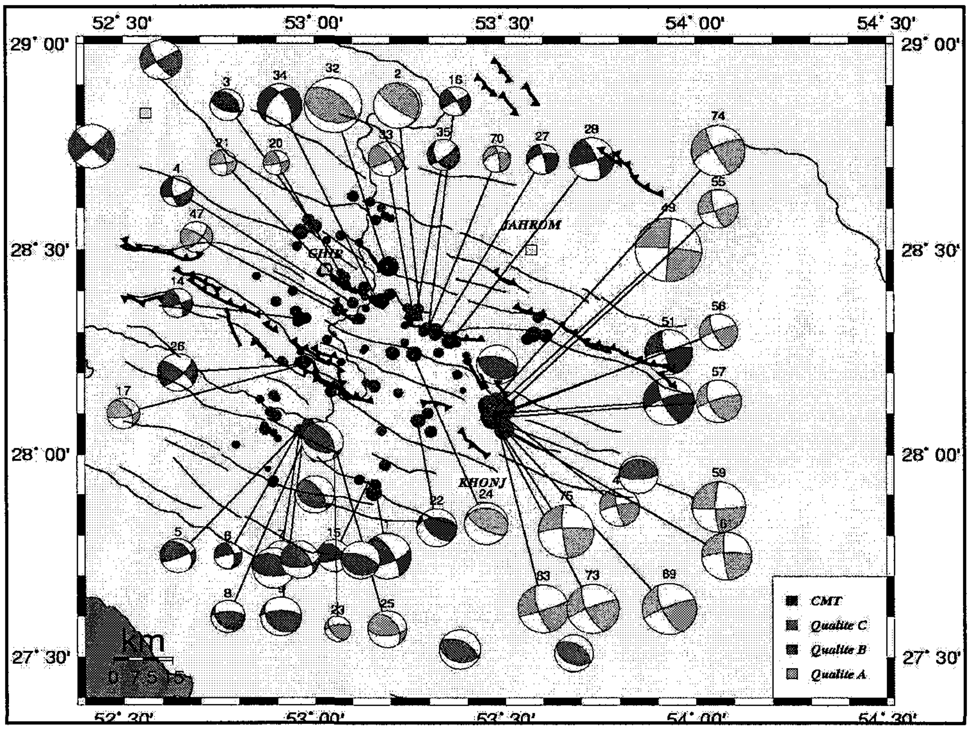

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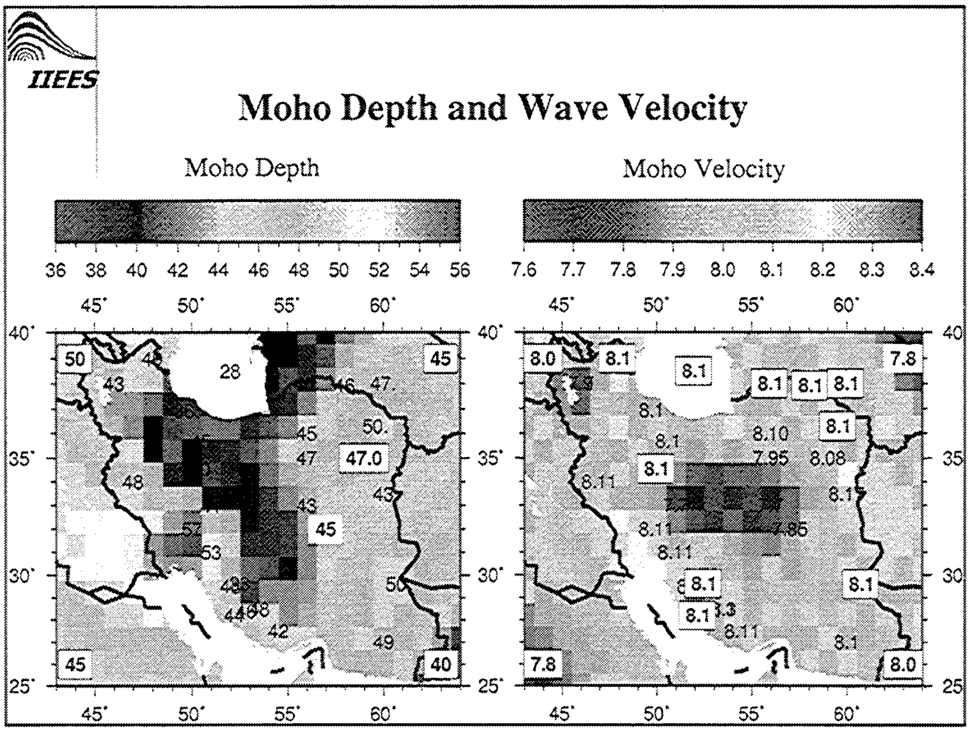

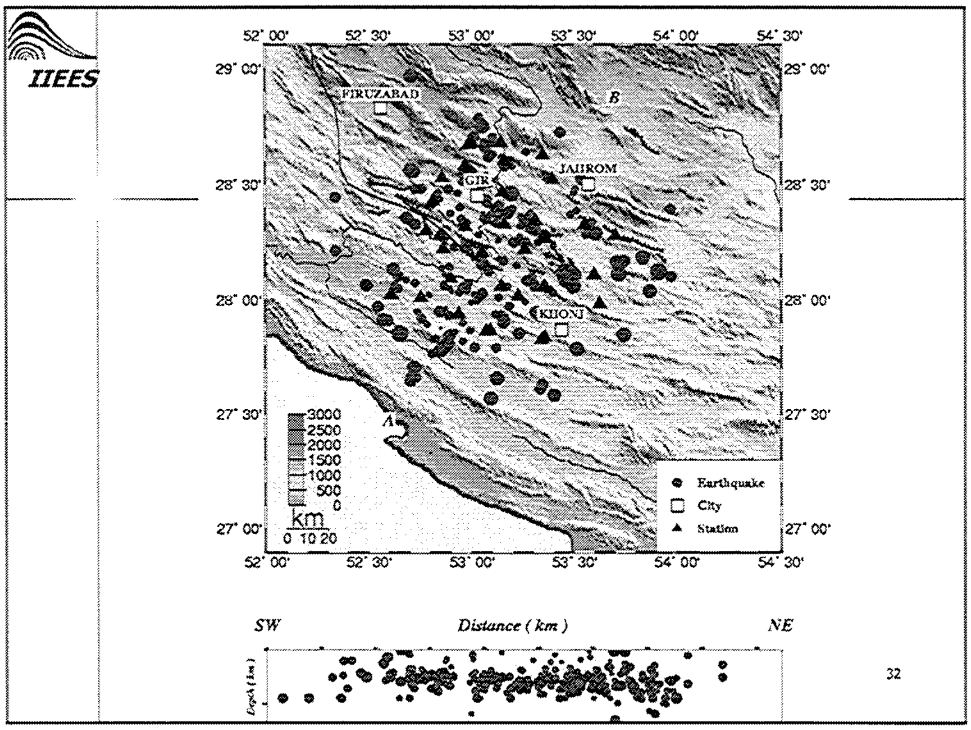

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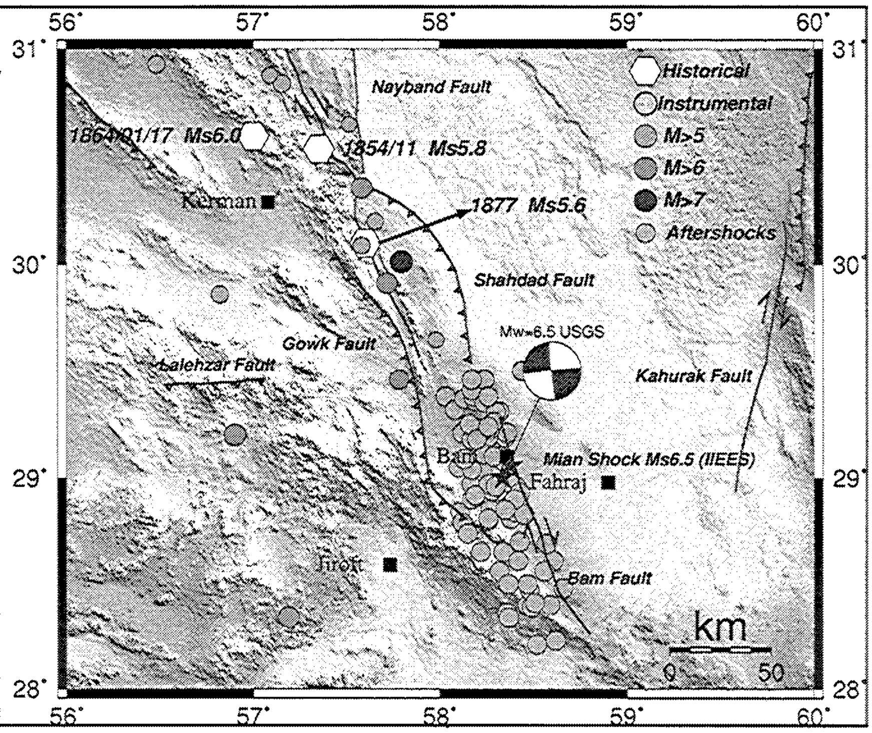

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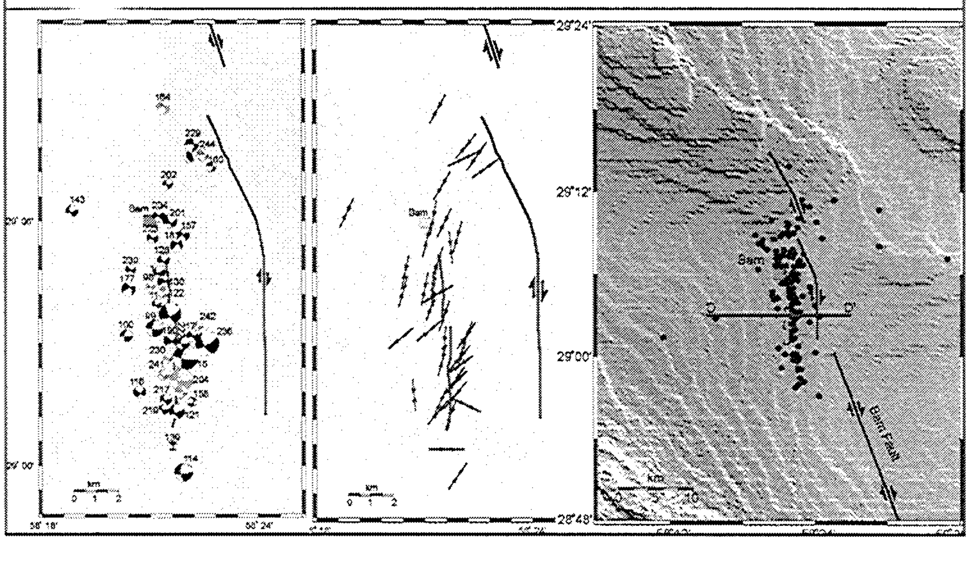
Bam Faults and Aftershock Distribution



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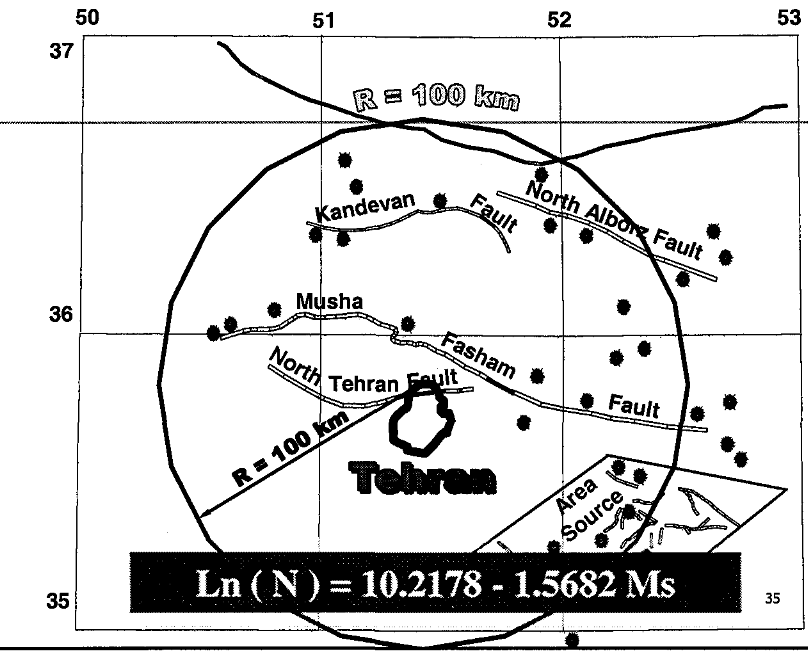

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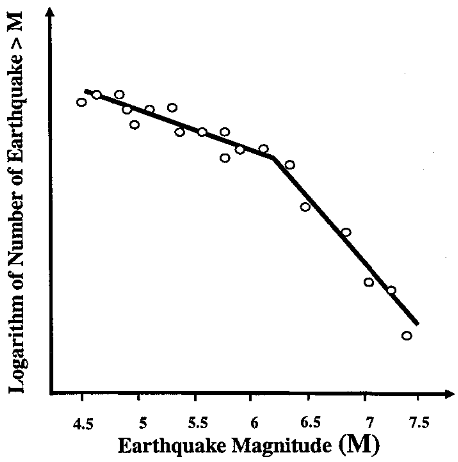
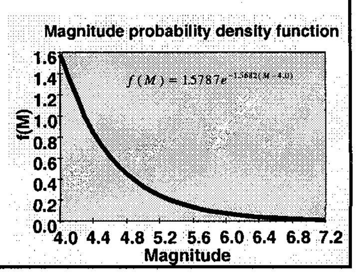
Gutenberg-Richter Type of Relation





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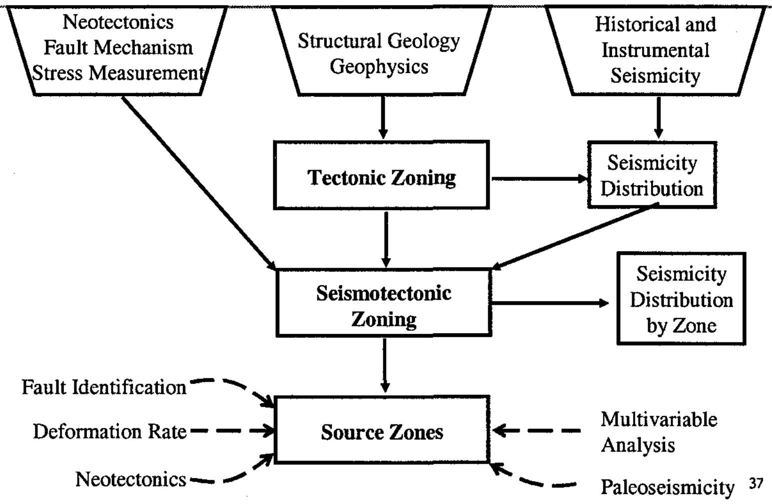
Seismic Source and Seismicity



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Questions and Issues in Seismicity

- How short term seismicity could represent the long-term seismicity of the region?
- How the data base of low and local seismicity could represent the seismicity of strong earthquake?
- How to model recurrence of large earthquake which occur at irregular time intervals?
- Is looking at number and magnitude of the earthquakes are sufficient parameters for defining the seismicity rate in SHA?

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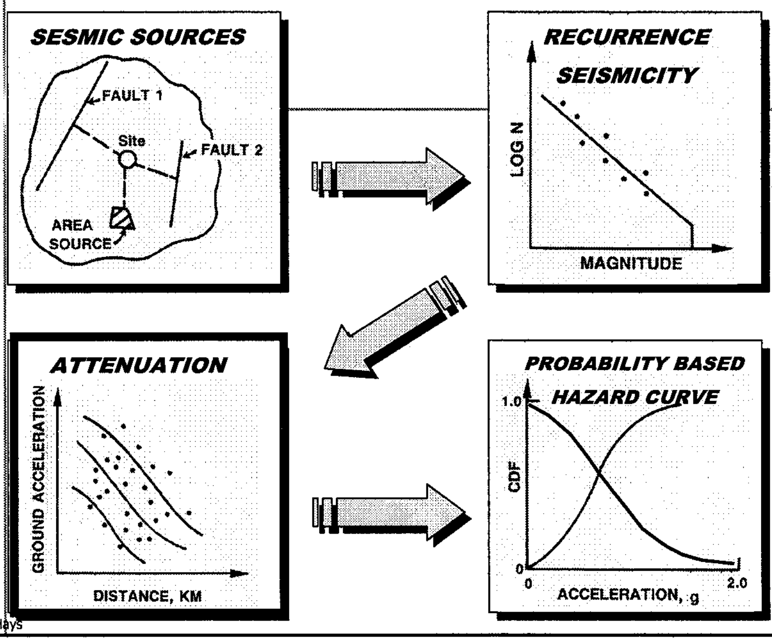
SEISMIC HAZARD ASSESSMENT



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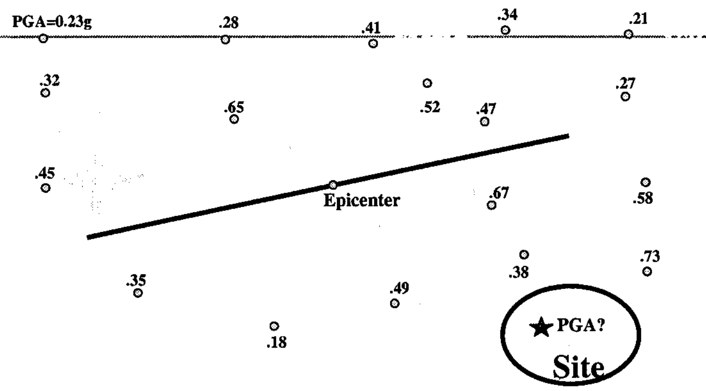
Strong Ground Motion Attenuation



Attenuation depends on site geology, soil, topography, distance, energy, source, faulting, etc.
Can all these parameters be modeled?
If Not; What should be Done?

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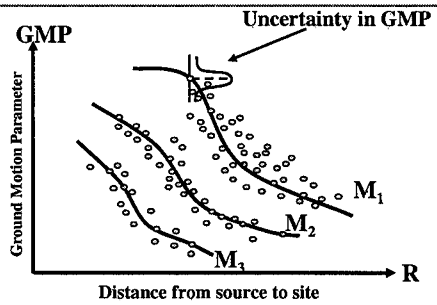
Ground Motion Attenuation Relation



- Ground Motion Parameters (GMP) are probabilistically defined based on the limited data, mostly from moderate earthquake.
- How accurately the models could represent strong ground motion which happen every 1000 years?

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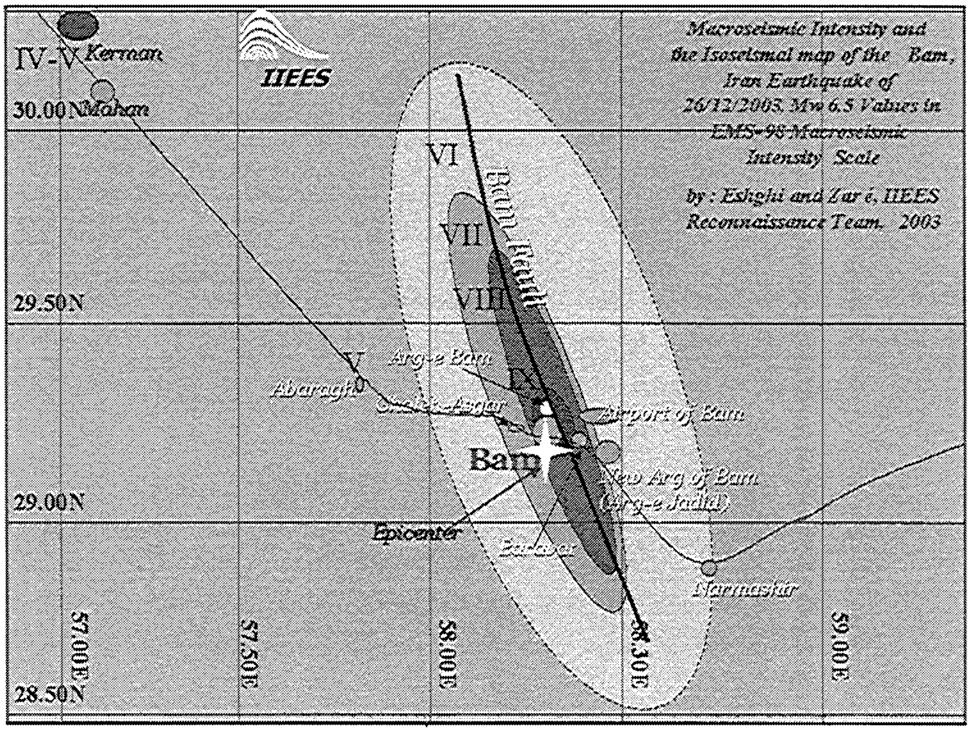

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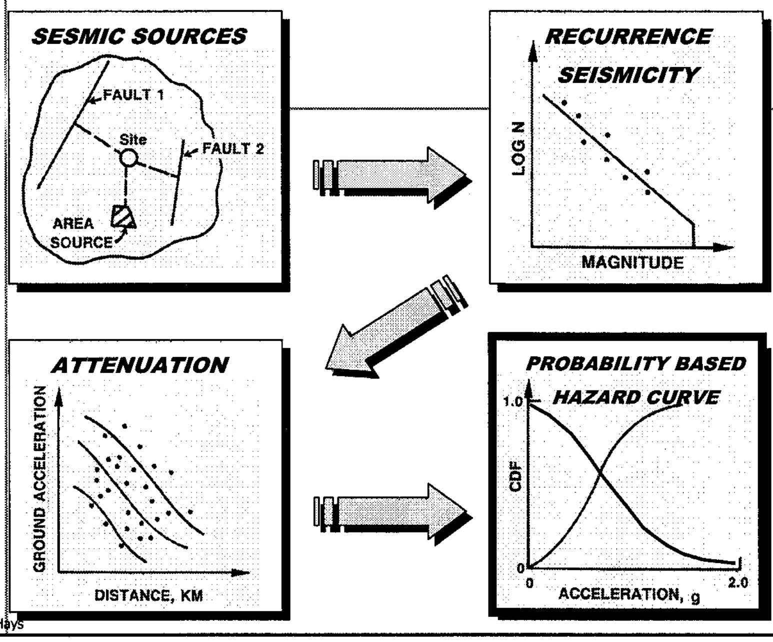
SEISMIC HAZARD ASSESSMENT



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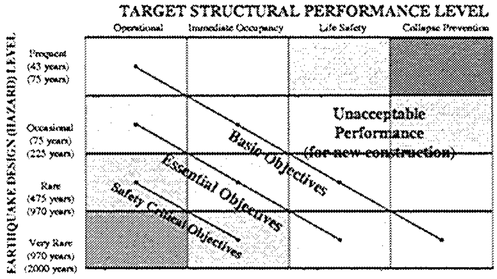
PSHA Methods

Probability of Occurrence During the Life of the Structure = R

Various Design Level are: DBE, BSE-1/2 ,OBE, SSE ,MCE ,MPE ,..

DBE (BSE1) = 10% Probability of Occurrence in 50 Years ➡ T_R = 475 years.

MPE (BSE2) = 2% Probability of Occurrence in 50 Years ➡ T_R = 2000 years.



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PSHA Methods

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DBE (BSE1) = 10% Probability of Occurrence in 50 Years ➡T_R = 475 years.

MPE (BSE2) = 2% Probability of Occurrence in 50 Years ➡T_R = 2000 years.

- **Almost in all of the codes in the world (with quite different seismic characteristic and structures and construction) same annual probability of exceedance or Return Periods is being used for the definition of the basic seismic hazard level in design. Why?**
- **Do we have enough reliable knowledge and data for the considered return period (1000 years) in order to make such prediction?**

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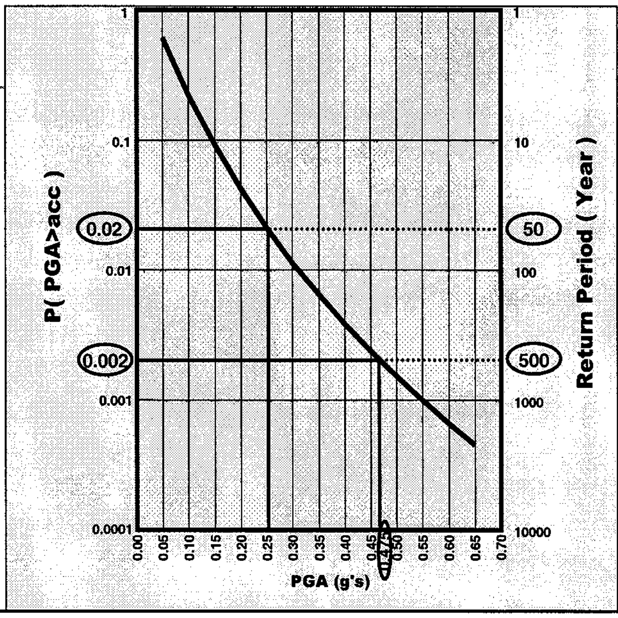
Hazard Curve



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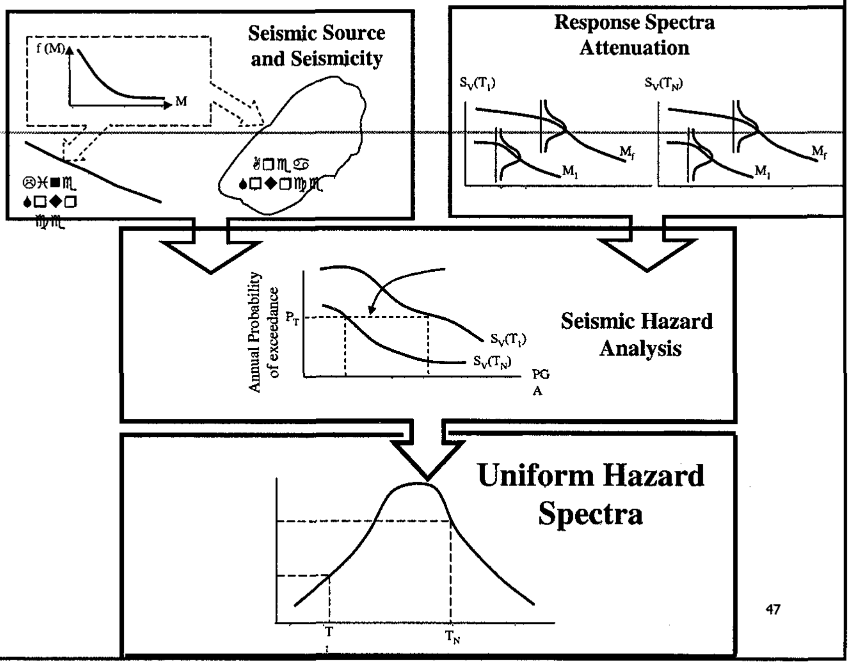
Uniform Hazard Spectra



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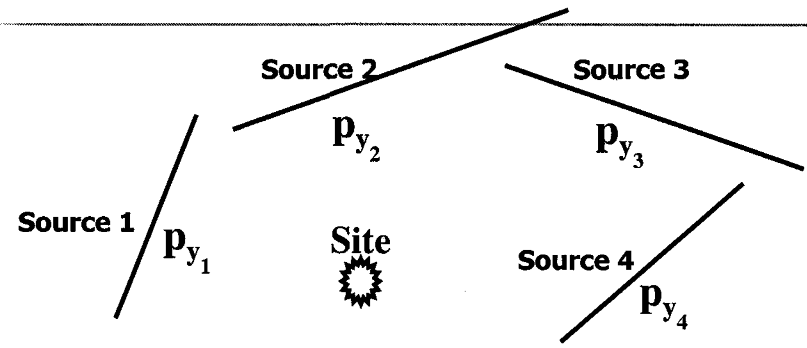
Multiple Source Effect



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Multiple Source Effect

	Aleatory Uncertainty (Single SHA)	Epistemic Uncertainty (Multiple SHA)
Magnitude Recurrence	Seismicity Parameters (a, b, M_{max})	Weighted seismicity parameter
Earthquake Rupture Size	Scatter in a given rupture length vs. magnitude relationship	Weighted rupture model
Earthquake Location	Random location of hypocenters on a given seismic source	Weighted seismic source geometrics
Motion Attenuation	Scatter in a given attenuation Model	Weighted attenuation models
Modeling Uncertainty	Unexplained scatter due to physical processes not included in a model	Uncertainty in the true bias of a model. Uncertainty in estimation scatter.
Parameter Uncertainty	Earthquake to earthquake variation in seismic source, path and site specific parameters of model	Uncertainty in probability distributions and/or median values of source, path and site parameter.

Reference: Dr. Robert T. Sewell Lecture note on PSHA, May 2001

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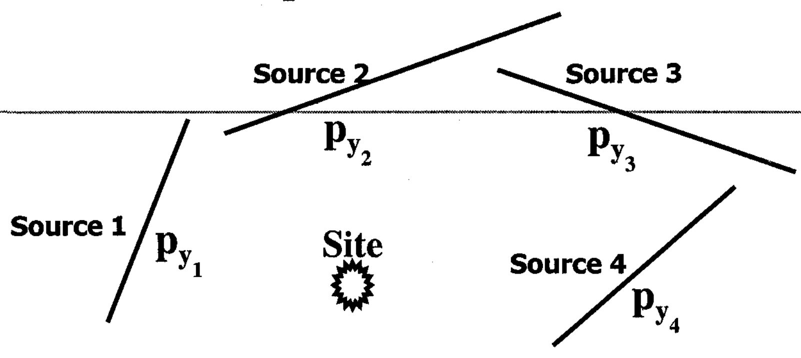
Multiple Source Effect



Is this type of approach is reliable?

Questions:

- Does all of the sources affect the site and the structure?
- Which source will have the highest effect on the site and the structures?
- Does Logic Tree or other probability based analysis will provide the actual answer?

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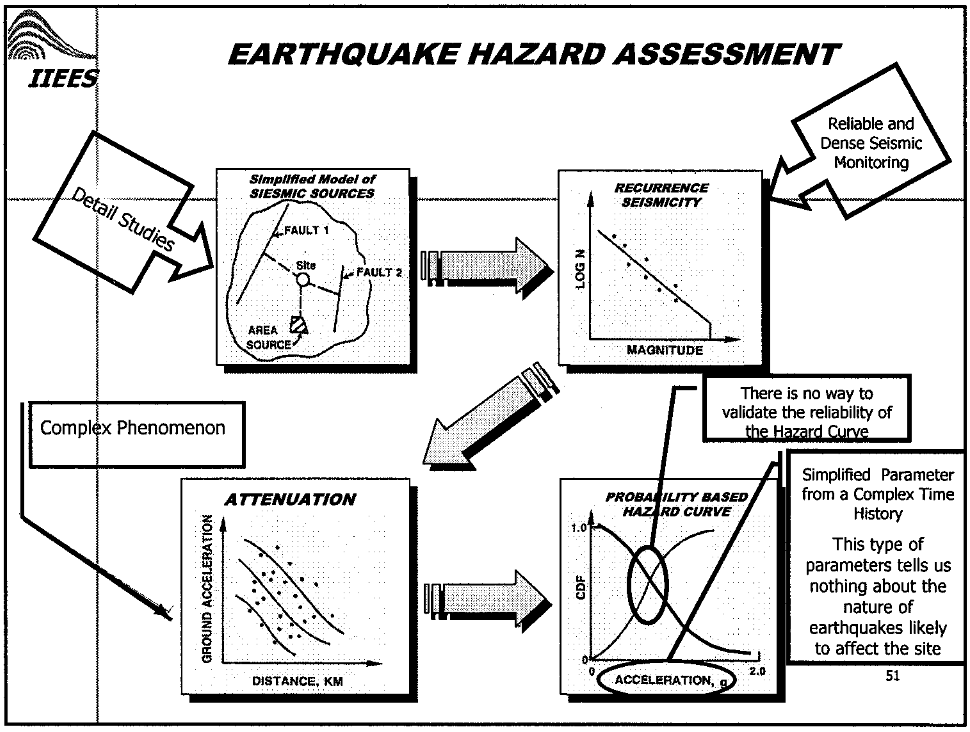

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Comment:

After decades of accelerometers operation and collection of data from strong ground motion, it might be possible to plot the actual variation of various ground motion parameters with time and observe how well the Hazard Curves are compatible with what actually may happen at a site. We just hope what we do is helpful and it is corrects!

But we always get surprised!

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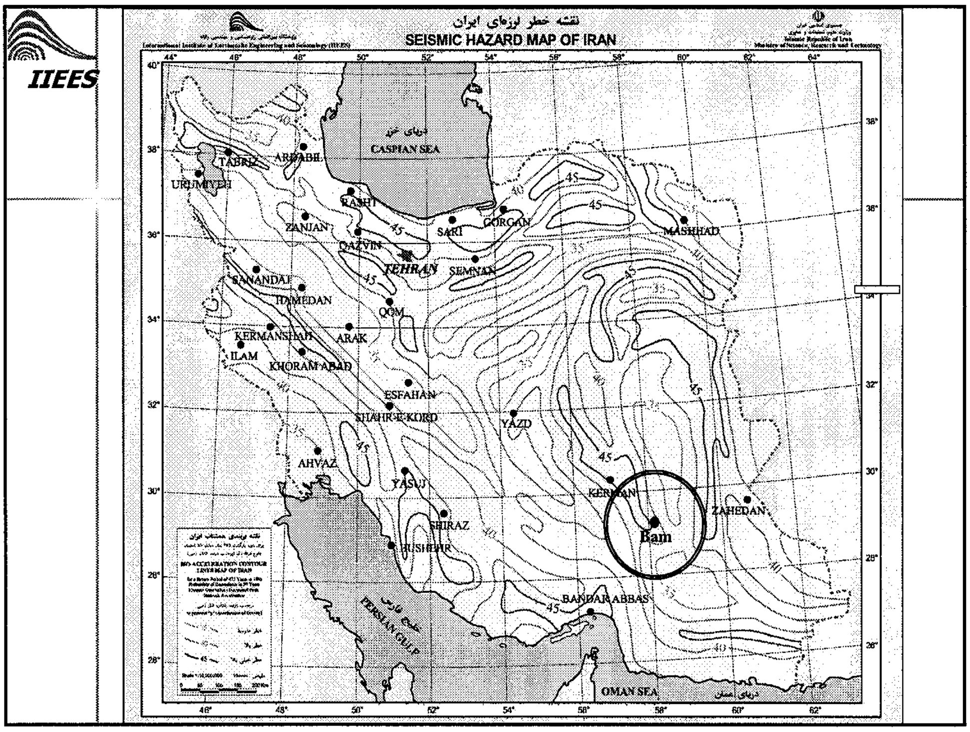

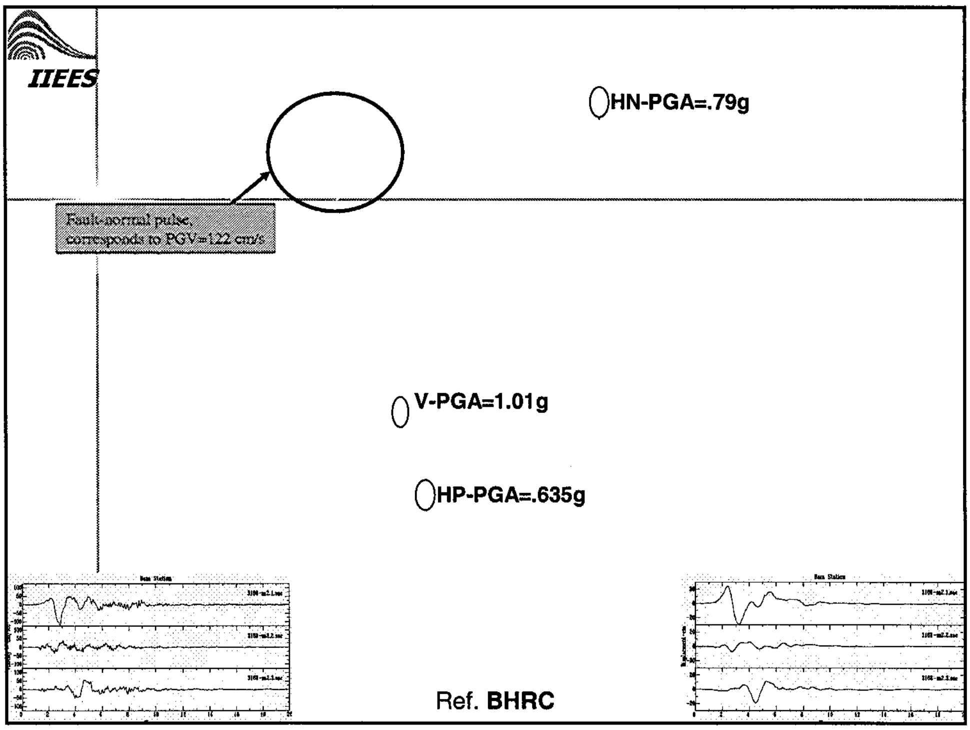

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Design Ground Motion

Hazard Curve → PGA, PGV, .. → Design Spectra

Hazard Curve → Uniform Hazard Design Spectra

→ Compatible Time History

QUESTION:

How Accurately and Reliably These Input Parameters are Representing the Real Case and The Input Energy??

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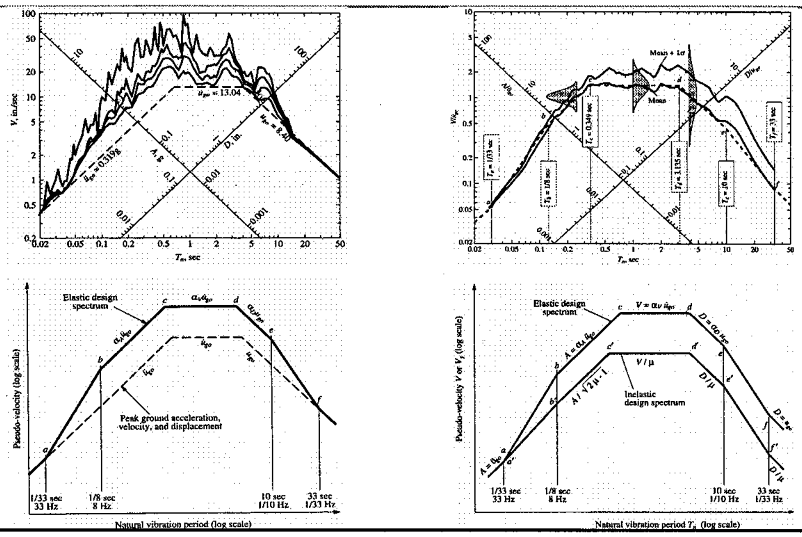
Fixed Shape Design Spectra

(Newmark-Hall)



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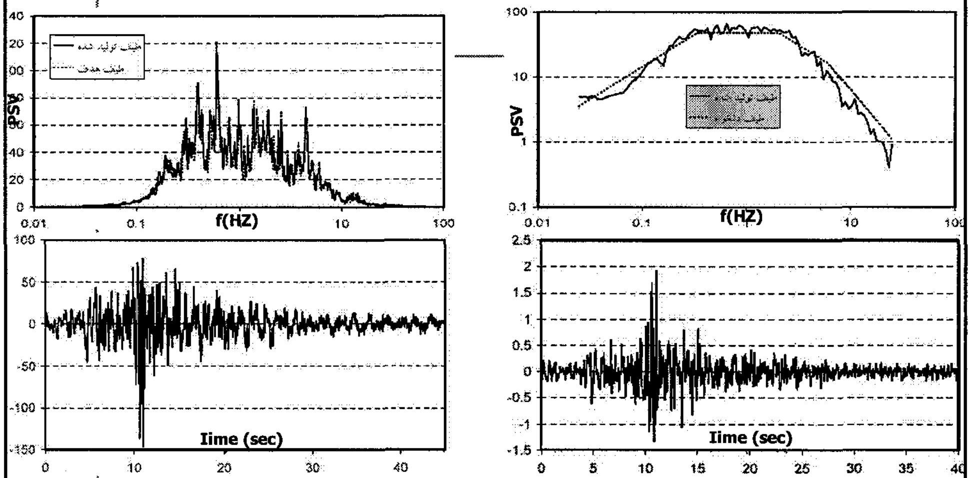
Compatible Earthquake Ground Motion



How these synthesized earthquakes represent the expected event??

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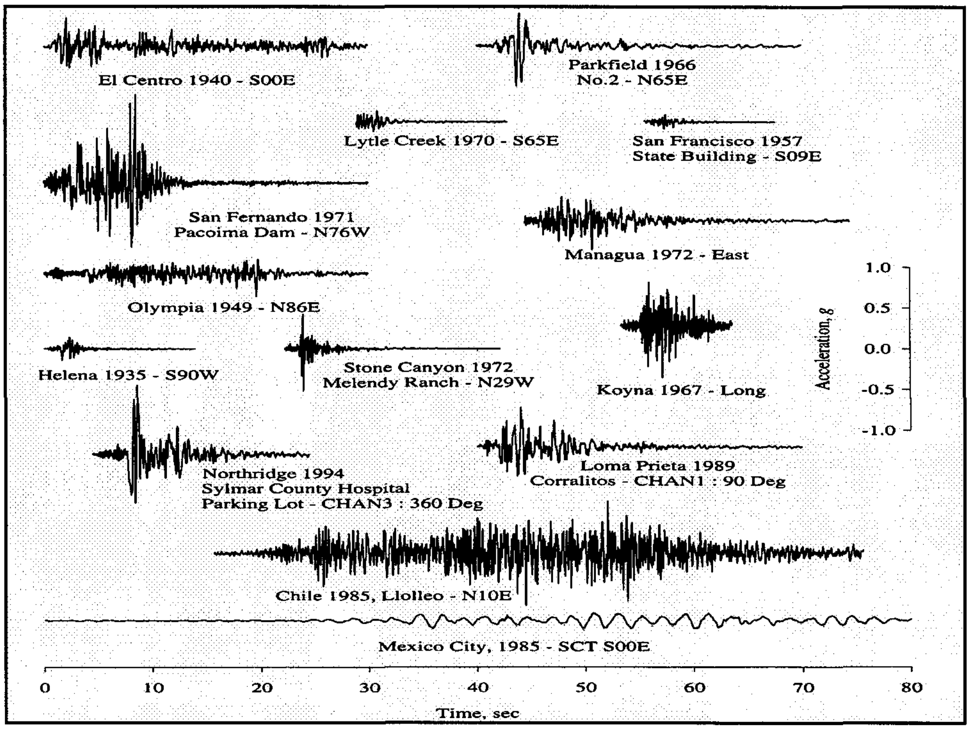

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Engineering Characterization of Ground Motion

Question:

How should the Earthquake Ground Motion be characterized for Engineering Purposes?

Answer:

- Time histories, or Response spectra, of spatially correlated ground acceleration, velocity, displacement at a given site associated with three dimensional wave propagation.
- Time histories of 6 correlated components of ground acceleration and velocity.
- Time histories of 3 components of ground acceleration and velocity.
- Nonlinear Response spectra for specified nonlinear behavior of oscillators of varying initial frequency.
- Linear acceleration, velocity and displacement Response spectra.
- Peak ground acceleration (PGD), PGV, PGD, etc.
- Intensity

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Illustrative Uses of Ground-Motion Characterization

Motion Characterization	Examples of Engineering Use
Spatially Correlated Motion	Analysis of linear systems and long-span structures due to multiple support excitation.
Time Histories	Nonlinear analysis of special structures such as: Earth structures, Dams, System with Soil-structure or Fluid-structure or Equipment-structure interaction, Secondary system,...
Nonlinear Response Spectra	Performance-based design, Fragility curve, ..
Linear Response Spectra	Engineering analysis and design based on modal analysis.
PGA, PGV, PGD, etc.	Simplified analytical methods, Seismic hazard zoning, fixed shape spectra, etc.
Intensity (MMI, MSK)	Estimation of probable maximum losses.

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Reference: Dr. Robert T. Sewell Lecture note on PSHA, May 2001

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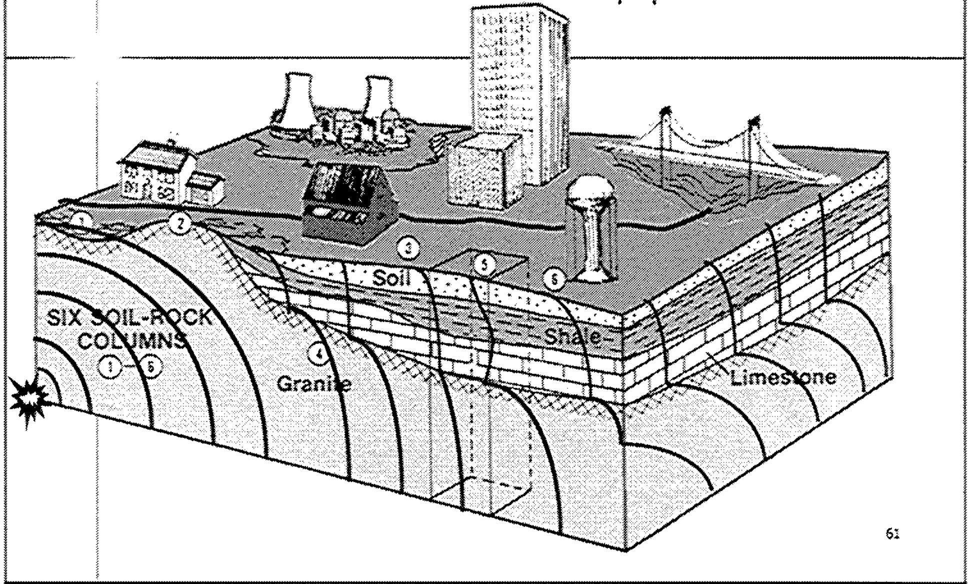
Earthquake Cause and Effect:

Seismic Wave-Soil-Structure-Equipment Interaction



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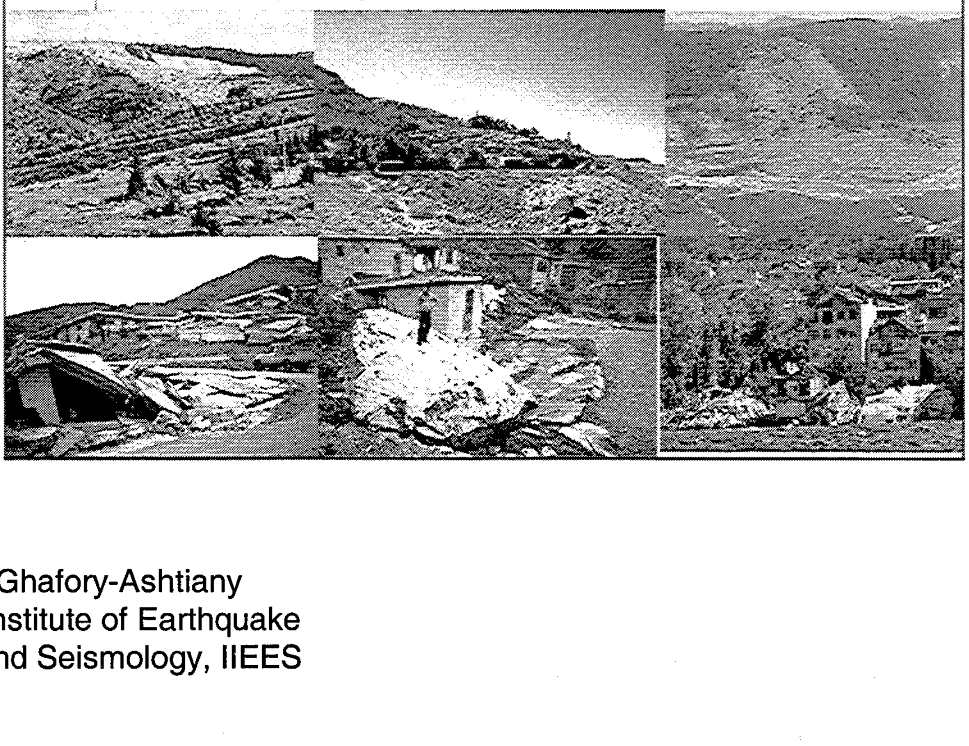
Land Slide

- These are the real consequences and threat that need to be accurately defined and addressed.
- People are not going to give up the good views and nice nature; Thus it requires good and doable solutions.



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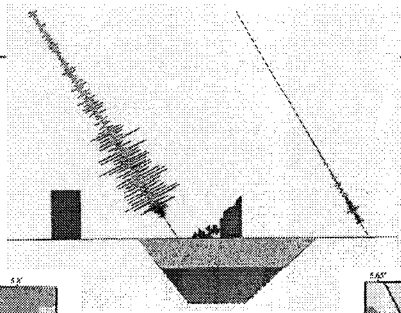
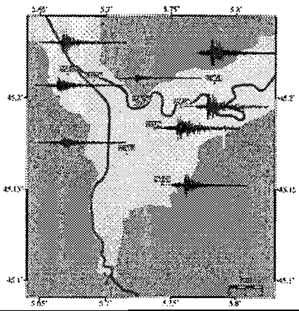
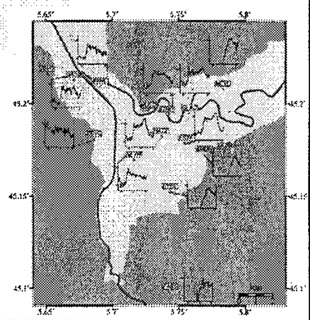
Seismic Wave-Soil Interaction

Most of the studies on soil response are based on Micro-seismic measurement. How these results can be interpreted for large events?



Considering the random nature of earthquake, can we base the expected soil response in a site based on the past earthquake behavior in another location?





Ref. Denis Hatzfeld

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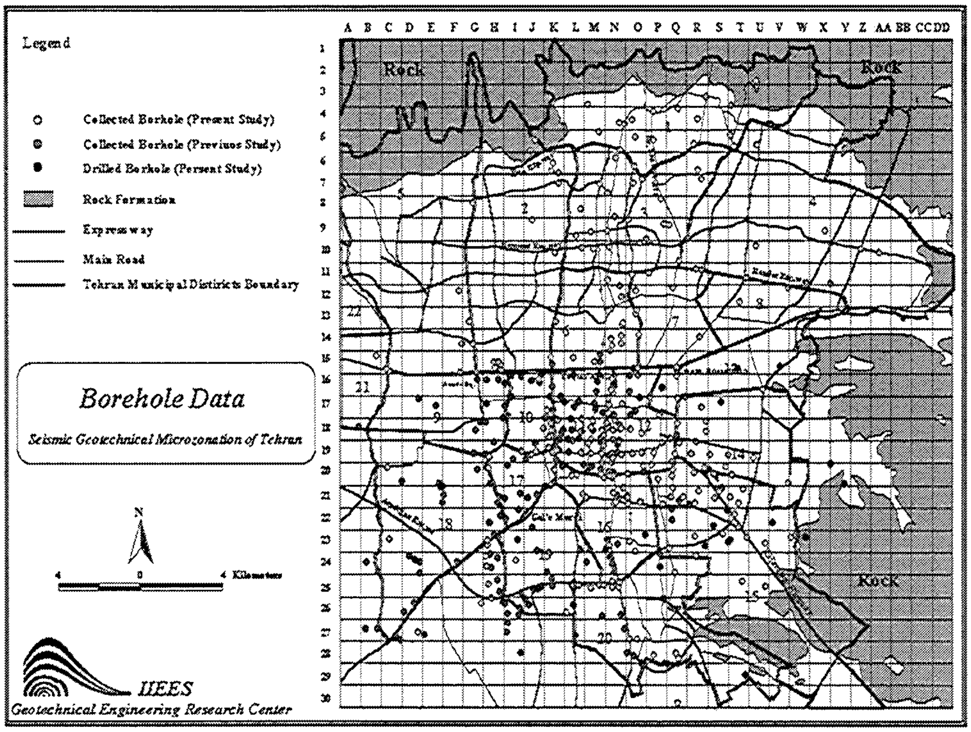

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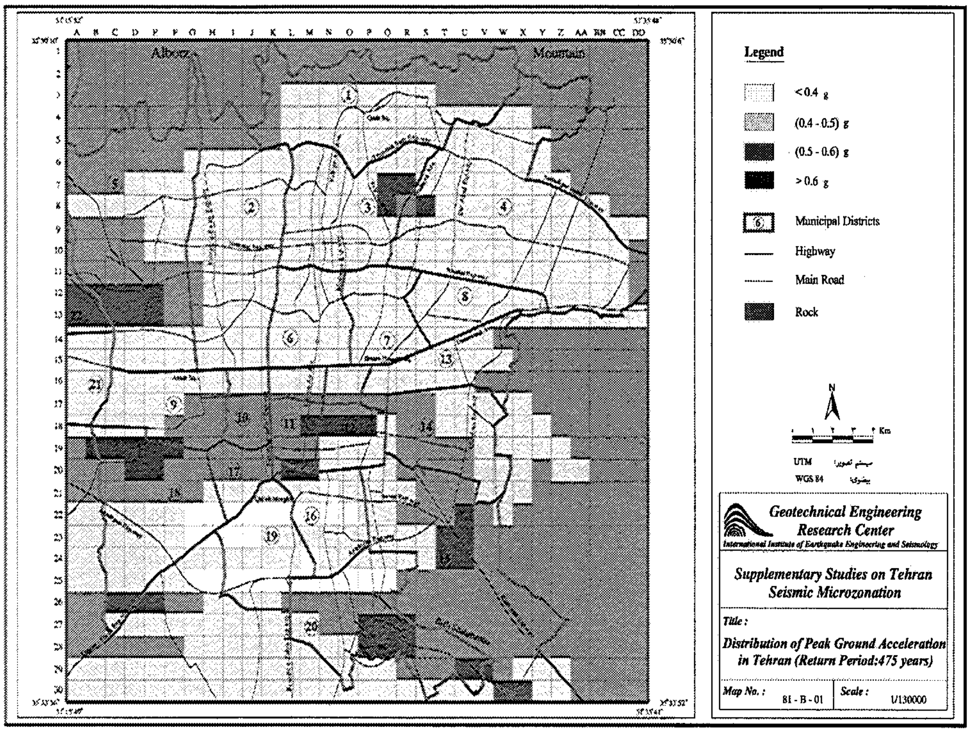
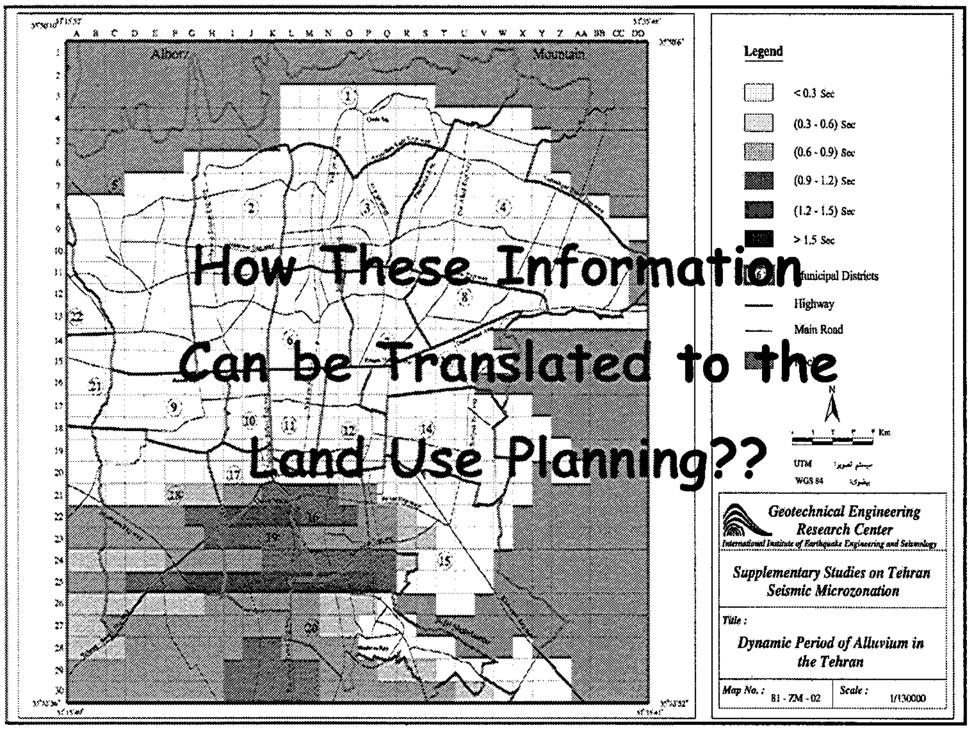

Legend
<0.4 g
(0.4 - 0.5) g
(0.5 - 0.6) g
>0.6 g
Municipal Districts
Highway
Main Road
Rock
Geotechnical Engineering Research Center
Supplementary Studies on Tehran Seismic Microzonation
Title :
Distribution of Peak Ground Acceleration in Tehran (Return Period:475 years)
Map No. : 81 - B - 01
Scale : 1/130000


Legend
<0.3 Sec
(0.3 - 0.6) Sec
(0.6 - 0.9) Sec
(0.9 - 1.2) Sec
(1.2 - 1.5) Sec
>1.5 Sec
Highway
Main Road
How These Information
Can be Translated to the
Land Use Planning??
Geotechnical Engineering Research Center
Supplementary Studies on Tehran Seismic Microzonation
Title :
Dynamic Period of Alluvium in the Tehran
Map No. : 81 - ZM - 02
Scale : 1/130000

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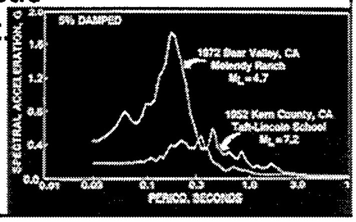
Geotechnical consideration (Seismic Wave-Soil Interaction)

- Low risk construction and development require adequate and seismically compatible and sound land use planning.
- Good land use planning require reliable definition and description of expected earthquake ground motion.
- Good land use planning should include the effect of topography, soil layers, nonlinear dynamic behavior of soil, etc.
- Design ground motion characteristic such as time history, spectra, etc. should reliably considers the effect of soil.



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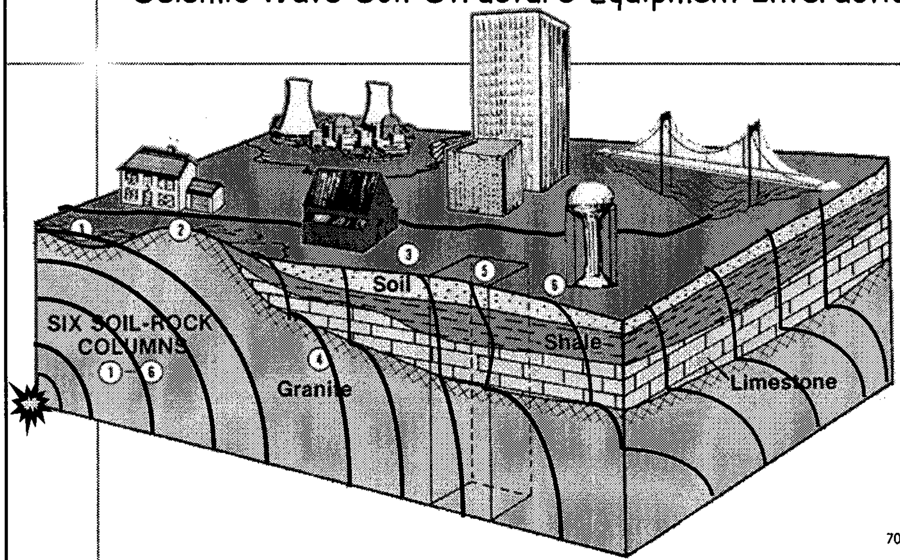
Earthquake Cause and Effect:

Seismic Wave-Soil-Structure-Equipment Interaction



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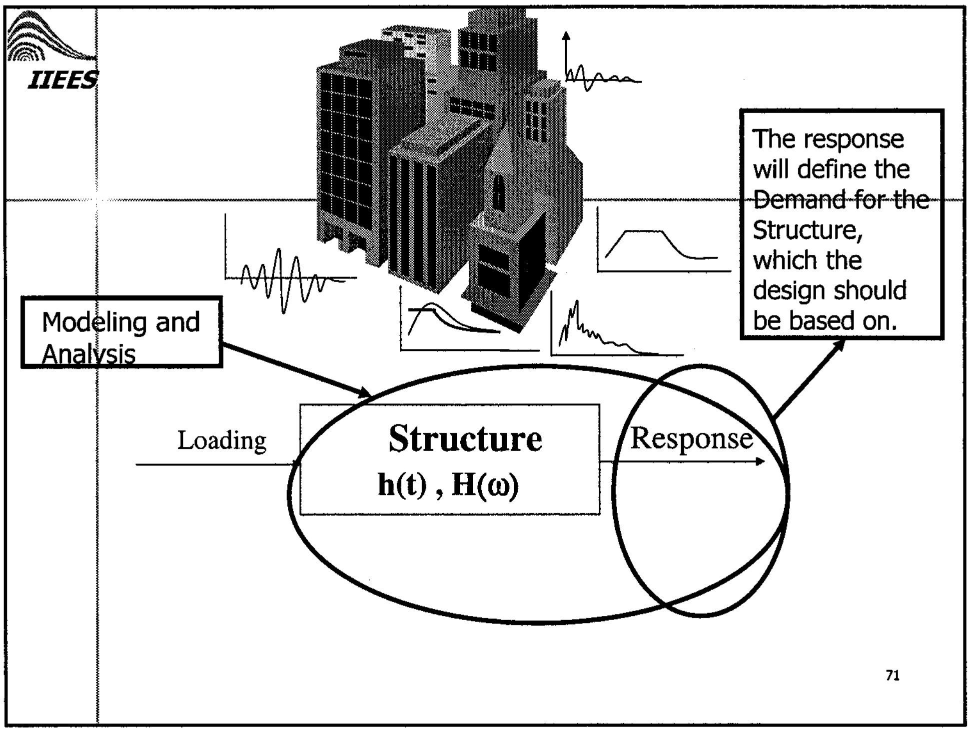

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Performance Base Design and Construction

DEMAND < CAPACITY

DEMAND:

- Ground Motion Input has been increased by the increase of knowledge
- Owner or Code Expectation has been increased in recent years

The demands are keep increasing, specially after each large earthquake, without engineering and socio-economical consideration

CAPACITY:

- **Good Site Selection**
- **Good Architectural Design**
- **Good Structural Design**
- **Good Material**
- **Good Construction**
- **Good Supervision**
- **Good Maintenance & Repair**
- **Good Management**
- **Good Financial Condition**

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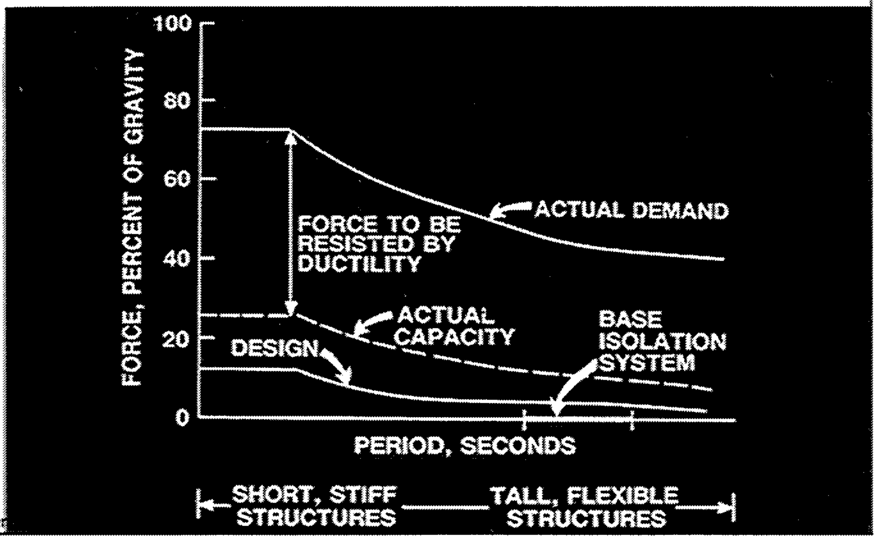
Today's Structural Design Concepts



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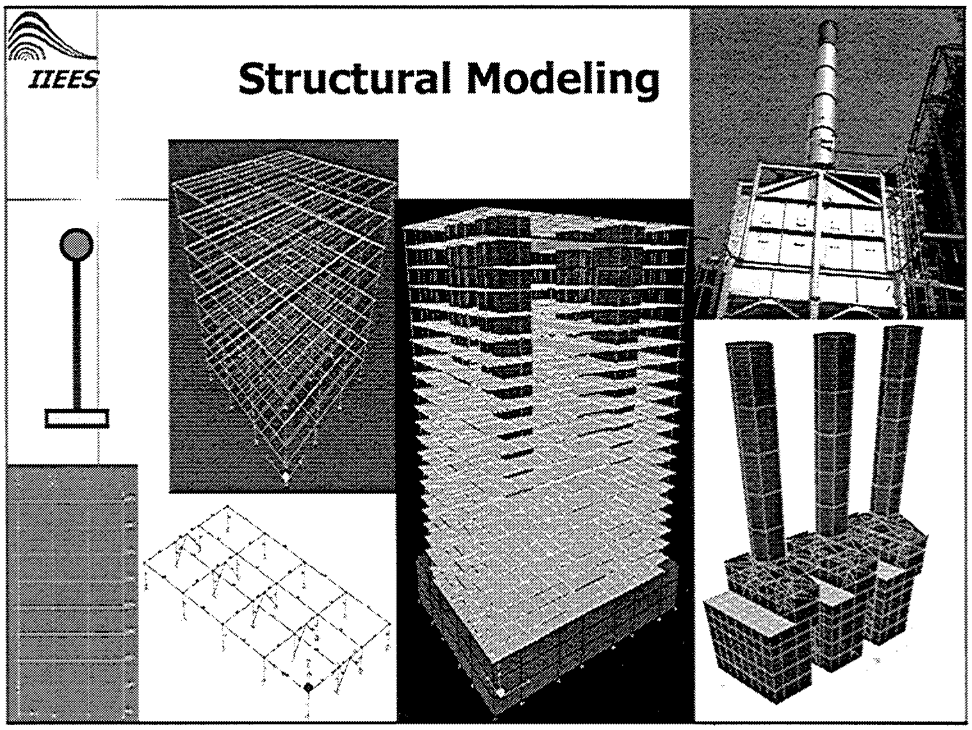
Structural Modeling



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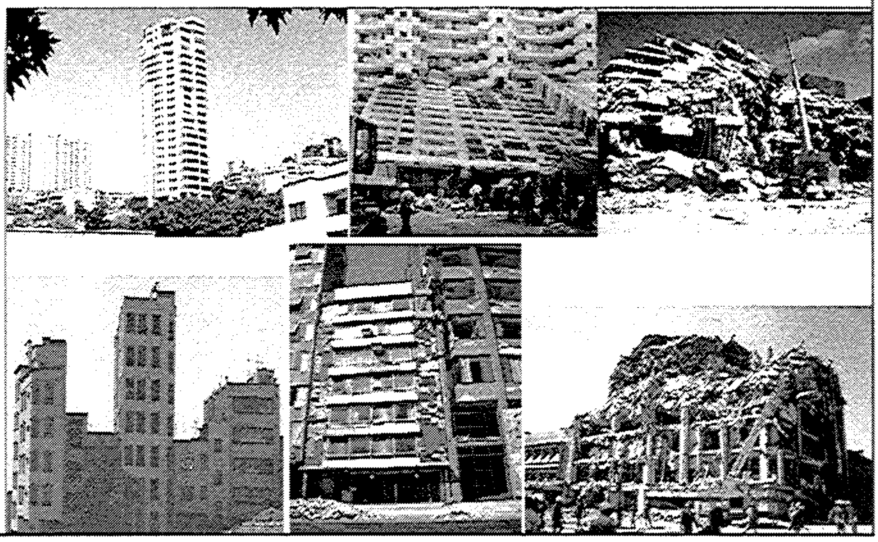
This what had happened and will Happen!



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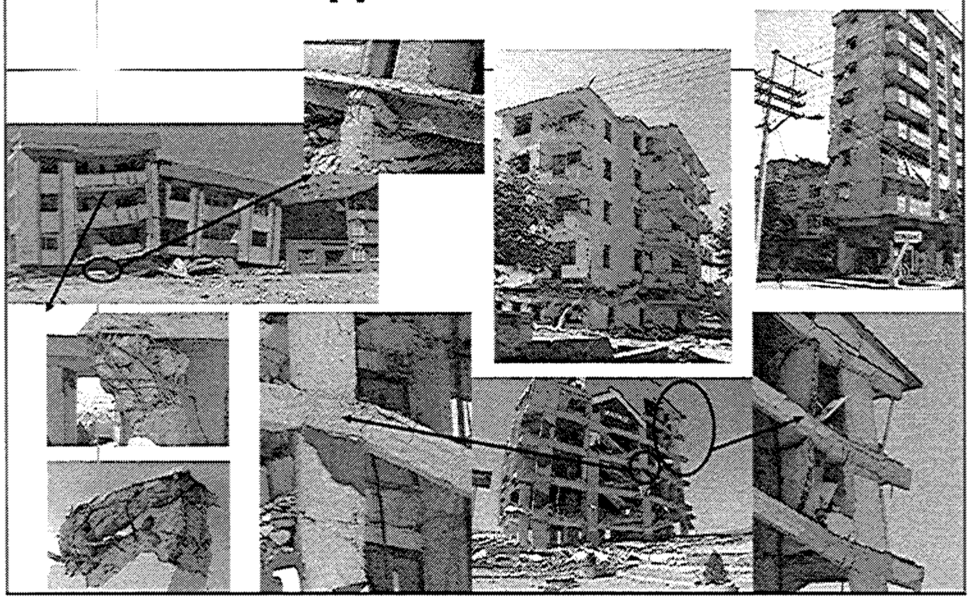
This what had happened and will Happen!



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Possible Comments after Each Strong Earthquake:

- It was a surprising earthquake in sense of...
- The fault was not mapped before, The ground motion characteristics was different, etc. and they were not expected.
- Soil behavior and soil-structure interaction was different than it was expected.
- Failures are due to poor design and construction.
- Most of the problems are due to ignorance of the ABC's of engineering principal, Thus more code reinforcement is required.
- More research and funds are required.
- Codes need to be modified in order to take into consideration of......

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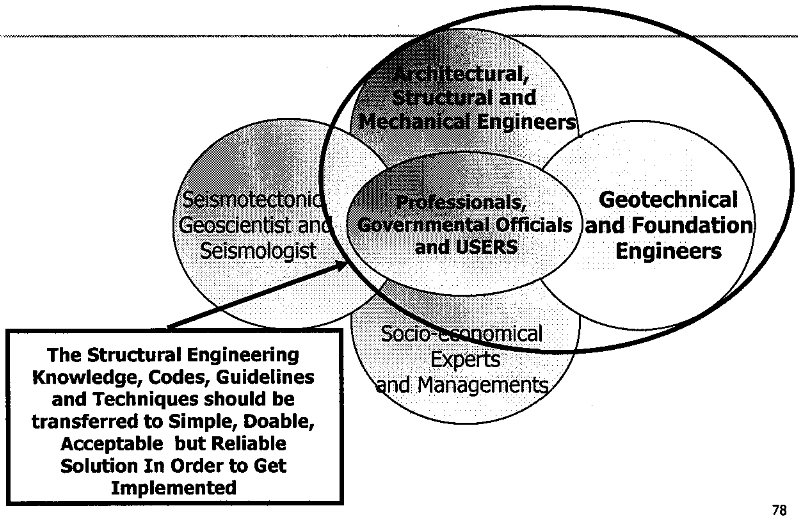
STRATEGIC GOALS:

WORKING TOGETHER TO ACHIEVE THE RISK REDUCTION OBJECTIVES



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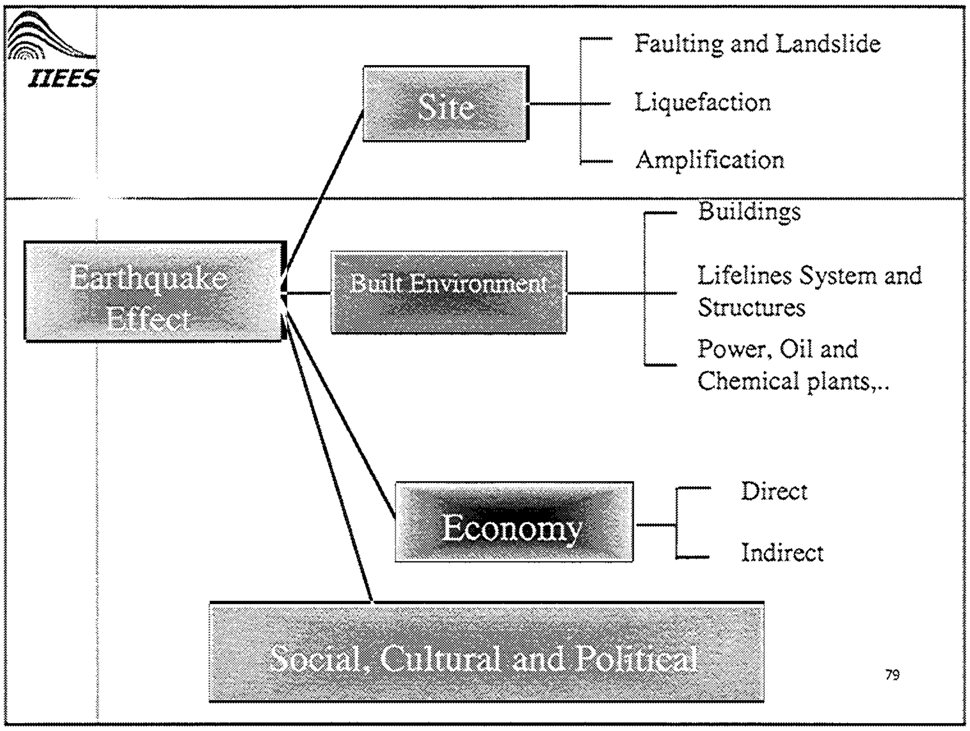

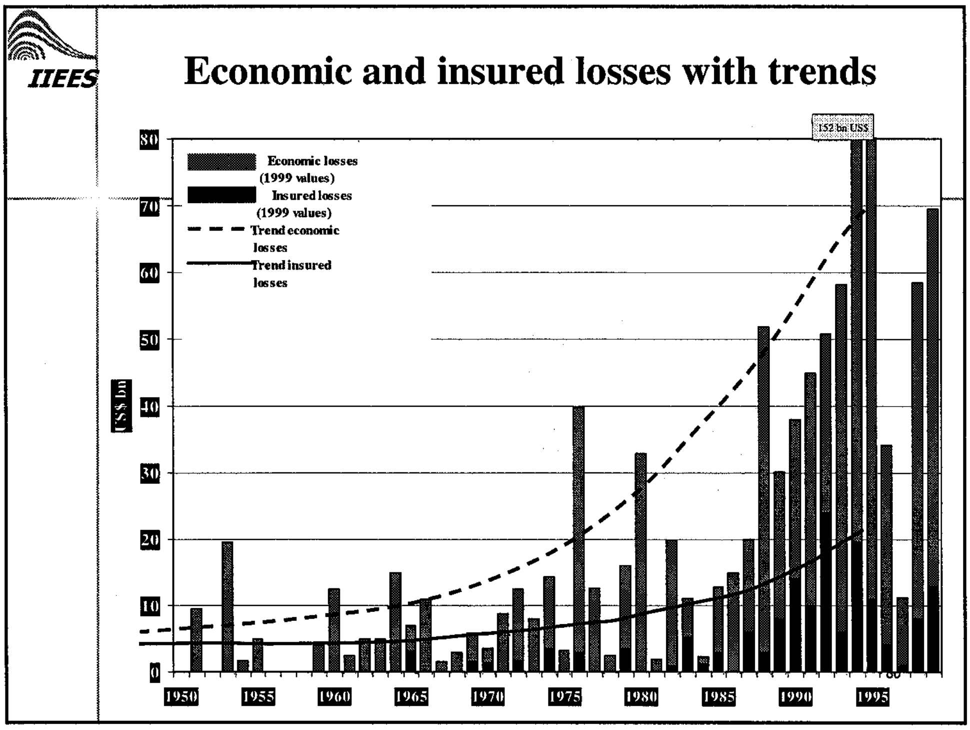

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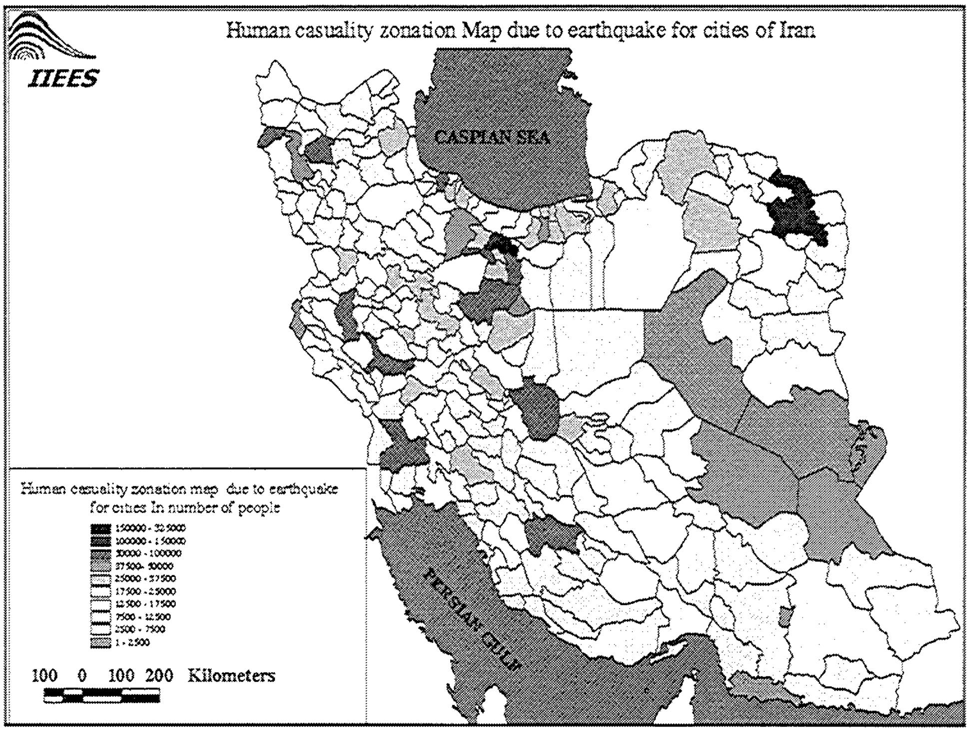

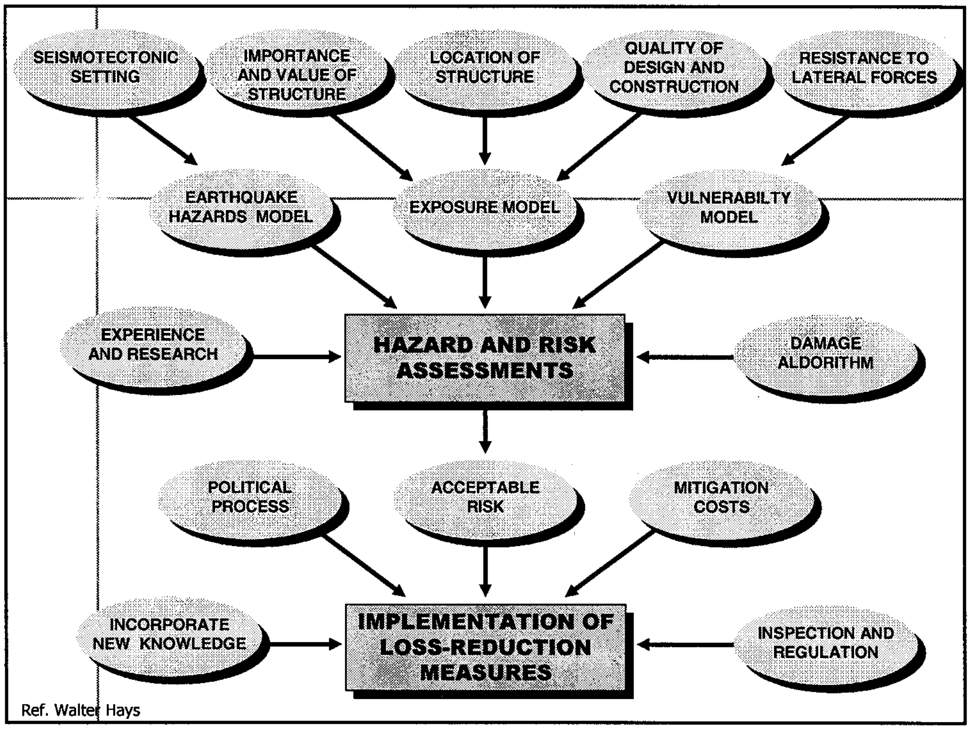

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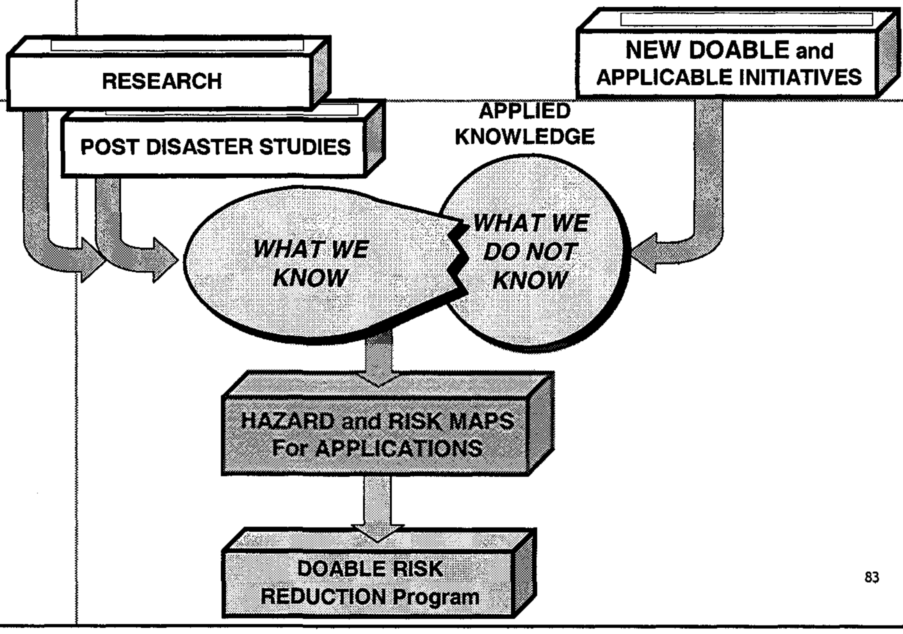
INTEGRATED KNOWLEDGE ACQUISITION



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CONCLUSION:

There is an urgent need to coordinate the acquisition, processing, synthesizing the research results, knowledge available and lessons learned from the past earthquakes and converted into

"Hazard and Risk Information Map"

for Development and Implementation of

"Doable RISK REDUCTION Program"

For

Safe Environment and Sustainable Development

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