Seismic Risk Assessment of Heraklion city & Relevant Seismic Scenarios

C. Gountromichou, Geologist MSc, PM

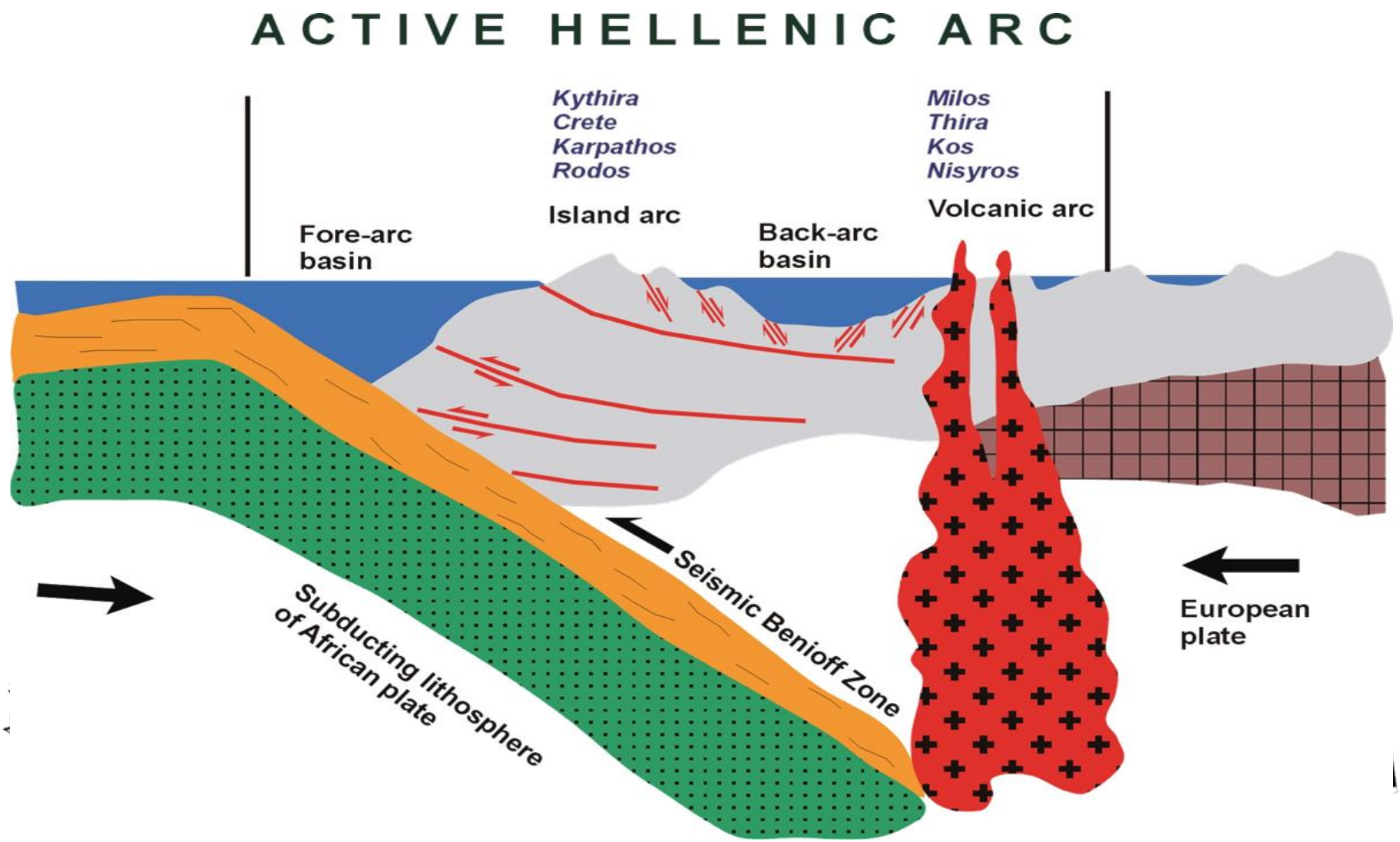
Head of Emergency Planning – Prevention Dept.,

D. Kazantzidou-Firtinidou, Earthquake Engineer MSc

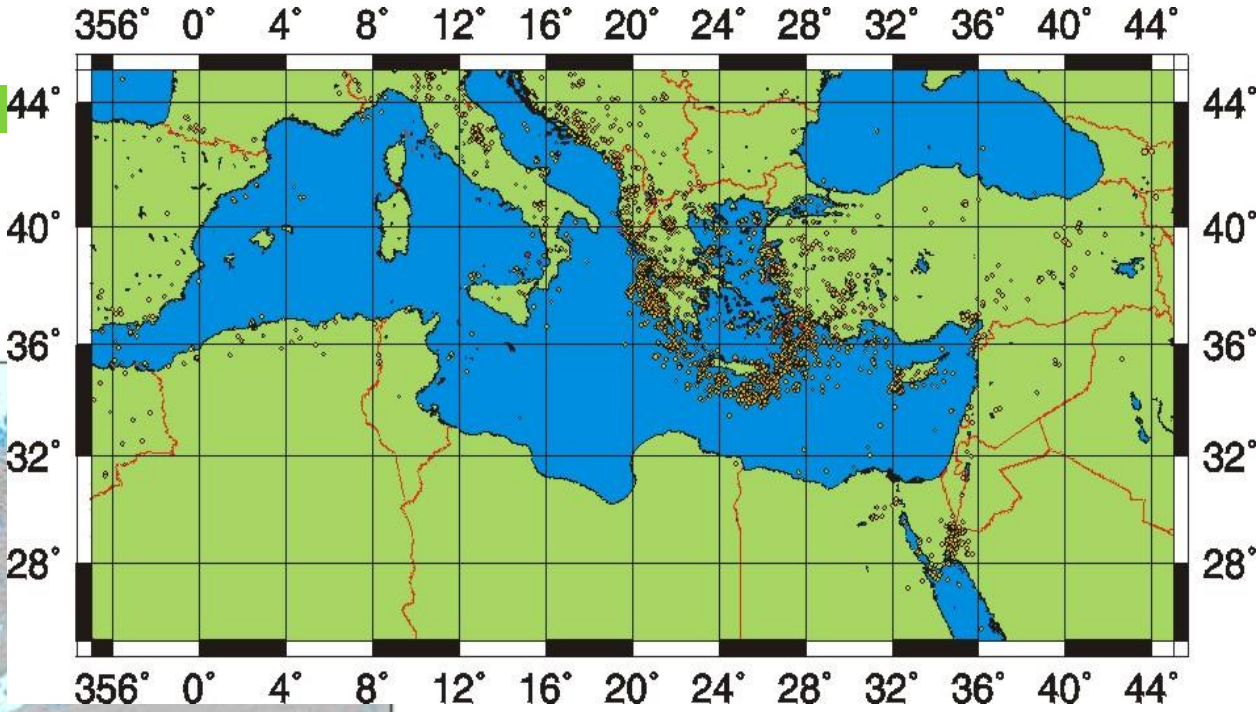
J. Delakouridis, Geologist, MSc in Natural Disasters

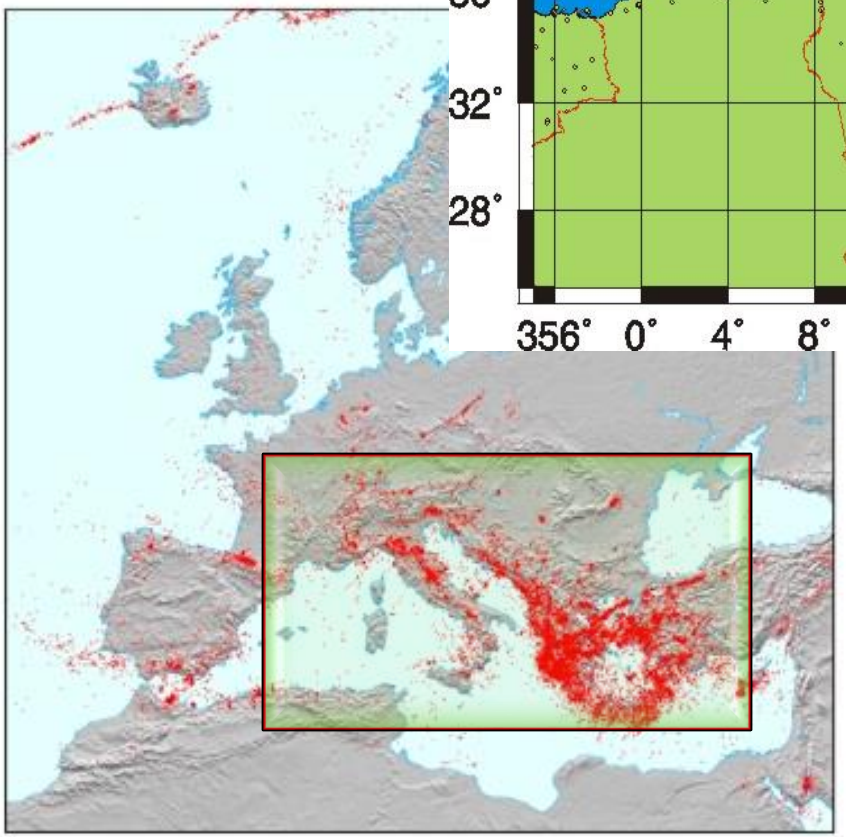
EARTHQUAKE PLANNING AND PROTECTION ORGANIZATION (E.P.P.O.)

Geodynamic Setting of Greece - Subduction



Seismicity of Southern-Eastern Part of Europe

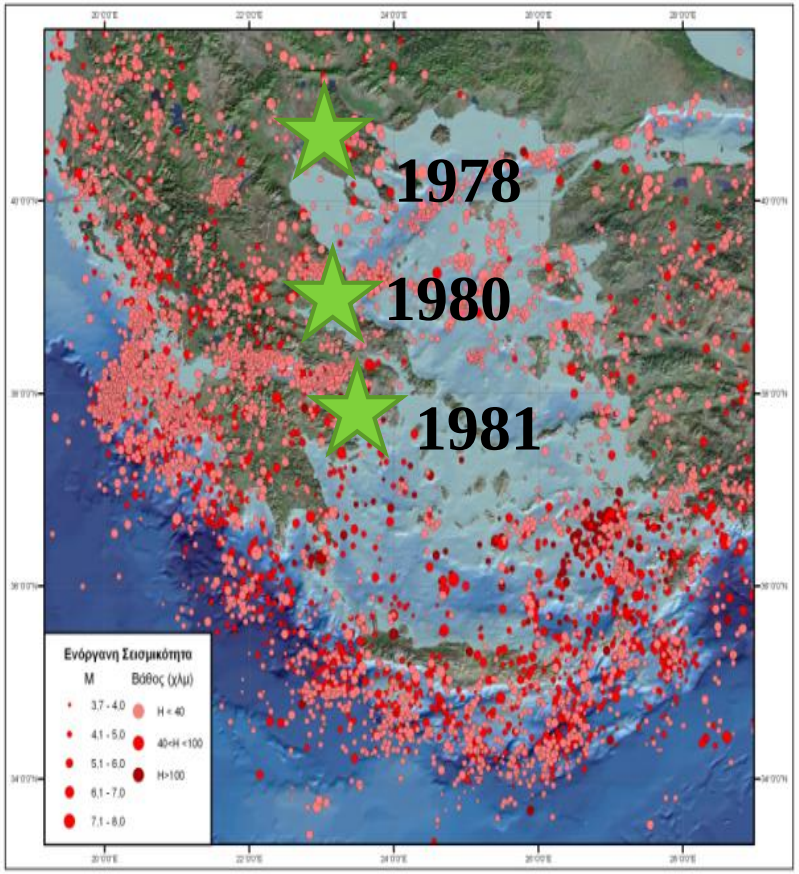




Seismic activity of the European-Mediterranean region in the 1973-2002 period with magnitude $m_b > 3.0$, from the USGS/NEIC PDE Catalogue.

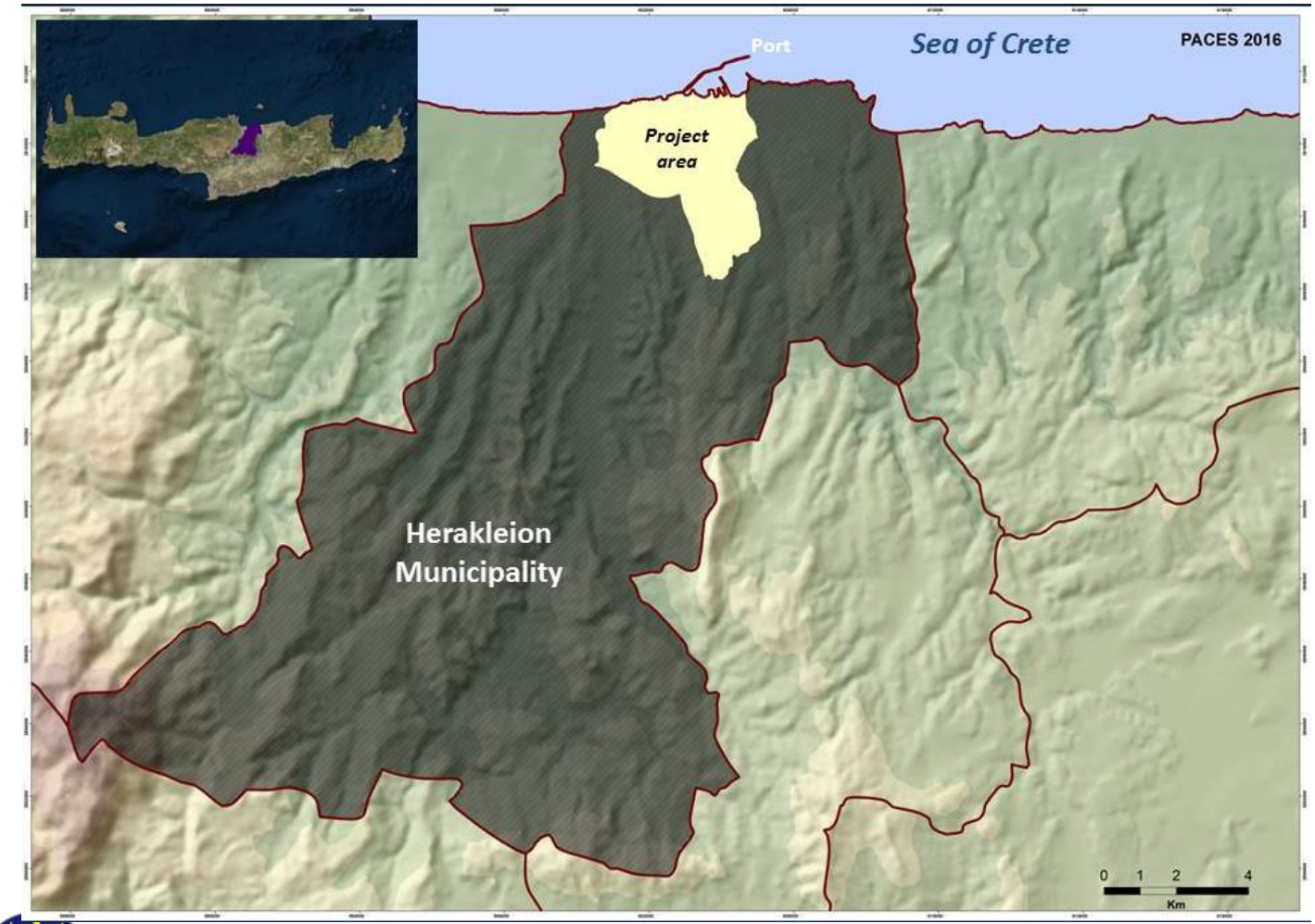
Earthquake Planning and Protection Organization (E.P.P.O.)

- Is a Legal Entity of Public Law and operates under the supervision of the **Hellenic Ministry of Infrastructure, Transport and Networks**
- Was founded in **1983**, as **the responsible authority for planning and processing the earthquake policy in Greece** - as well as to coordinate the public and private resources for the implementation of this policy

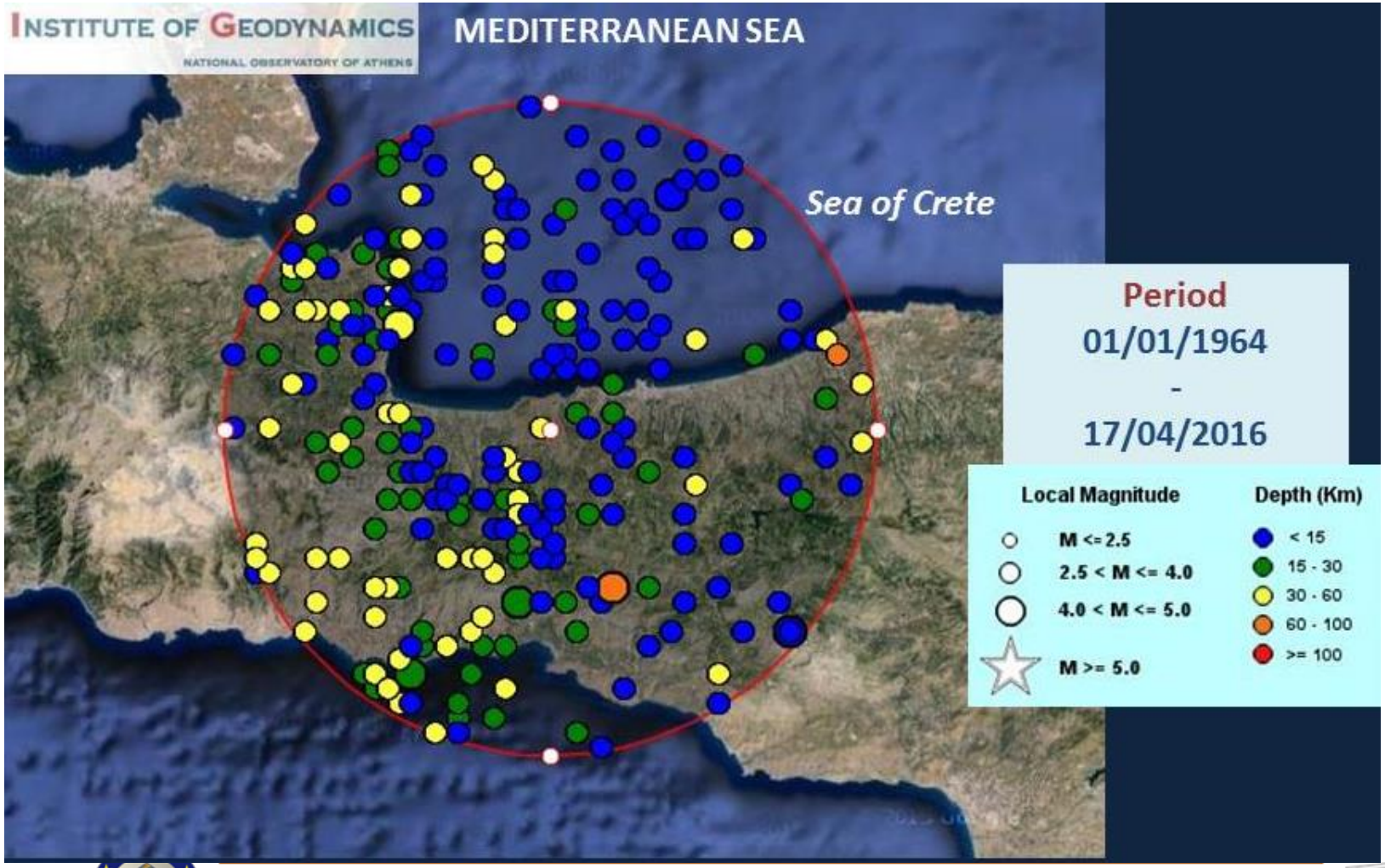


Seismicity of Greece (1900-2007)

Seismic Risk Assessment in Heraklion city



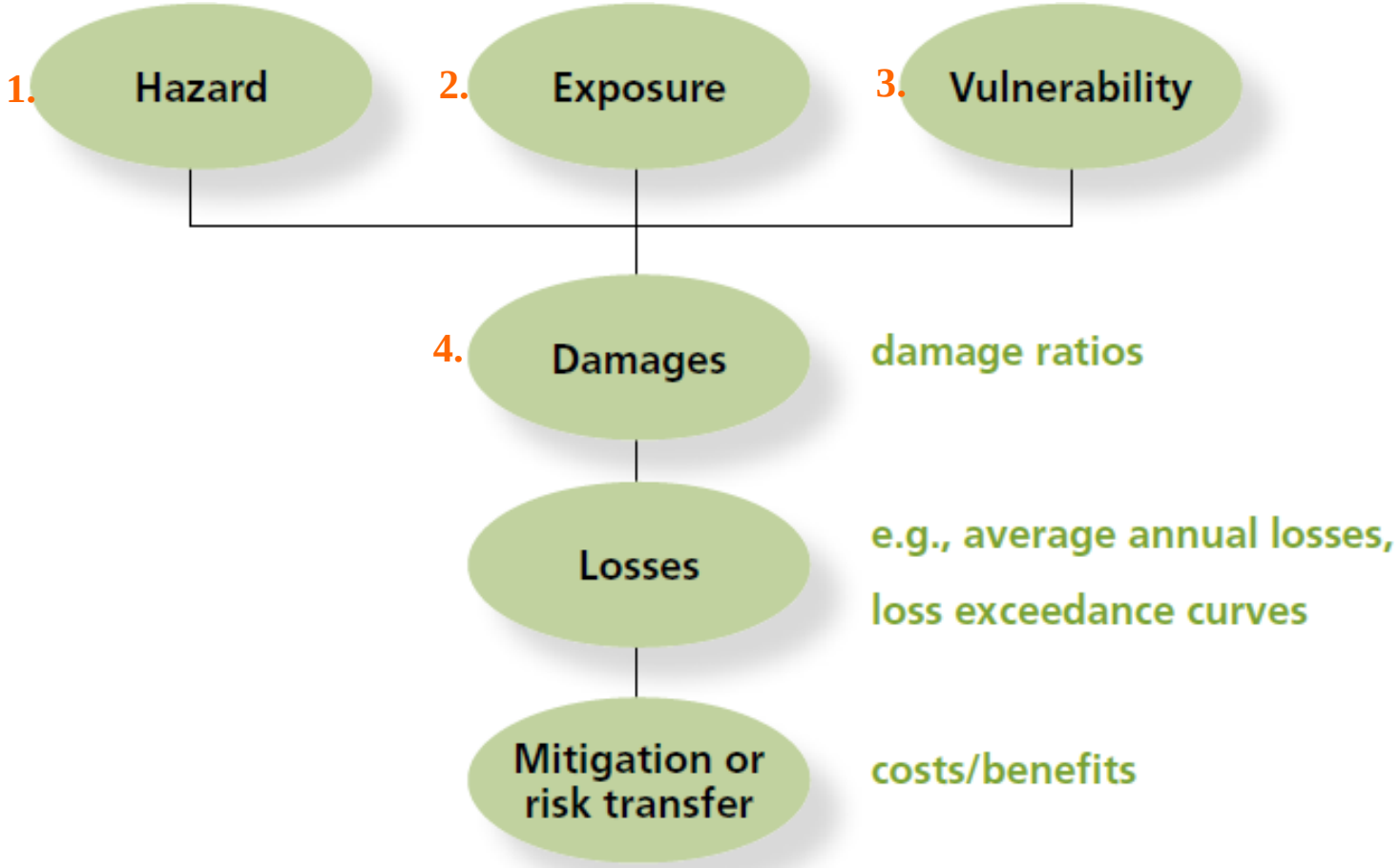
Seismicity in Heraklion city



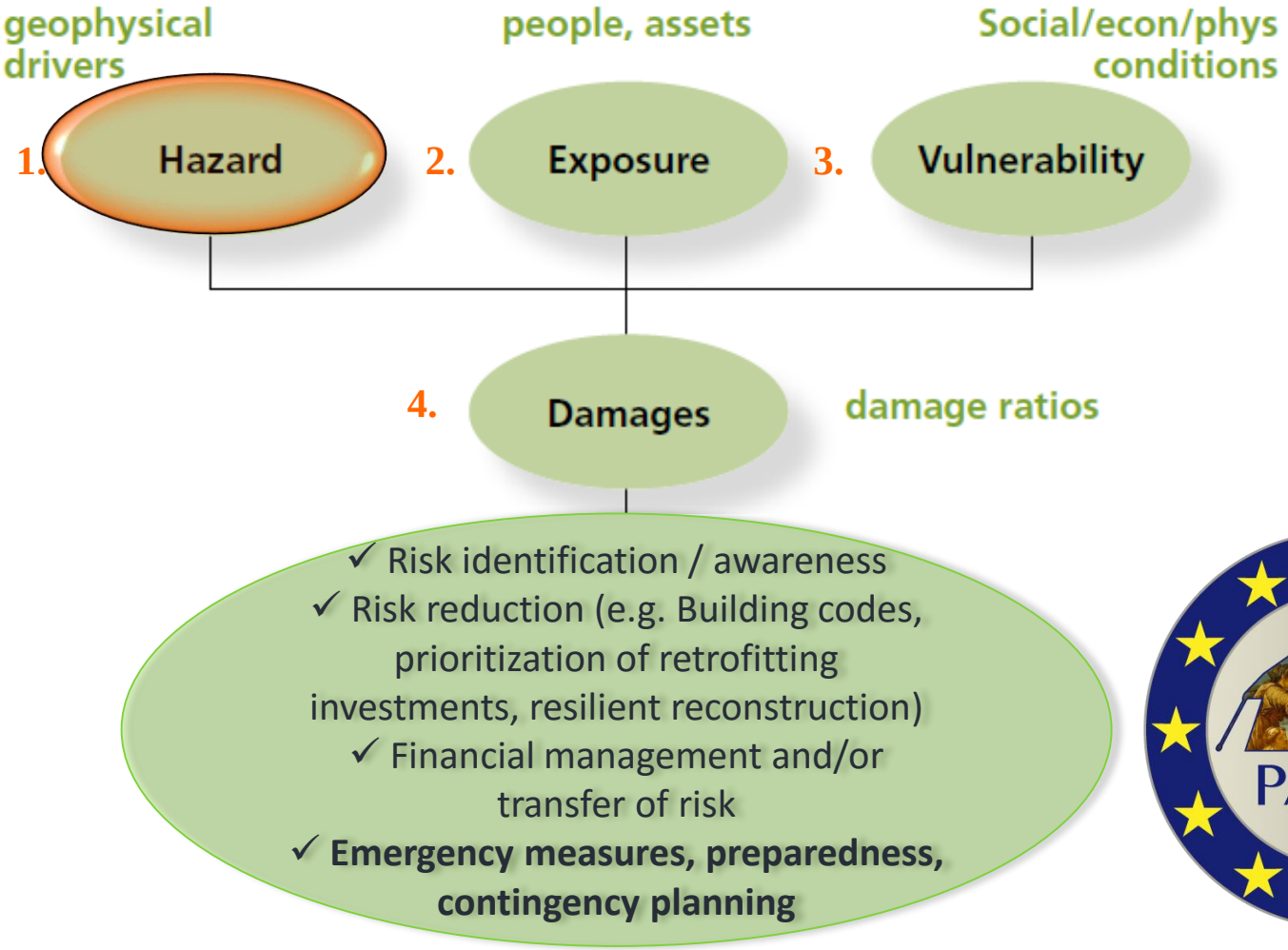
Data used for this study

- Geographic Military Service
  - Topographic map – 1:50.000, DEM - Slope map, Hill shade
- Herakleio municipality
  - Microzonation study (1998) – scale 1:10000
    - Geological map of Herakleio city
    - Neotectonic map
- Hellenic Centre for Marine Research (HCMR)
  - Submarine fault map
- Hellenic Statistic al Authority (EL.STAT.)
  - Population data (Census 2011)
- EPANTYK 2009, Census 2001
  - Building stock data
  - Digital maps
- "ASPIDA PROJECT"
  - Fault map

Seismic Risk Assessment in Heraklion city



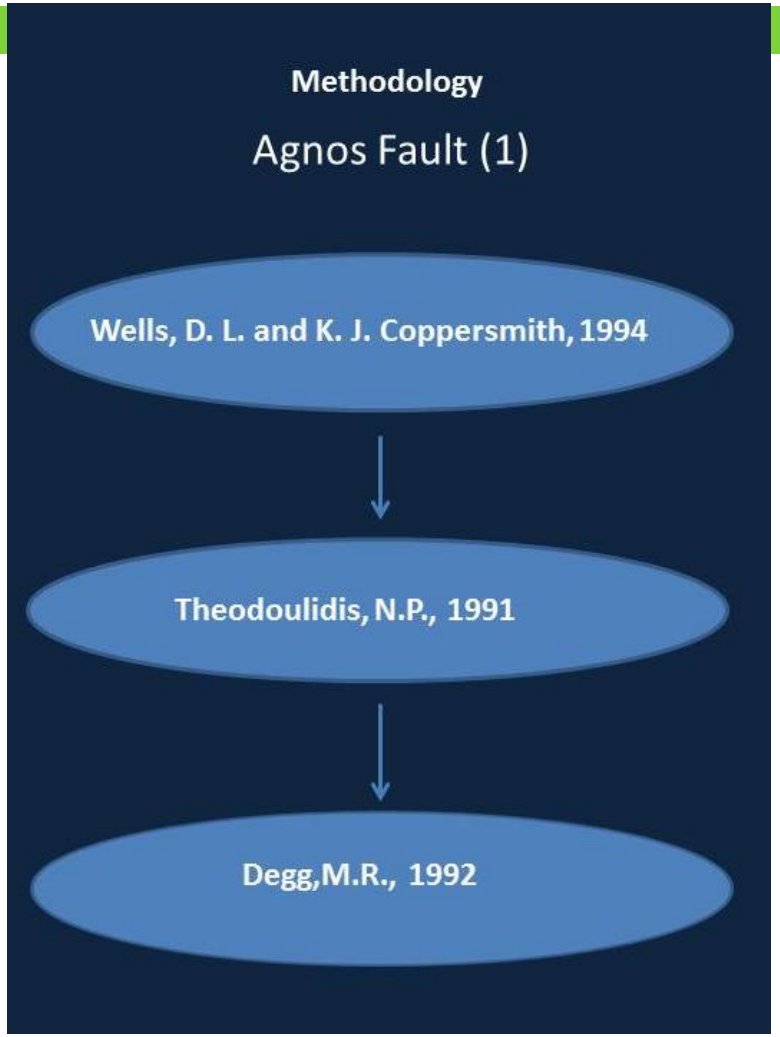
Seismic Disaster Risk Assessment



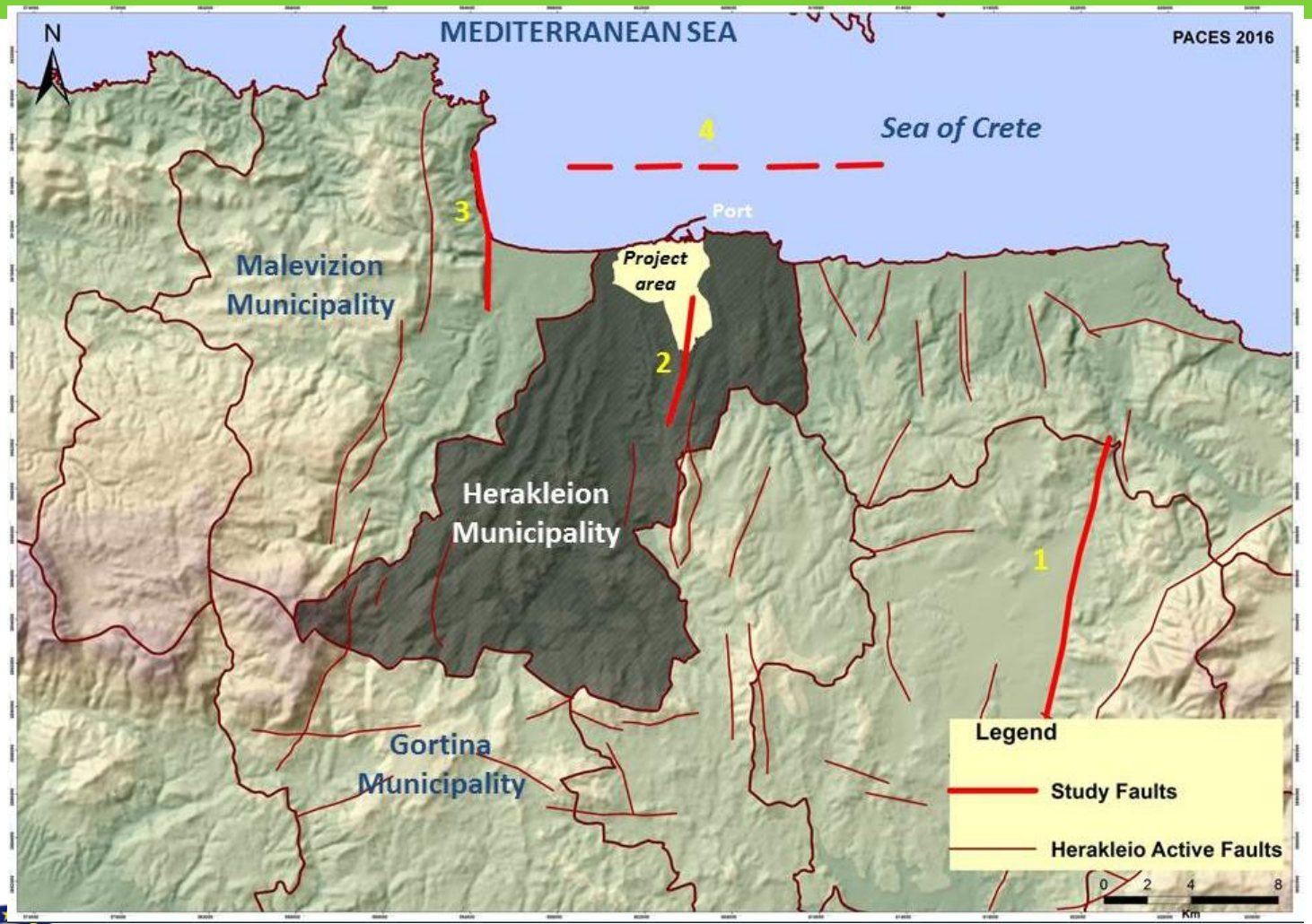
Deterministic seismic hazard assessment

- Stages followed:

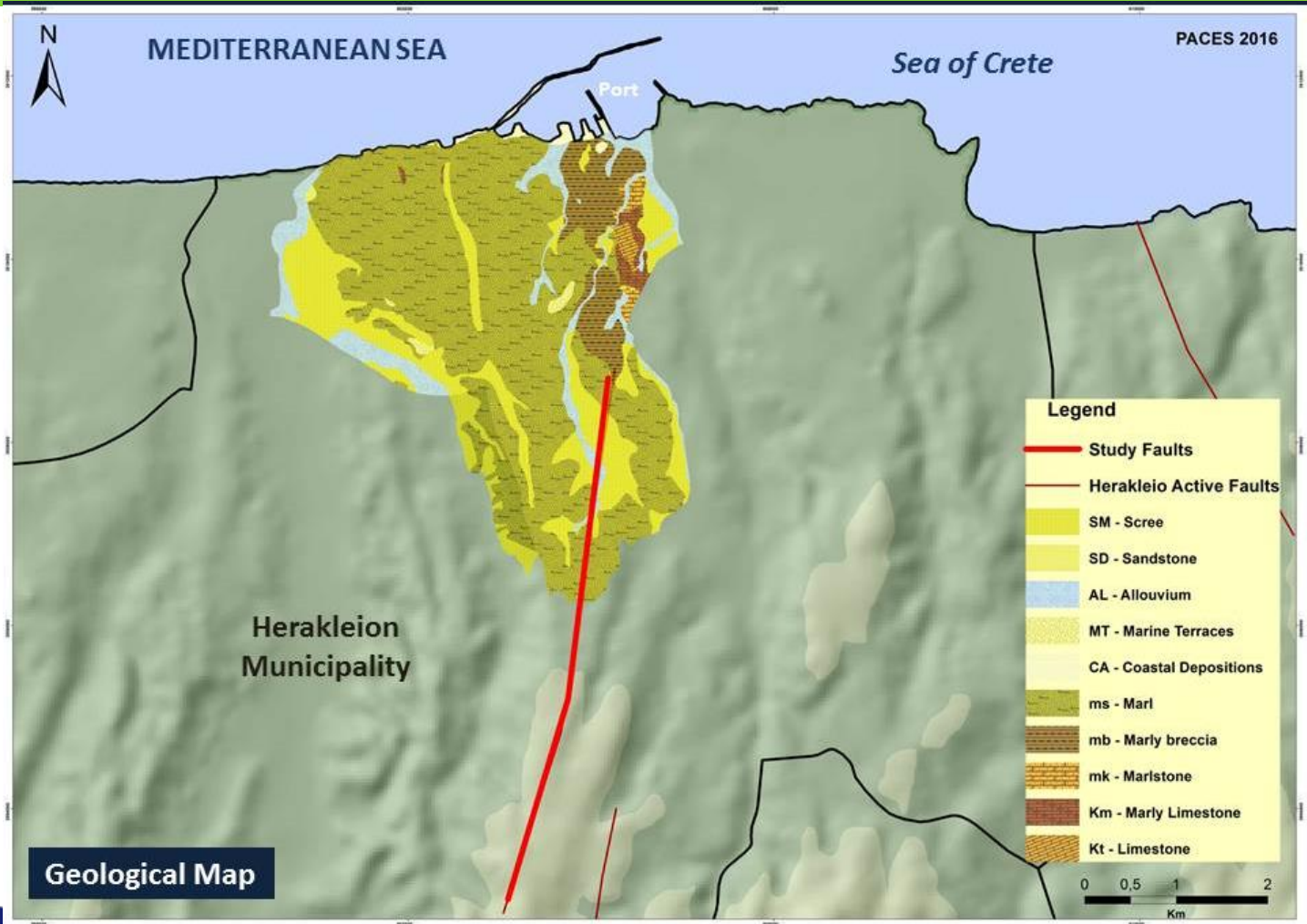
1. Identification of the nearest active faults **(Microzonation study)**
2. Calculation of the largest earthquake that could happen on this fault and the expected intensity **(Wells, D. L. and K. J. Coppersmith, 1994)**
3. Estimation of the distance of attenuation of the strong ground motion **(Theodoulidis, N.P., 1991)**
4. Calculation of **increase or decrease of the expected seismic intensity** among different rock categories **(Degg, M.R., 1992)**



Active Faults in the broader area of Heraklion city

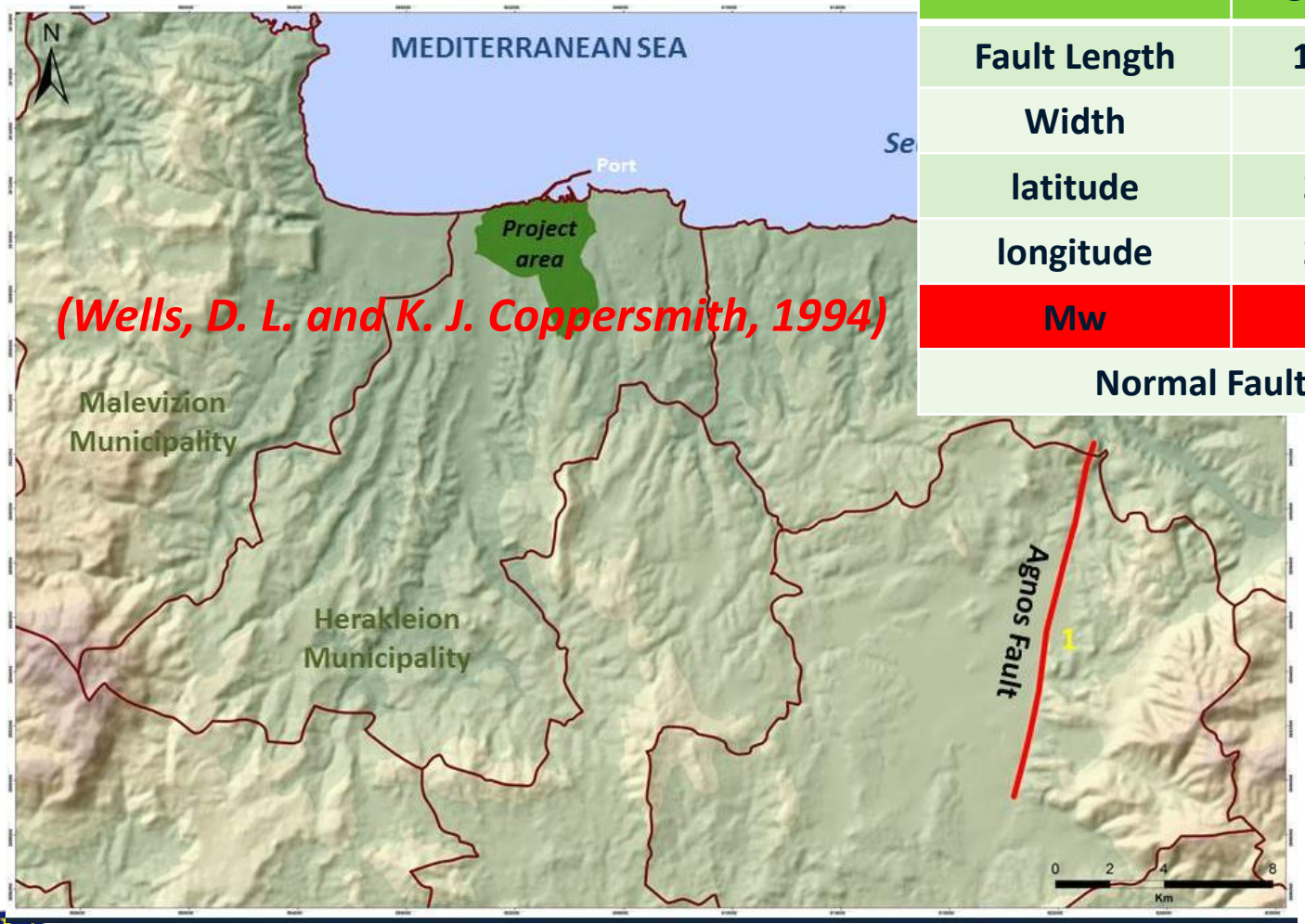


Geological & active fault map of the Study area

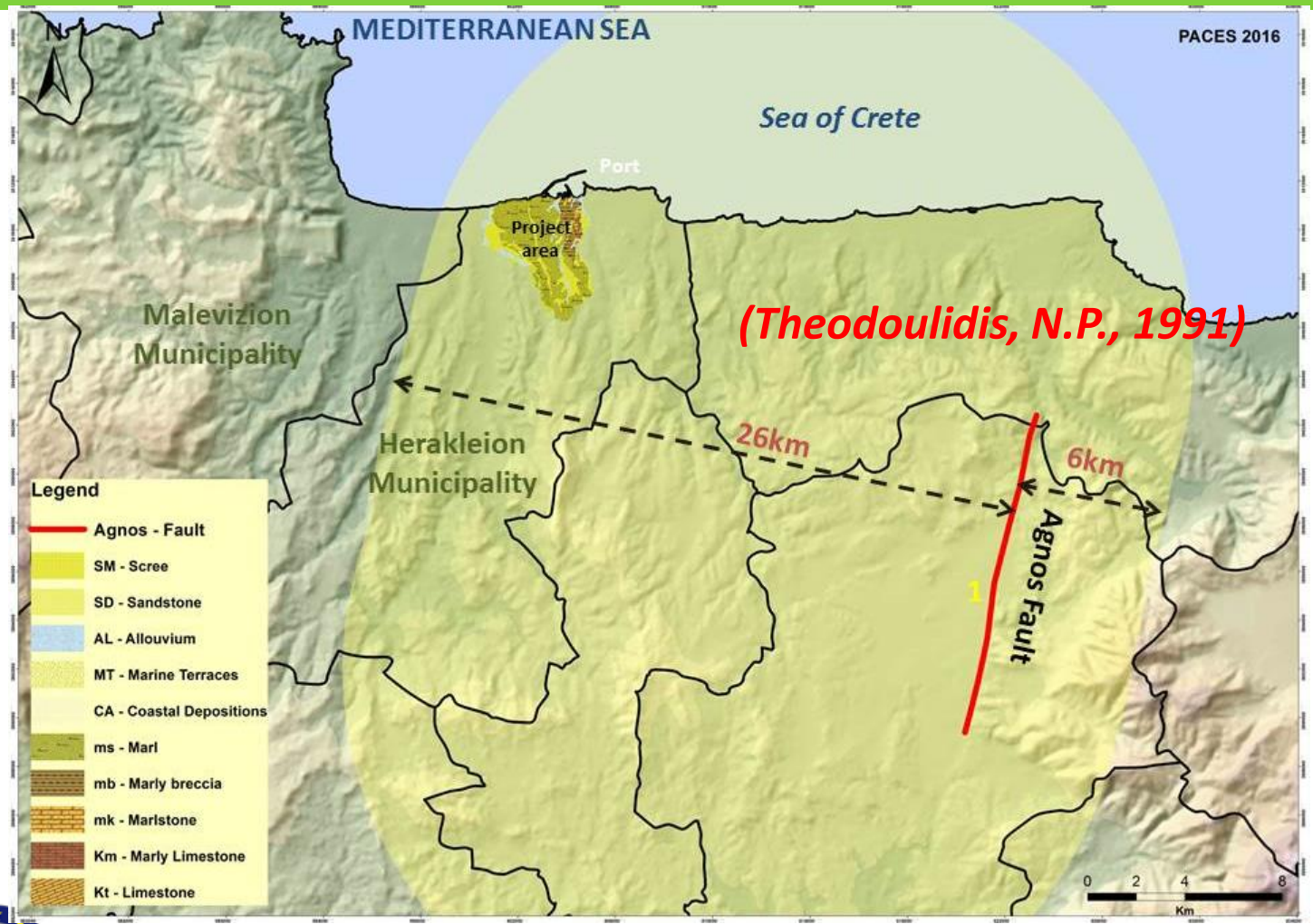


Agnos Fault – hazard assessment methodology

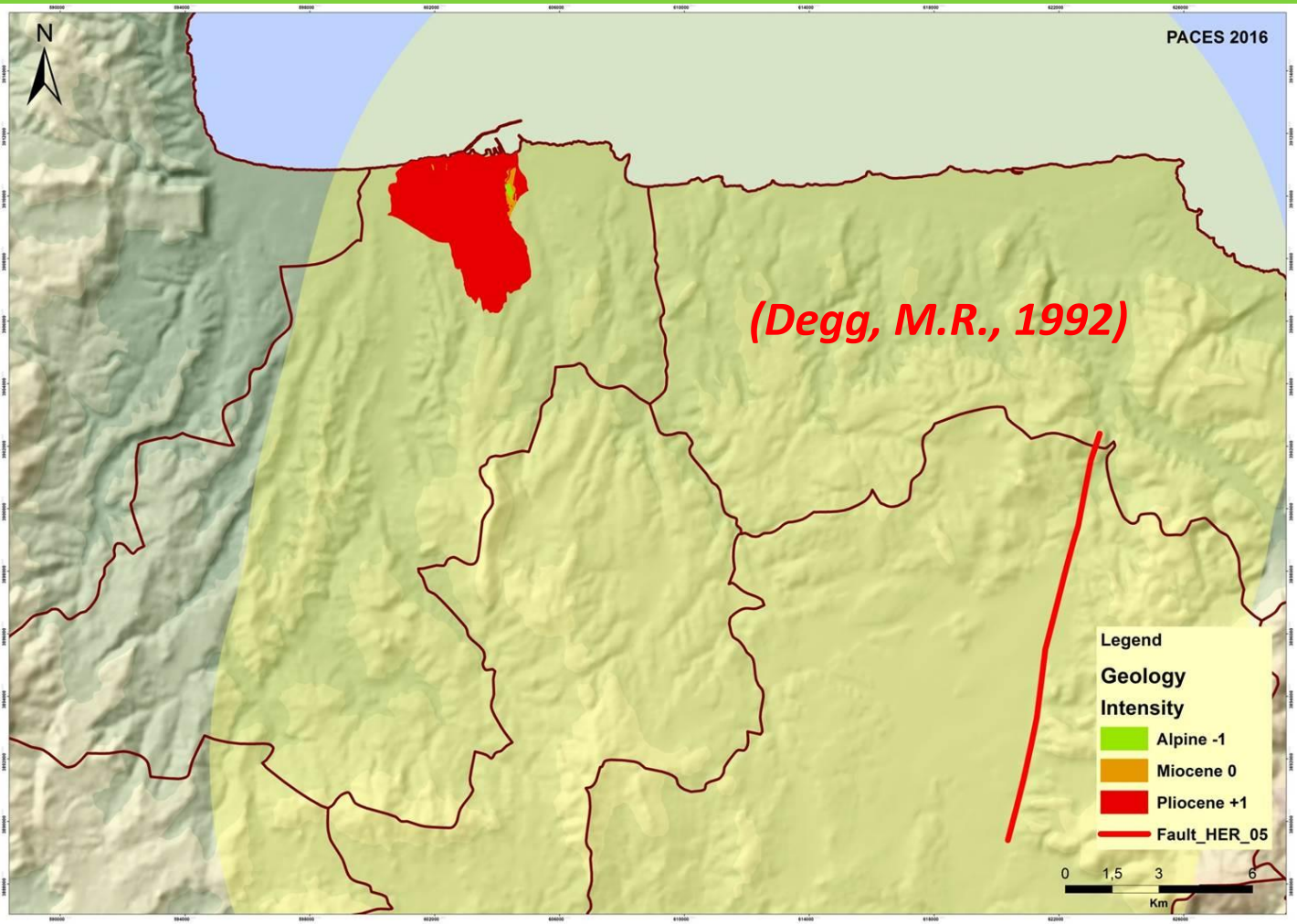
Tectonic Feature	Agnos Fault
Fault Length	13.3 km
Width	10km
latitude	35.14*
longitude	25.14*
Mw	6.3
Normal Fault	



Agnos Fault – hazard assessment methodology

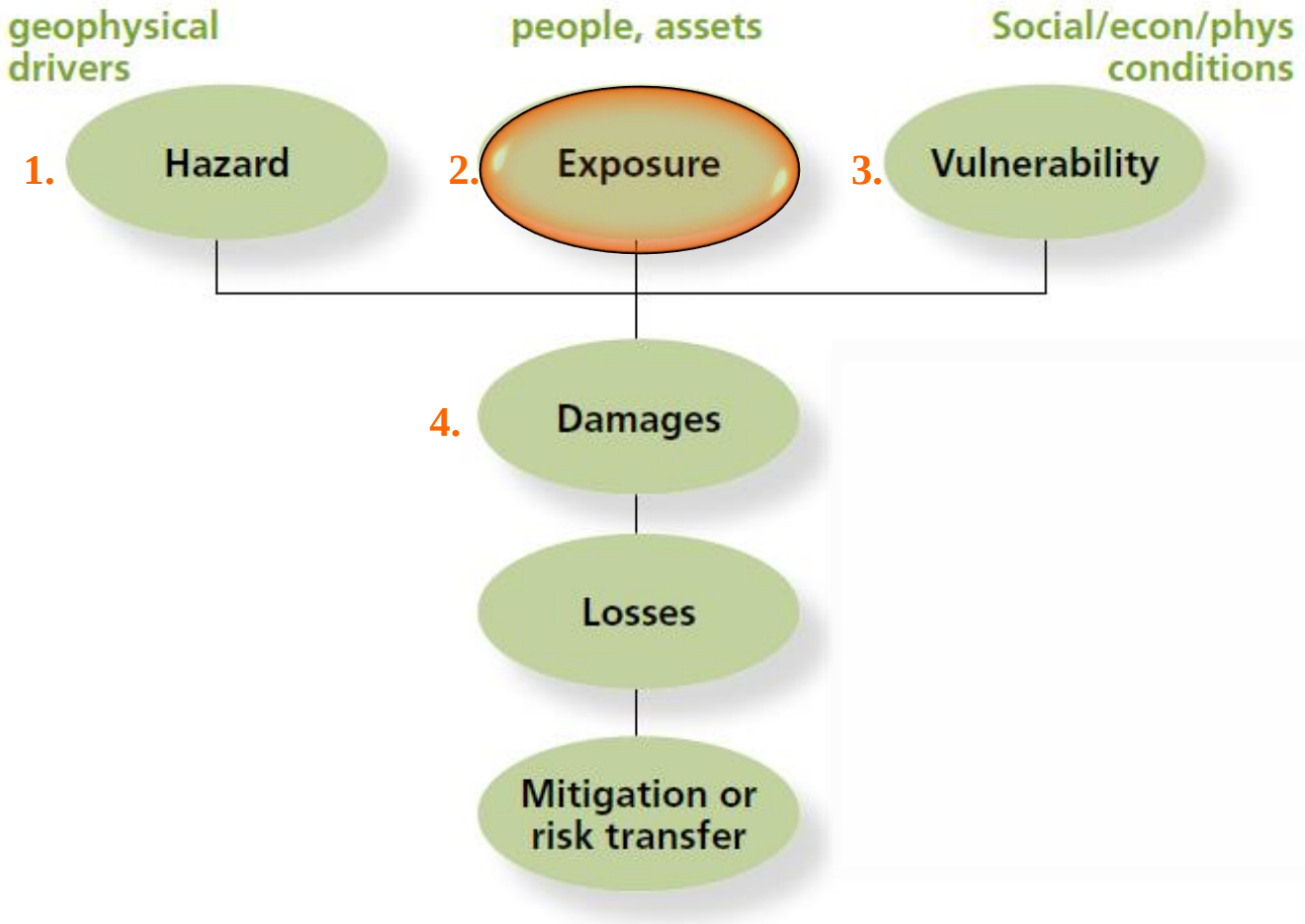


Agnos Fault – hazard assessment methodology



Agnos Fault – hazard assessment methodology

Seismic Disaster Risk Assessment



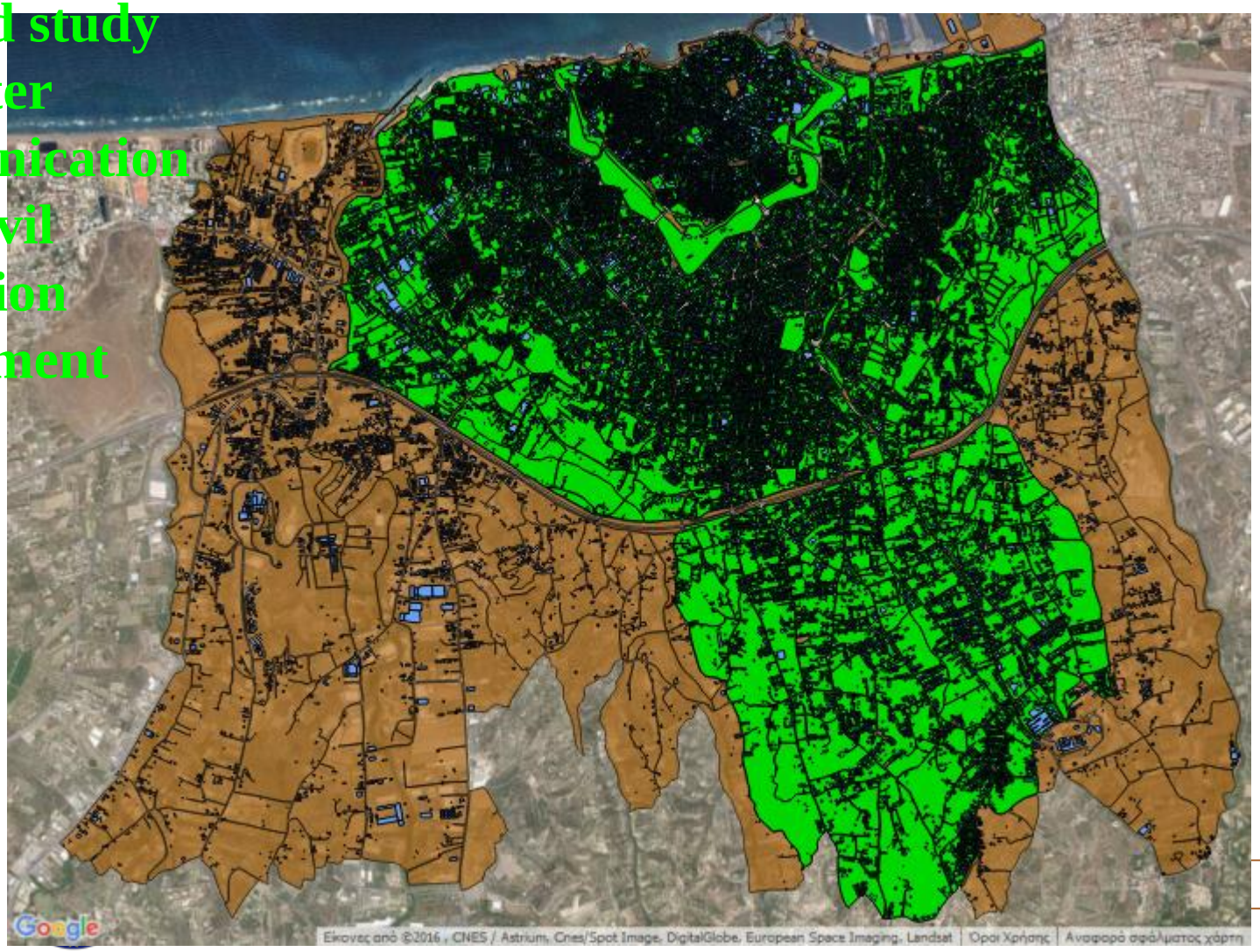
Exposure Model of Heraklion city

- Capital city of Crete, biggest port and administrative center of the island
- Surface: 120km^2 (after “Kallikratis” aggregation policy)
- Municipality population: 174’000
- No buildings: 34’860 (Census 2001)

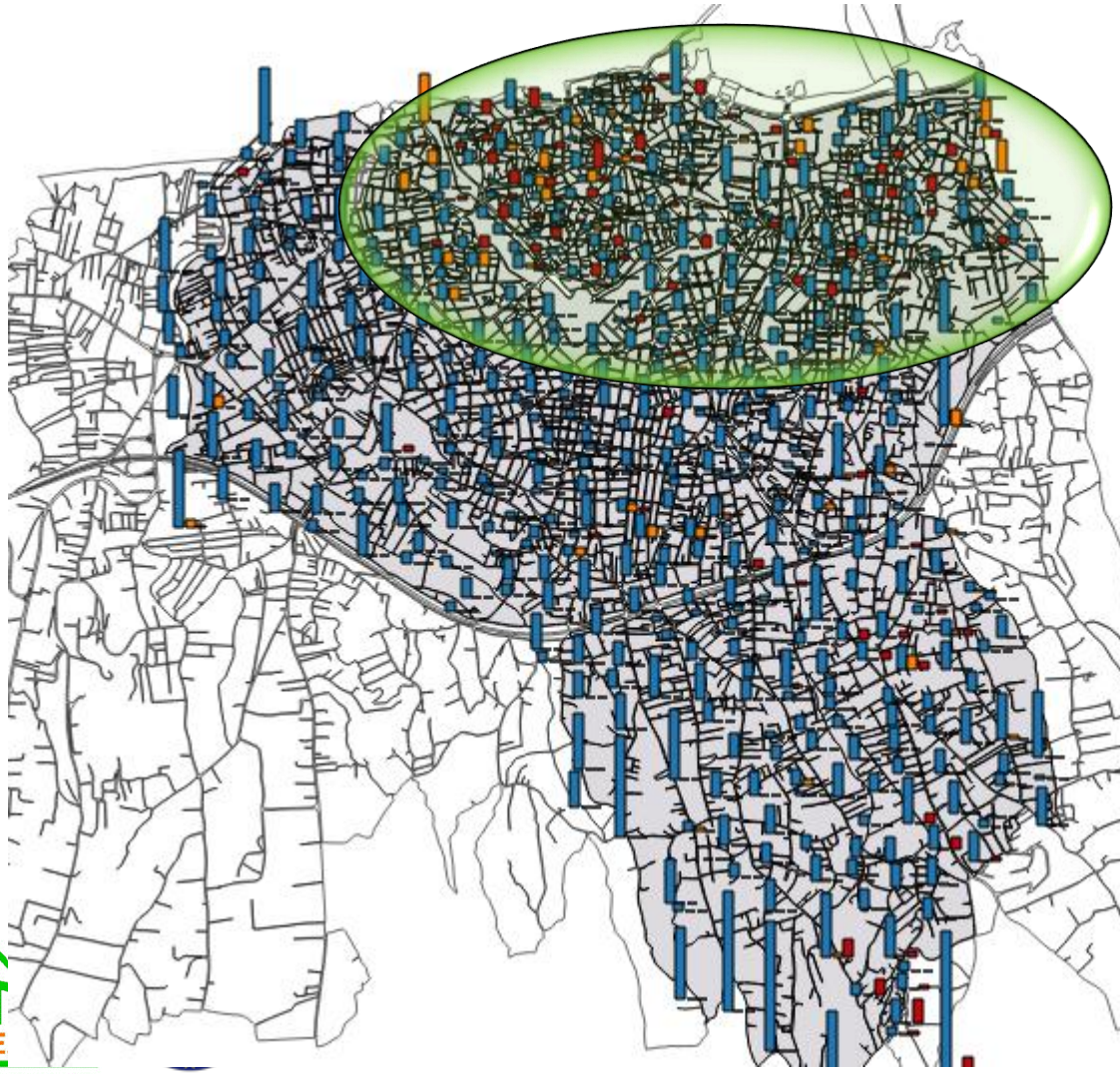
Exposure Model – City of Heraklion

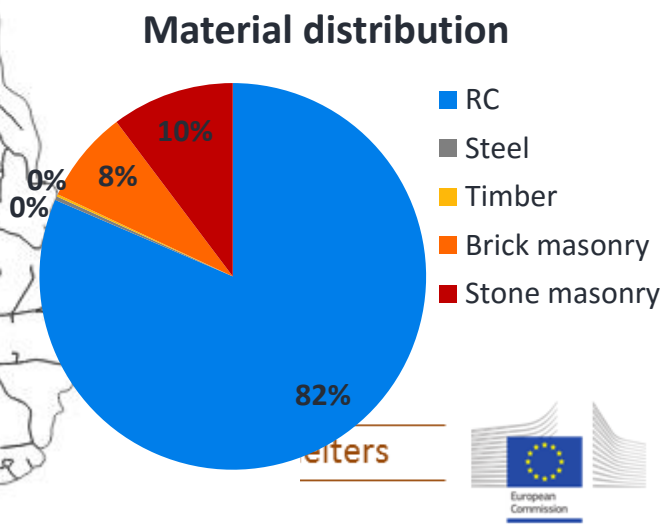
Exposure Model – City of Heraklion

Selected study area after communication with Civil Protection Department



Exposure database – Material Distribution

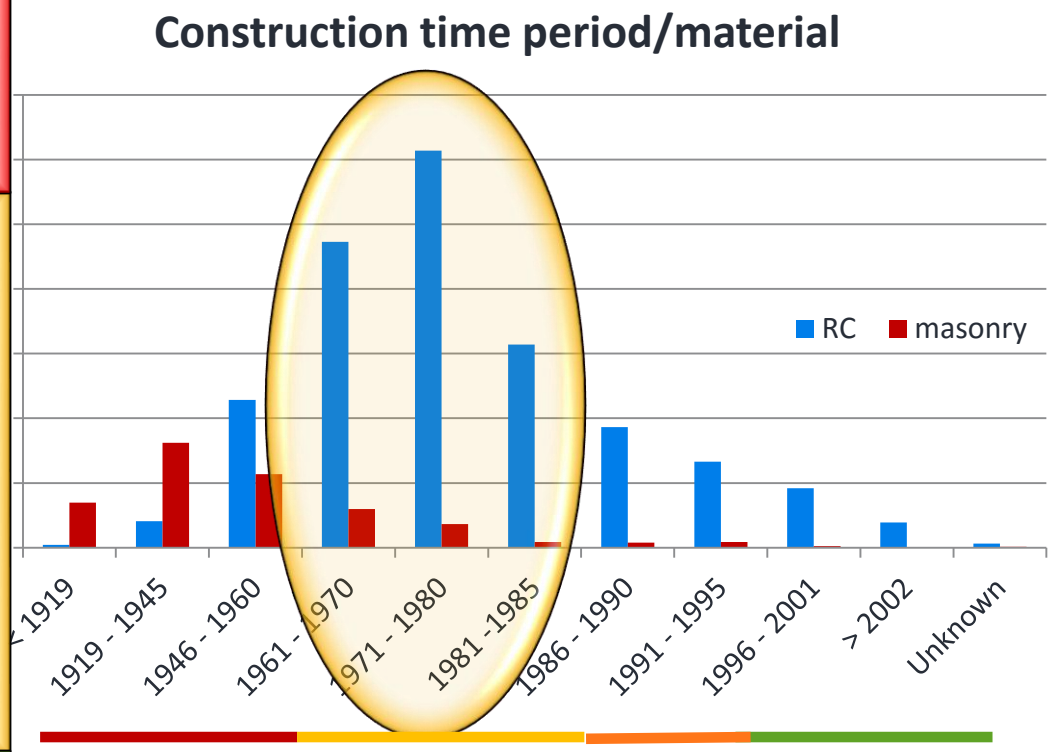




Exposure database– Construction time period

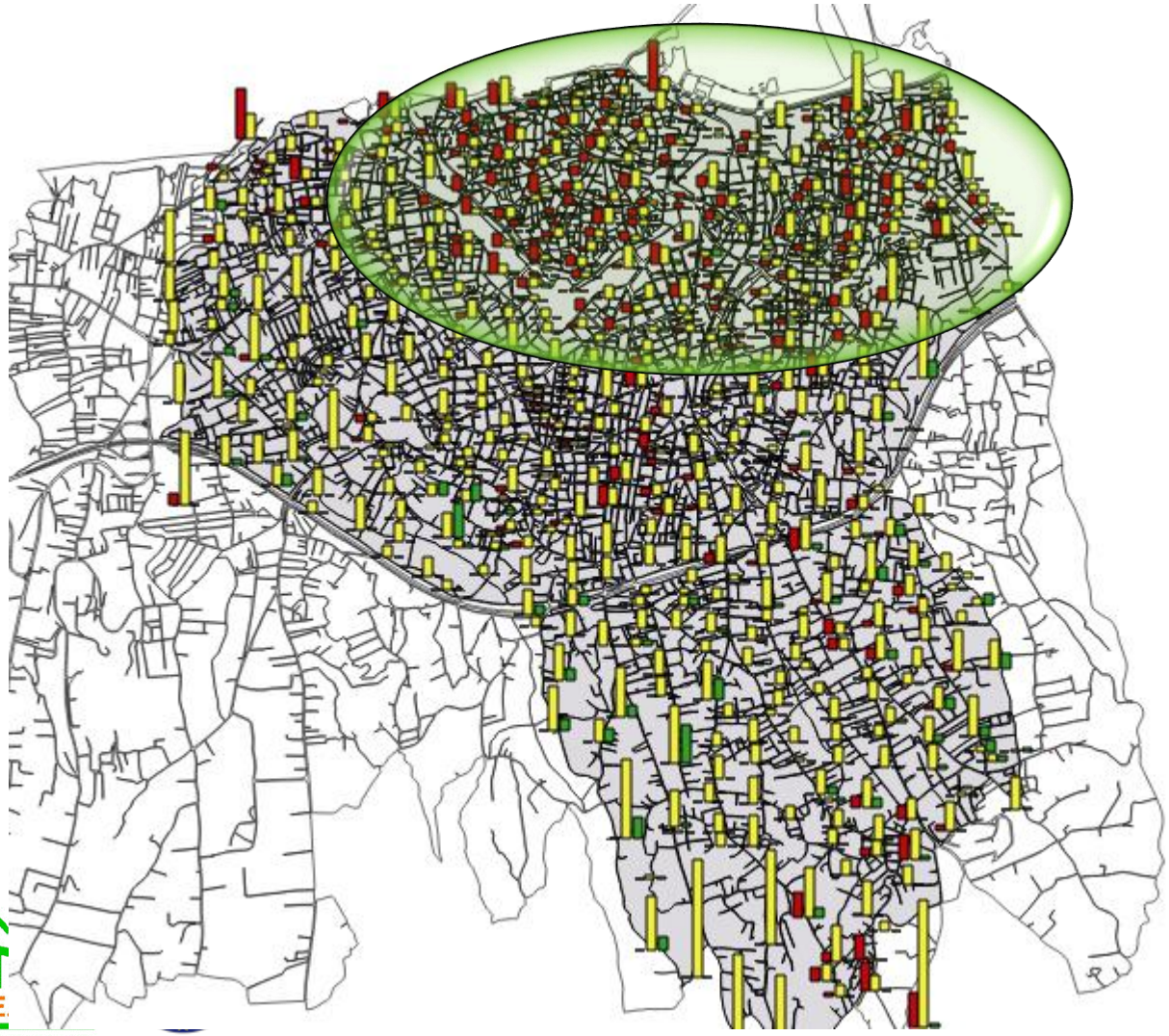
Earthquake Resistant Design (ERD) Codes evolution

- **Prior to 1959**: No ERD, low quality material, shallow foundations
- **1959-1984**: first ERD, static lateral loading with seismic coefficient (ε) &weight, use of rod steel long. Reinforcement
- **1984-1994**: Some modifications, triangular loading, spatial model
- **1995, 2000**: New ERD, dynamic methods, spectrum, capacity design, ductility



No ERD | Β.Δ. 1959 | Π.Α. 1984 | ΝΕΑΚ 1995, ΕΑΚ 2000

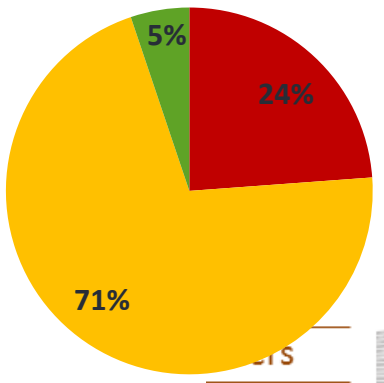
City of Herakleion – Construction time period



Distribution per ERD

- without
- mid-code
- high-code

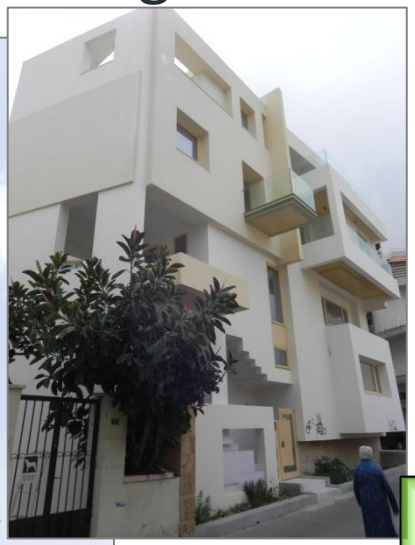
Design with ERD



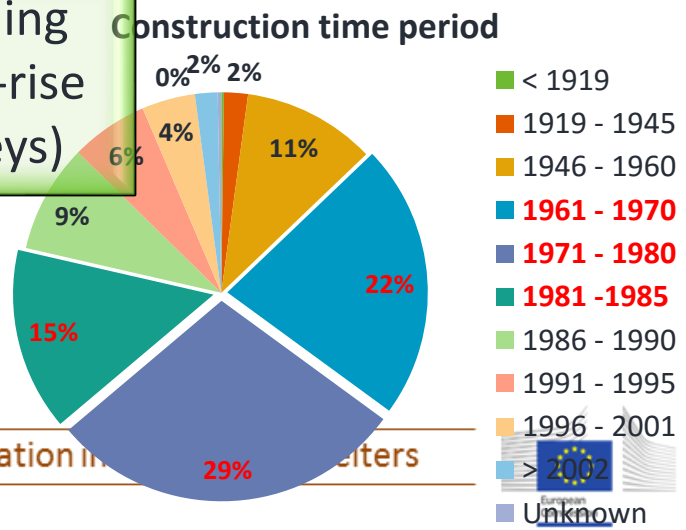
- without
- moderate
- high

City of Herakleion – Site survey

- RC frame buildings



87% building stock: low-rise (0-2 storeys)



City of Herakleion – Site survey

- RC frame buildings

No seismic joint, slabs in different levels, prone to vulnerability

Additional loading – short column

Vertical irregularity

High ground
"soft store

City of Herakleion – Site survey

- Masonry buildings
  - Stone masonry
  - Brick masonry

City of Herakleion – Site survey

- Timber buildings

Top floor timber, GF stone masonry

Not in good preservation conditions

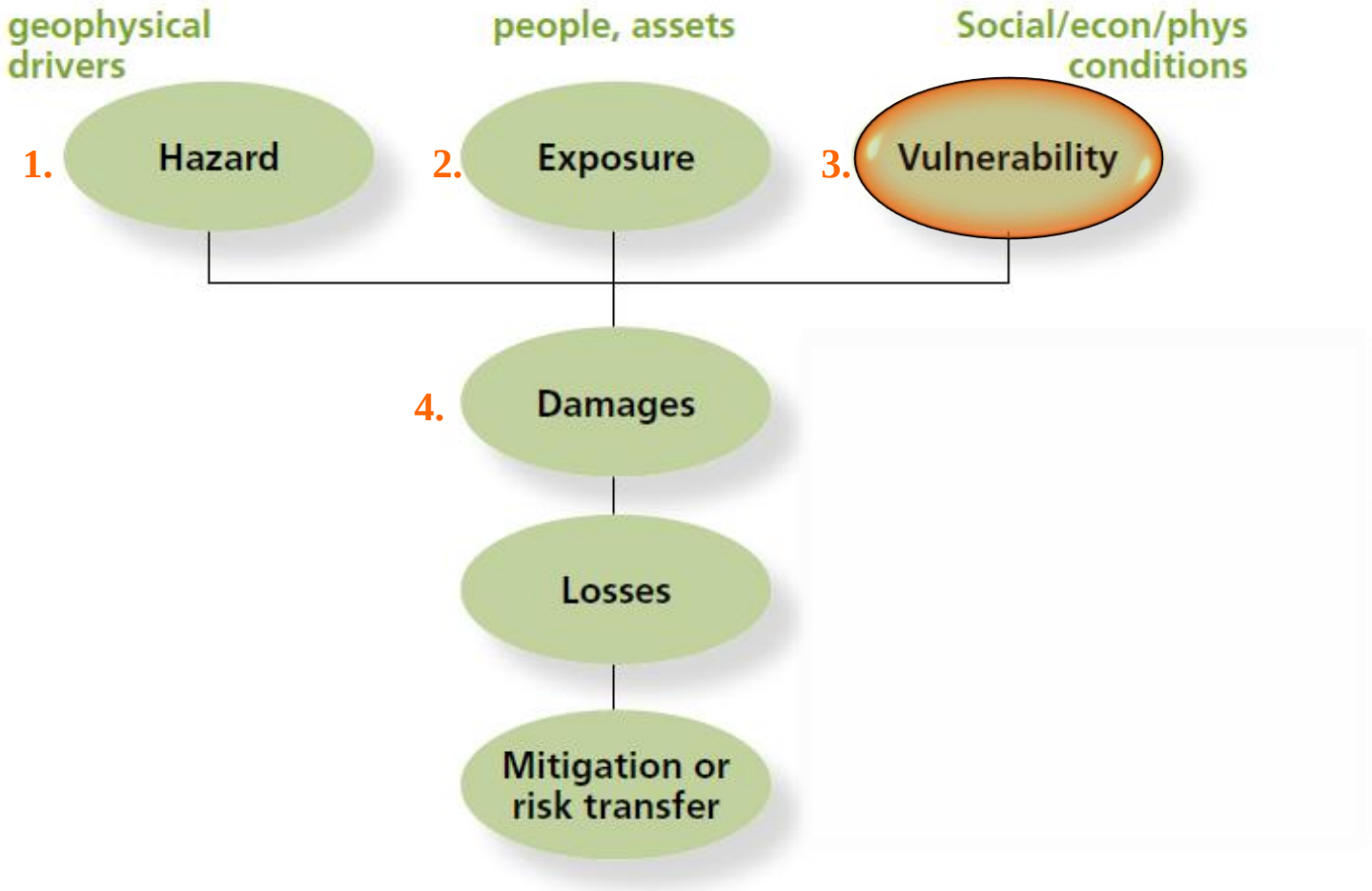
2‰ total building stock

Elements for vulnerability analysis

EPANTYK, 2009; Census 2001

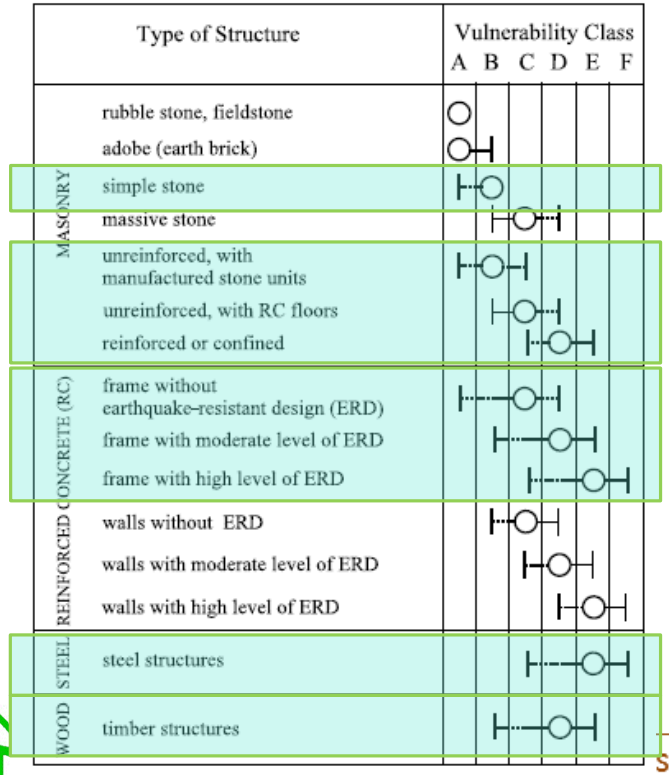
1. Time construction period
2. Construction material
3. Structural bearing system
4. Number of storeys
5. Irregularity: “Soft storey” (pilotis, glass panels)
6. Use
7. Adjacent buildings for pounding risk

Seismic Disaster Risk Assessment



Vulnerability model

Vulnerability *summarizes the characteristics of exposed people or physical assets that make them more or less likely to be affected by a hazard event.*



Macroseismic Method (LM1-RiskUE)

(Giovinazzi & Lagomarsino, 2004)

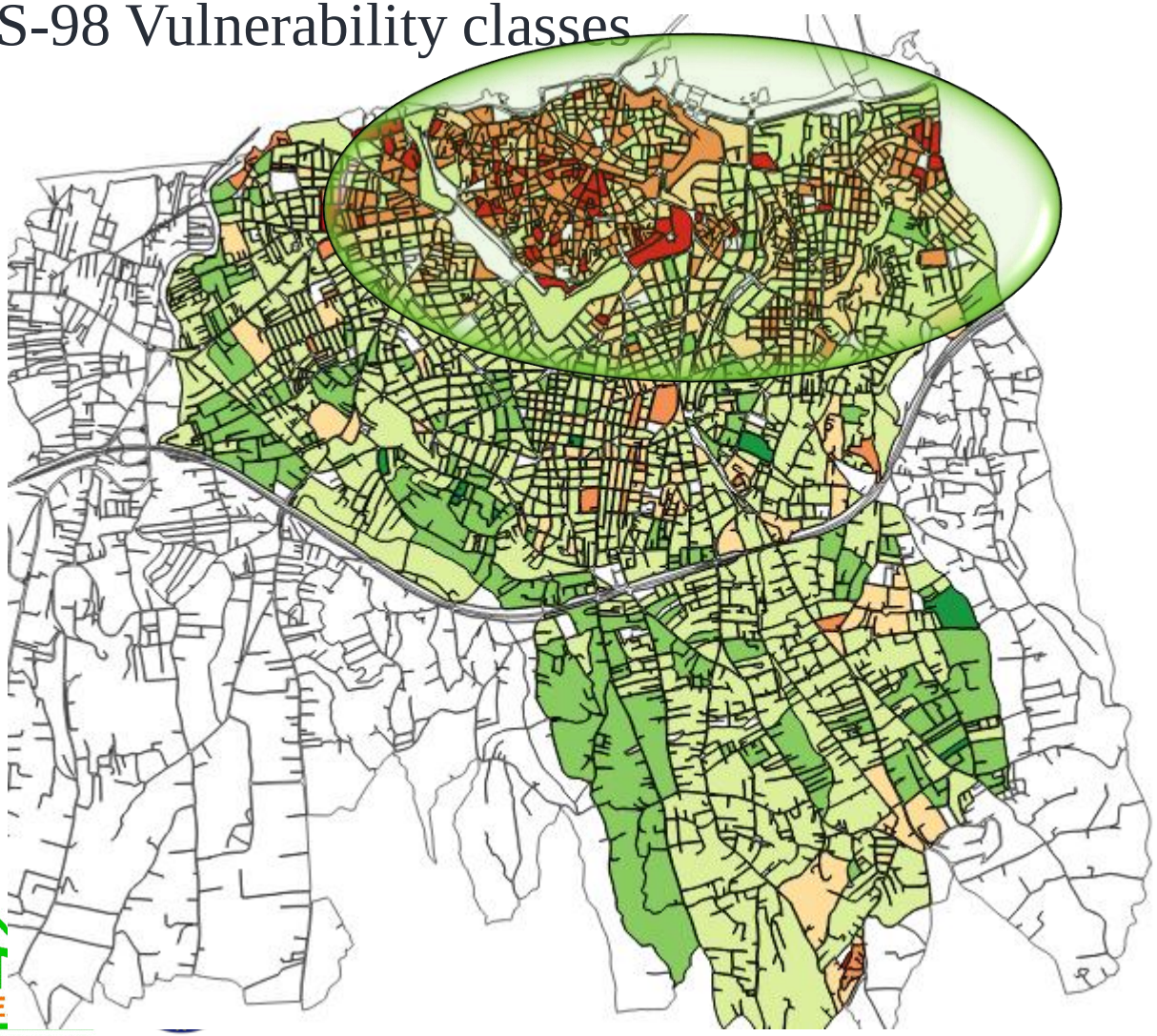
$$V_I = V_I^* + \Delta V_m$$

V_I^* : Typological vulnerability index within an uncertainty range (V_I^{min},V_I^{max})

ΔV_m : Behavior Modified factor

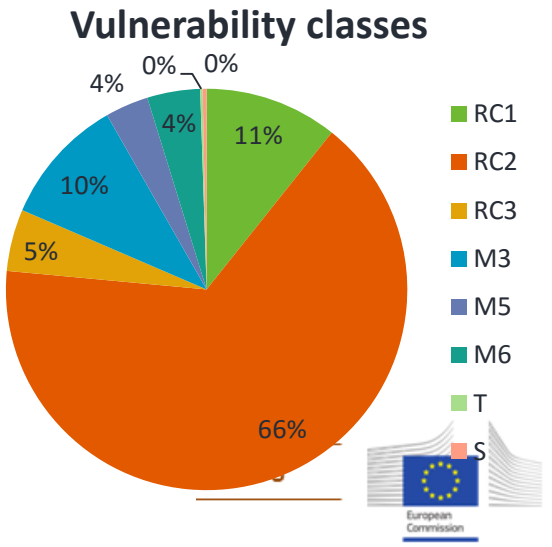
Vulnerability model

EMS-98 Vulnerability classes



Vulnerability index

- 0.304 - 0.377
- 0.377 - 0.449
- 0.449 - 0.522
- 0.522 - 0.595
- 0.595 - 0.668
- 0.668 - 0.740



Risk Assessment – Damage estimation

Damage Risk = Building Stock * vulnerability * seismic hazard

$$\mu_D = 2.5(1+\tanh((I+6.25V_I-13.1)/2.3))$$

I: macroseismic intensity
V_I: Vulnerability index

β-distribution of mean damage grade→ probability of occurrence of each damage grade

μ_D for max prob.

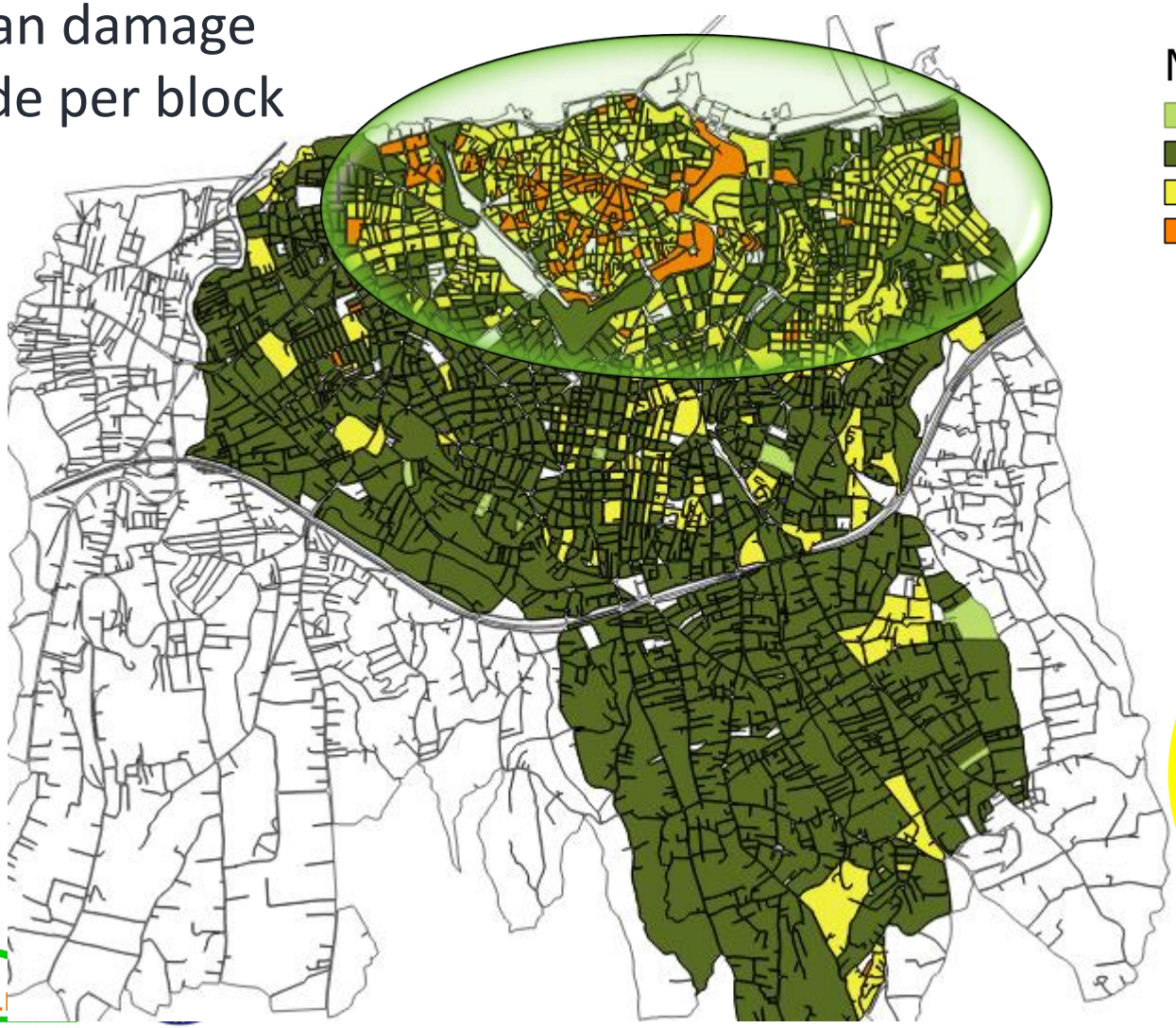
Classification of Damage

Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5

No damage | Negligible to slight damage | Moderate damage | Substantial to heavy damage | Very heavy damage | Destruction

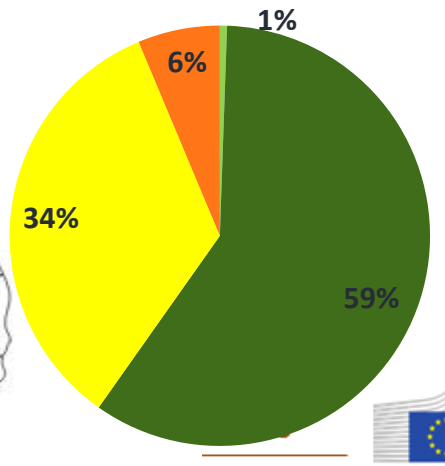
Damage estimation – Scenario 1

Mean damage grade per block



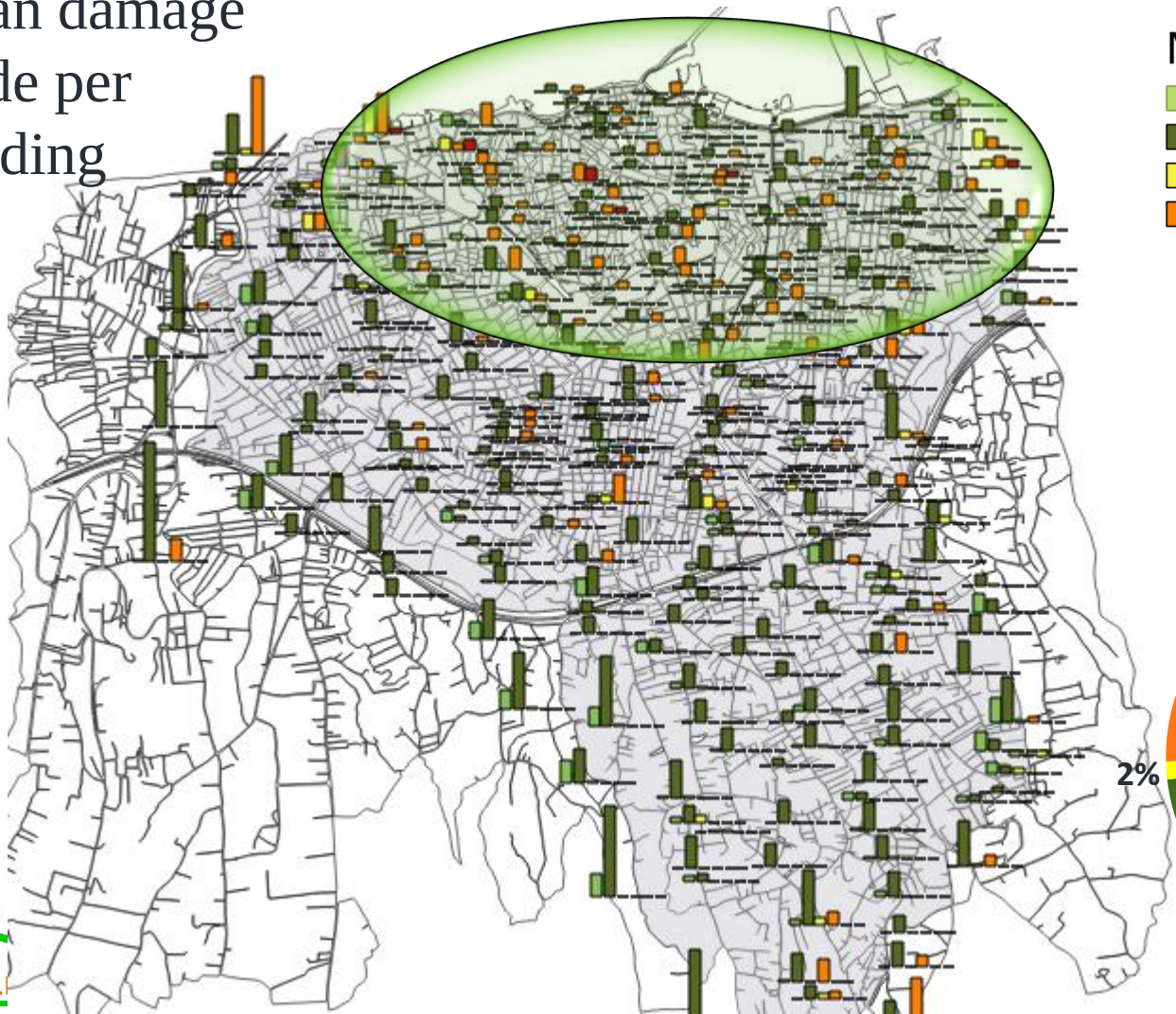
Mean damage grade
0 - No damage
1 - Slight damage
2 - Moderate damage
3 - Heavy damage

Damage per block



Damage estimation – Scenario 1

Mean damage grade per building



Mean damage grade
0 - No damage
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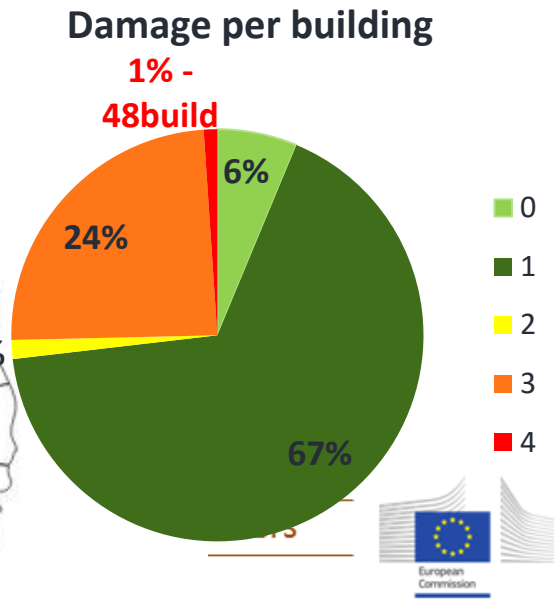
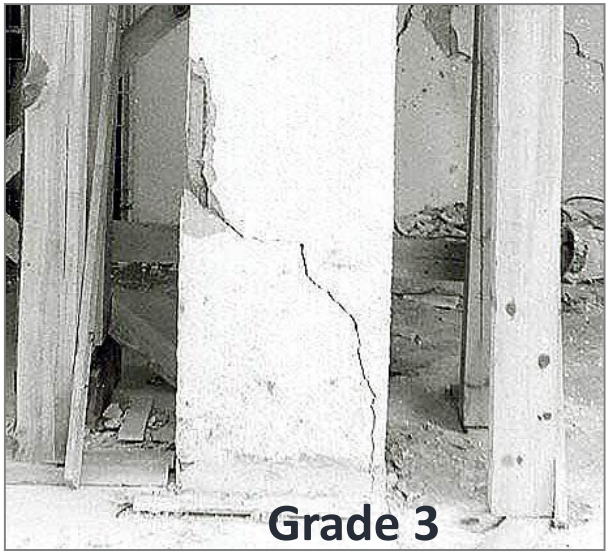
2 - Moderate damage
3 - Heavy damage



Damage estimation classification

Grade 2

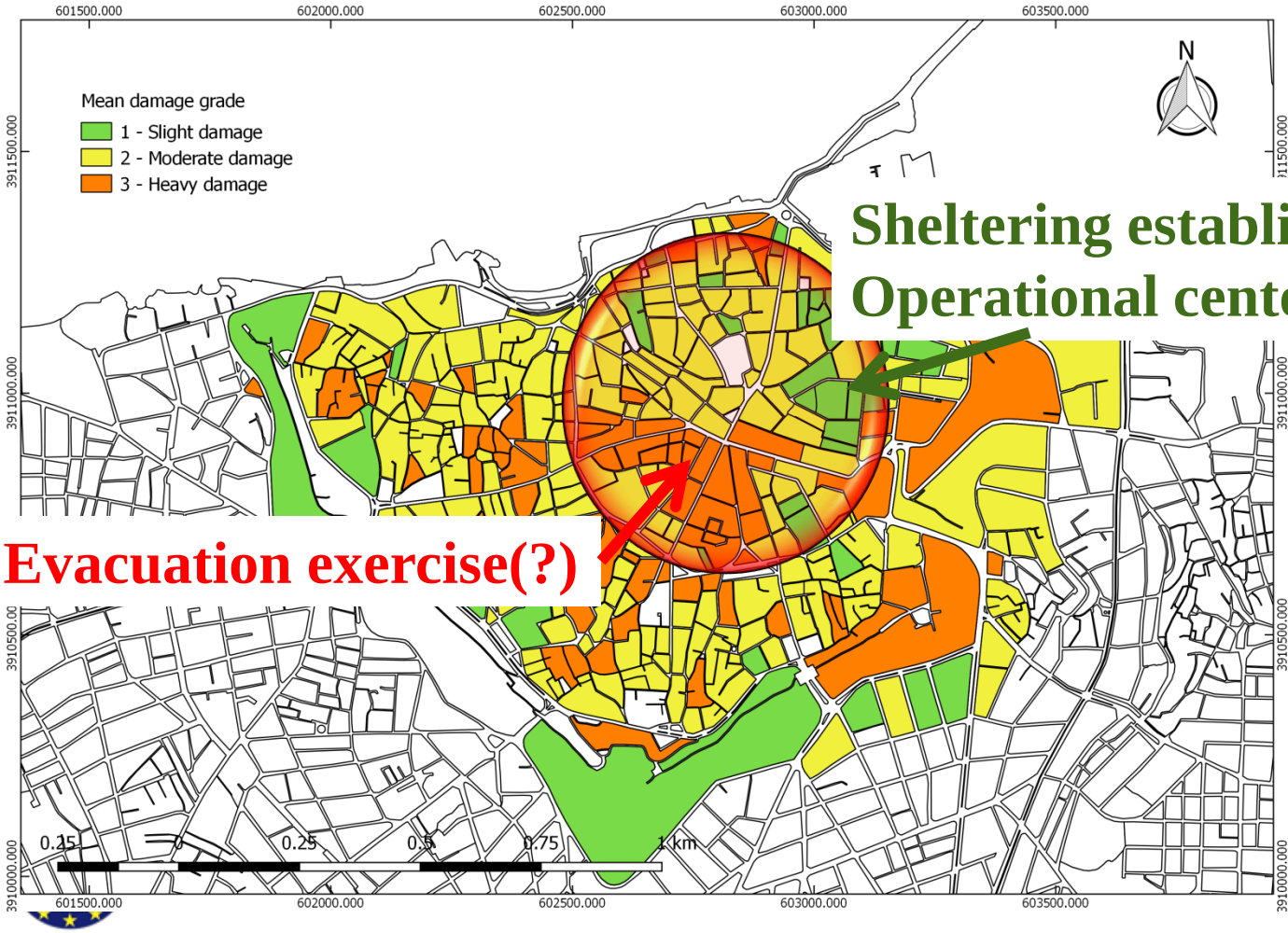


Grade 3

Grade 1

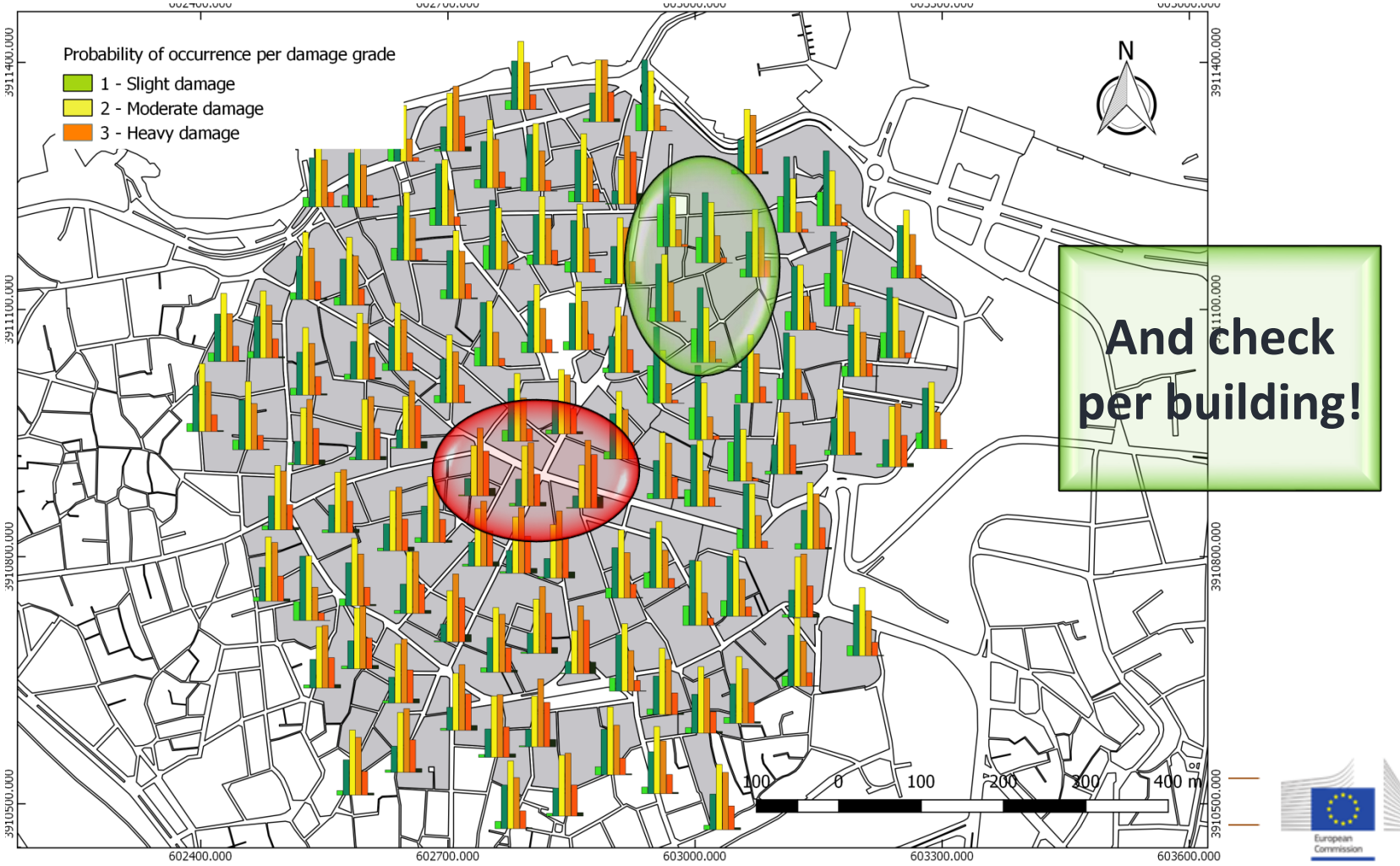
Damage estimation – Scenario 1

Zoom into the most affected area



Damage estimation – Scenario 1

Probability of occurrence of all damage states per block



And check per building!

As Results so far

- Heraklion city accommodates many active seismic sources. 4 are selected for the development of the seismic scenarios. Agnos Fault – 13 km in length – has been elaborated so far.
- Hazard analysis of Agnos Fault indicates an estimated intensity of IX almost in the entire city
- The northern part of Heraklion city assessed as the most structurally vulnerable area
- Damage estimation in strong correlation with vulnerability distribution for constant hazard intensities

Future steps

- Seismic scenarios will be implemented taking into account the other 3 active seismic structures.
- Direct economic losses and losses in terms of population (casualties,injuries) will be assessed for the selected seismic scenario applied for the evacuation exercise, according to available data
- Based on the final selected seismic scenario will take place the evaluation of
  - most affected districts for evacuation selection
  - less affected areas as appropriate for emergency sheltering

  & operations center location

References (1/2)

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Thank you very much!

Earthquake Planning & Protection Organization (E.P.P.O.) Team for PACES

Chrysa Gountromichou, cgountro@oasp.gr
Geologist MSc PM, Head of Emergency Planning – Prevention Depart.
Danai Kazantzidou-Firtinidou, danai.kazantzidou@gmail.com
Civil Engineer MSc, Scientific collaborator

Giannis Delakouridis, Geologist Msc, Scientific collaborator
Gabriela Zagora Civil Engineer MSc**, Evangelia Pelli** Civil Engineer MSc,
Maria Manousaki Geologist, **Maria Podimata** Civil Engineer MSc