PACES: Preparedness for Appropriate Accommodation in Emergency Shelters

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- Case study area
- Building stock
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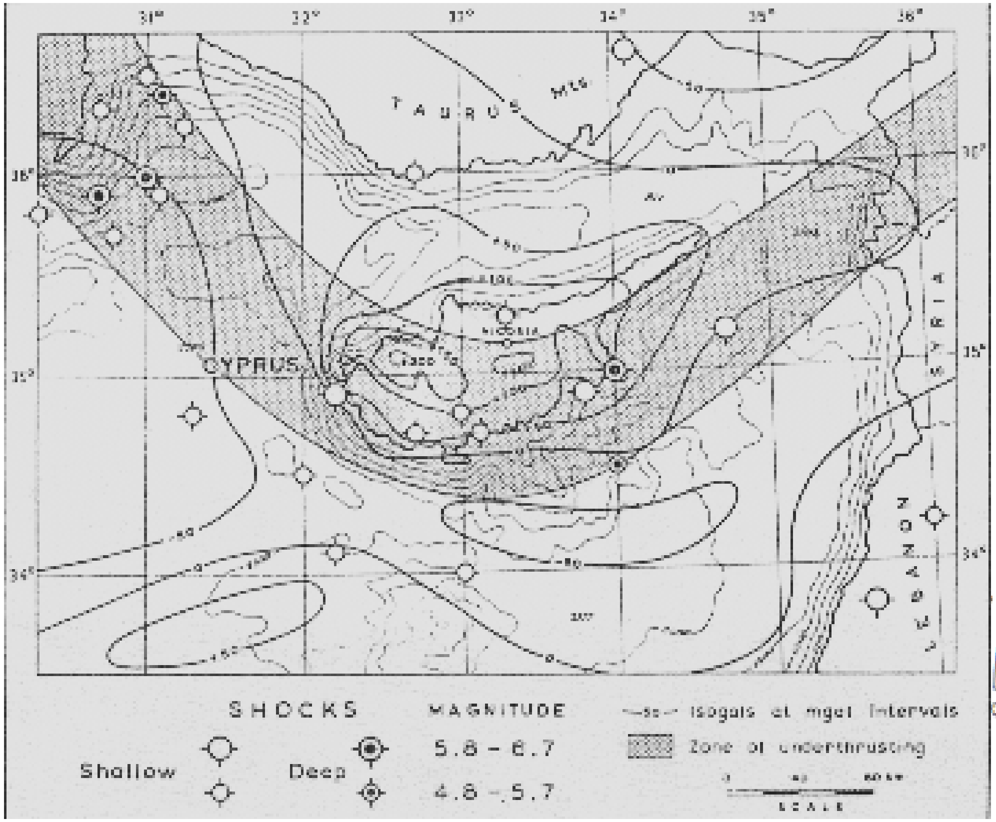
Introduction

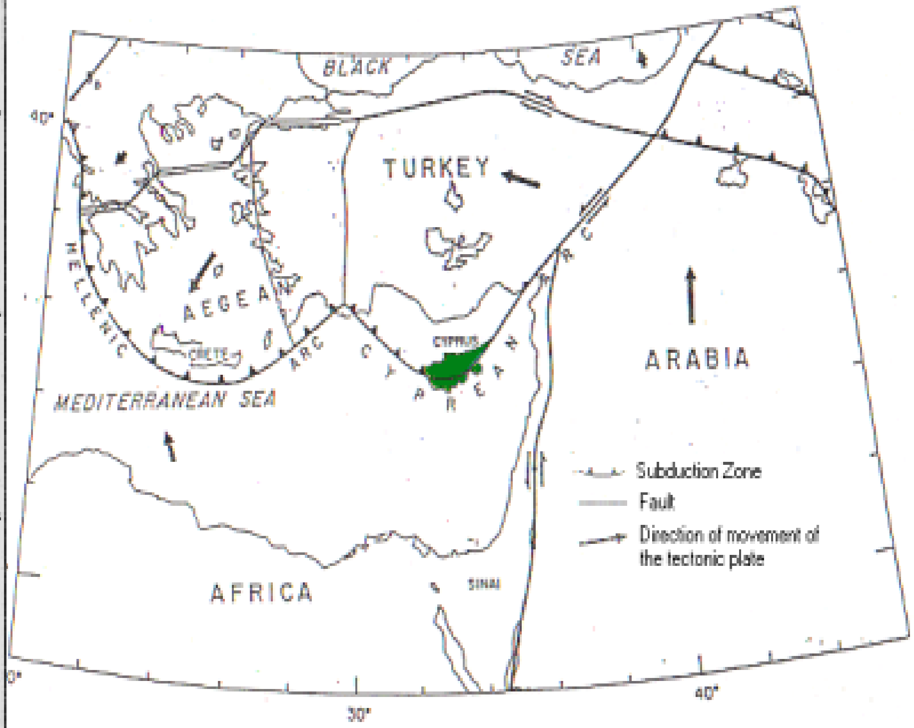
- The island of Cyprus, which is located in the North Eastern Mediterranean region, lies within the second highest seismic hazard zone of the earth. Throughout its history, Cyprus has suffered significant damage due to earthquakes. Since 1995, three major earthquakes, with magnitudes Ms > 5.7 have hit the island, causing three fatalities, approximately 50 injuries, severe structural damage and economic losses, which add up to approximately €15 million. This has increased concern amongst the people of Cyprus and highlighted the need for improved risk assessment and management. The first basic seismic provisions in the island were introduced in 1986 followed by a formal and comprehensive seismic code in 1994.

Introduction

- Cyprus lies on the southern part of a diffuse boundary between the African and the Eurasian tectonic plates
- The African plate, which is moving towards the north pressurizes the Eurasian plate. The Cyprian Arc is the point of contact of the African plate with the Eurasian plate, which is regarded as either a plate boundary or a broad zone of thrusting and is believed to responsible for most of the earthquakes occurring in the island

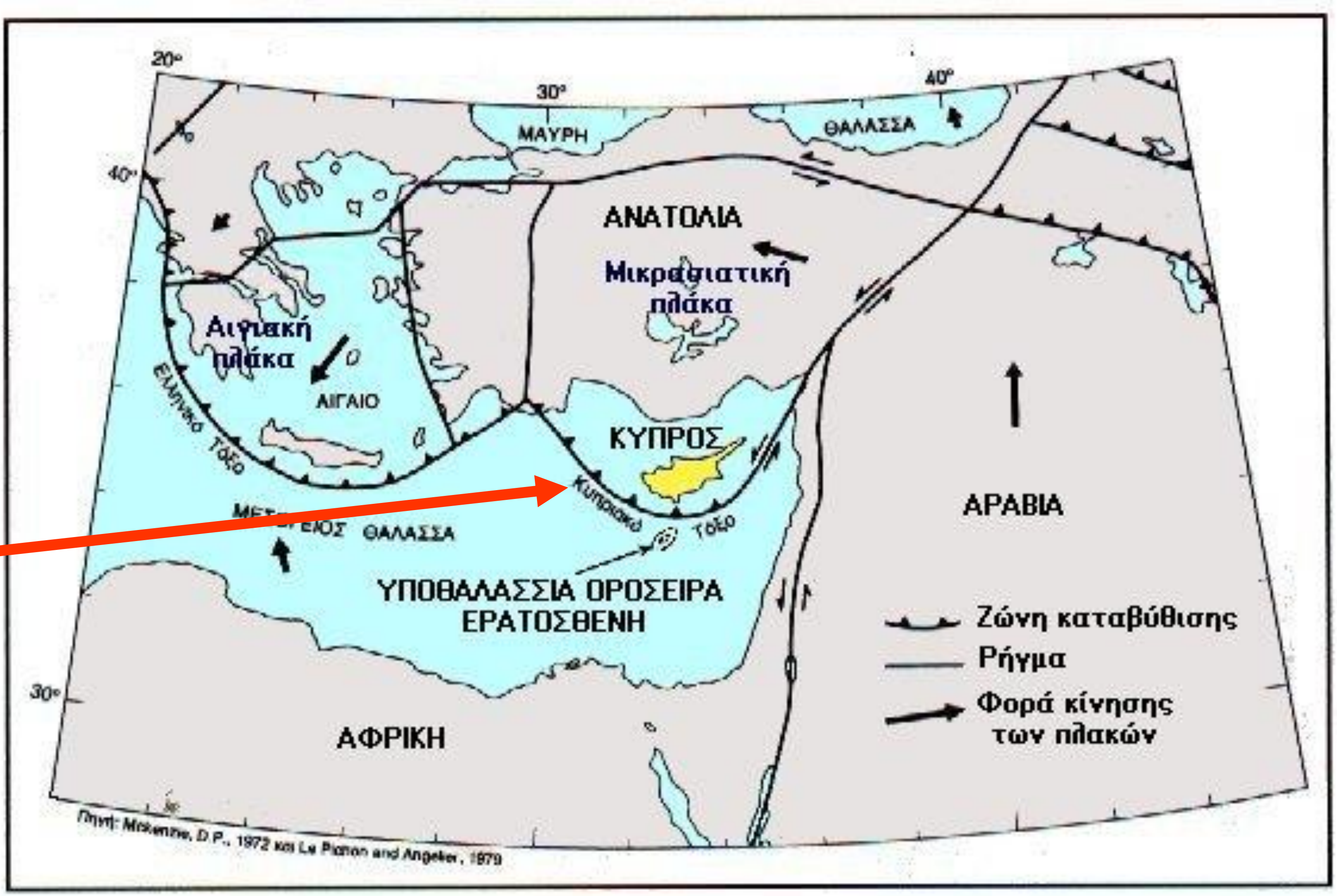
Introduction





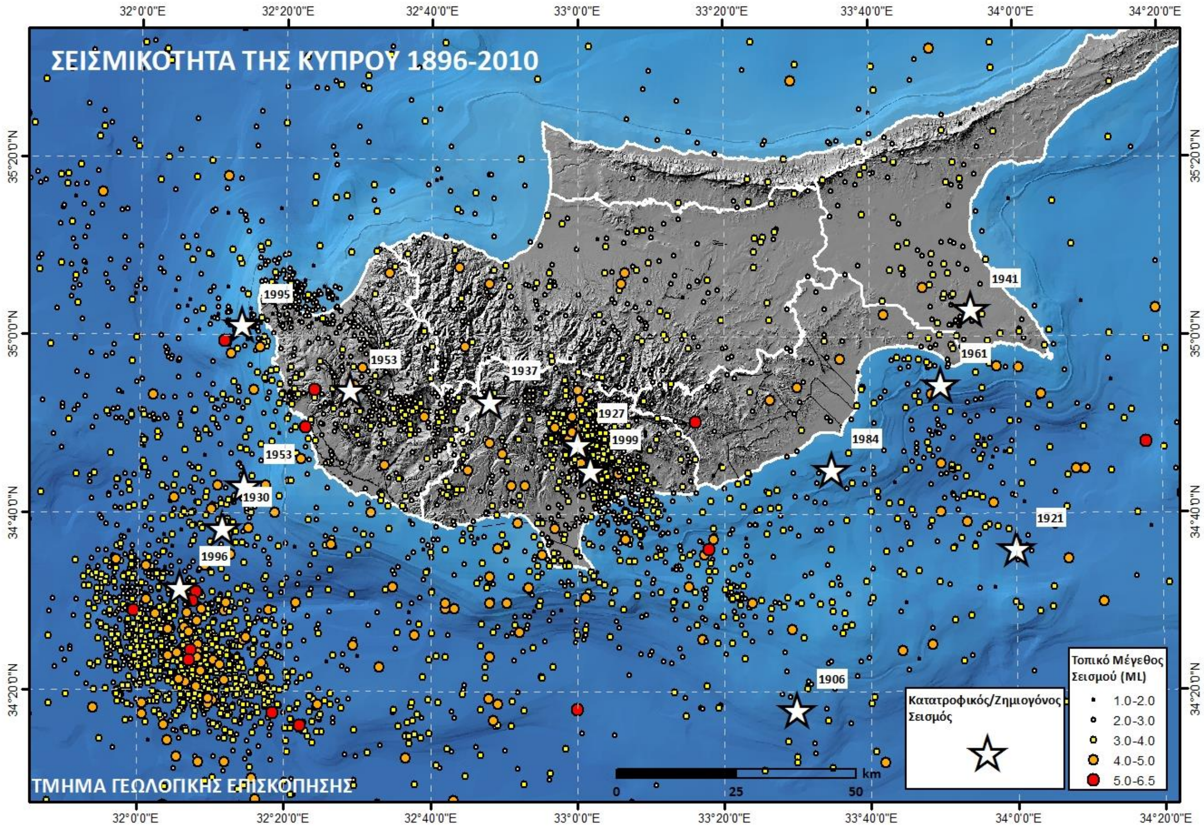
Introduction

Cyprean Arc



Introduction

- Seismic activity in the area
- Concentration in the south-west offshore area in the Cyprean arc zone and lately increased activity near Yerasa

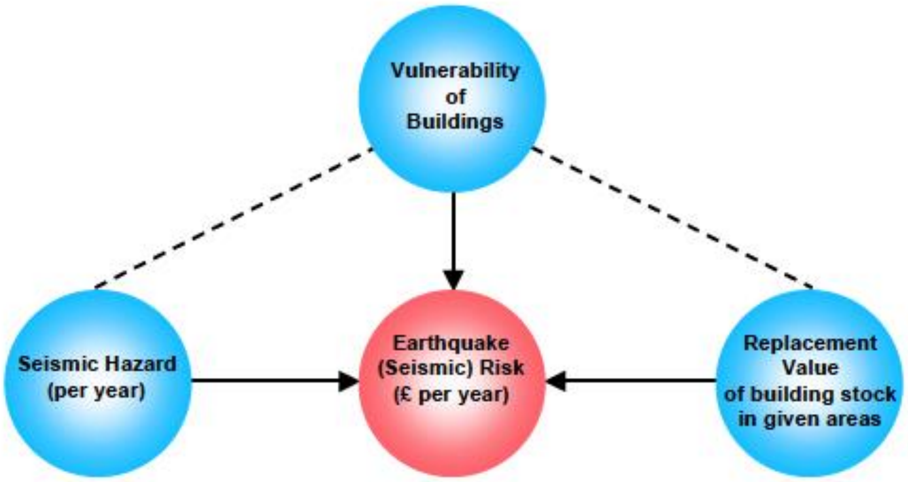


Introduction

- The quantification of the unwanted consequences from earthquakes can be achieved through risk assessment, which defines, monetarily, the amount of prospective damage inflicted on structures and the population by an earthquake. Seismic risk assessment is used as a tool for the prevention, preparedness and mitigation of the consequences from seismic events and is based on the assumption that losses depend on the quality of the building stock (zero seismic risk in deserts).

$$R = \sum_{i=1}^{n}\sum_{j=1}^{m}(H_i * V_{ij}) * C_j$$

where: H_i is the Seismic Hazard (i=1 to n).
V_{ij} is the Vulnerability, of each element j at risk for ea
C_j is the Value of element j at risk, e.g. buildings public services etc, in the area under consideration.

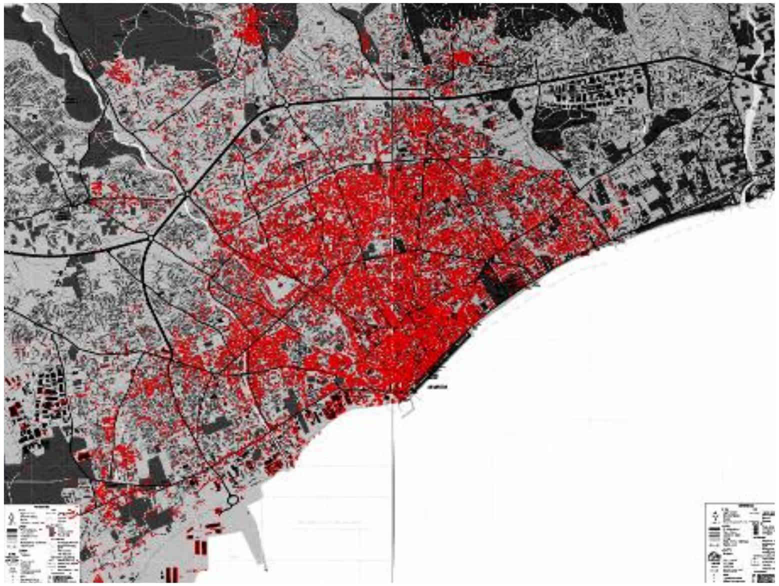


Case Study area

- In order to examine the seismic risk of the existing building stock of the island it was decided to use the municipality of Limassol as a case study as
  - it is situated at the southern part, which has proven to be of higher risk due to its proximity to the Cyprian Arc
  - most of the buildings were constructed prior to the enforcement of the aseismic code, which is the case for all the tall buildings (>6 floors), with the use of low strength concrete and very low ductility reinforcement.
  - Densely populated

Case Study Area

- The boundary of the district of Limassol is shown with the red line (left figure), whereas the borders of the Limassol municipality, which is the case study area, are shown with the black line. The spatial distribution of buildings in the municipality is shown in the right figure. It is observed that it comprises of a very dense building stock concentrated close to the coastal line.



Compilation of building stock

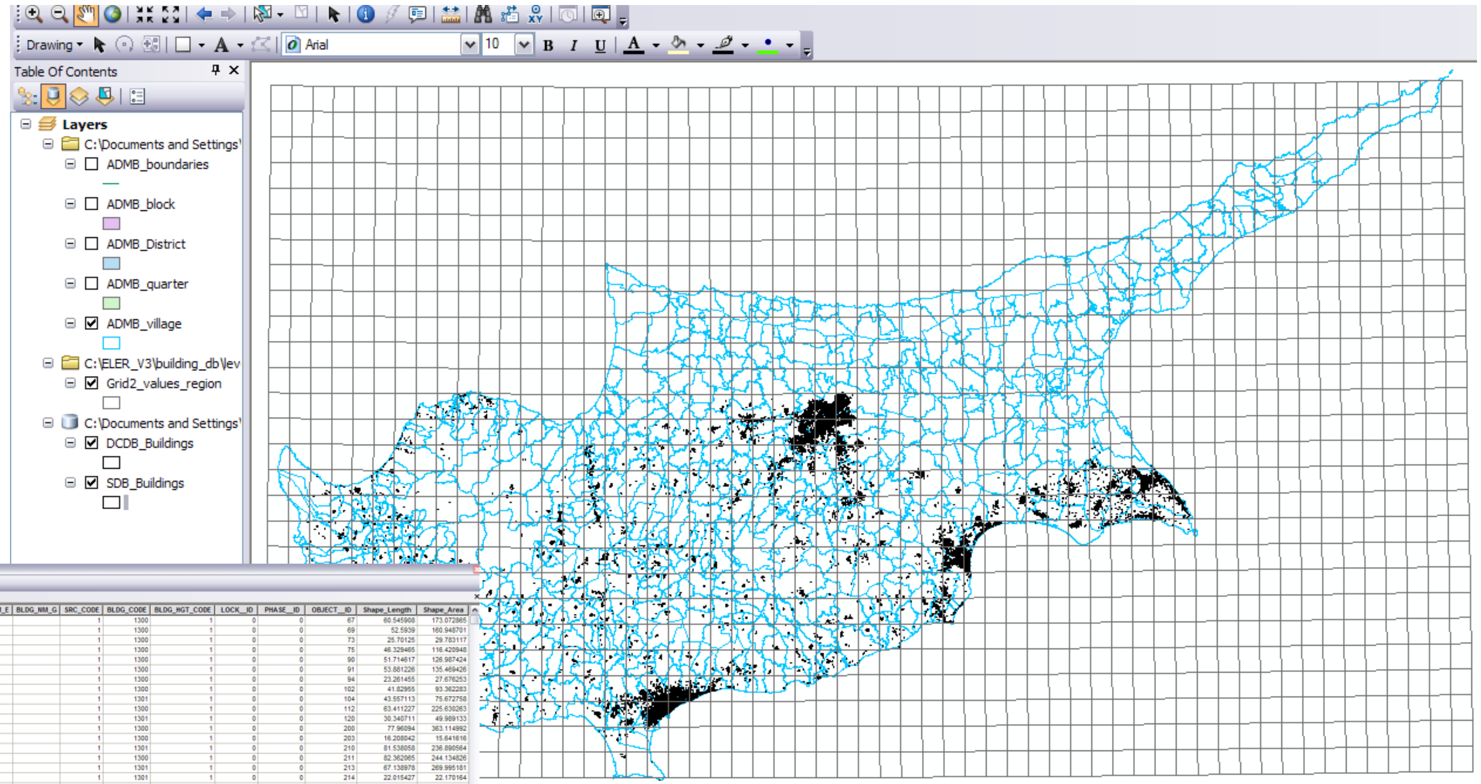
- The Building database was provided by the Department of Land and Surveys in GIS format (building level). The database was updated up to 2011.
- The Population database in GIS format per municipality and community was obtained from the 2011 Census of Population which was conducted by the Cyprus Statistical Service
- Based on the estimated data from the municipality it was observed that nearly 70% of the existing building stock lacks any seismic design (i.e. constructed prior to 1994)
- Of those, approximately 600 buildings are 3-5 floors and 200 ≈ 7 floors

	1946-1960	1961-1970	1971-1980	1981-1990	1991-1995	1996-2001	2001-2011
Houses	3510	4474	6192	6577	2314	2056	4945
Apartments	284	826	2649	3801	1214	755	4512

Building classification-
Risk UE building taxonomy

1. RC1L: Nearly 70% of the existing building stock (65% are one floor). 60% of them were build with no seismic provisions (DCL).
2. RC1M: Nearly 70% are ≤ 5 storeys (approximately 600 buildings are 3-5 floors). Very few are on average 7 floors (≈ 200)
3. Construction period was determined based on assumption for the % of buildings before and after seismic codes (1991). Such statistics were established from local studies.
4. Building height was provided by the database
5. M2 (adobe) and M6 (massive stone) are approximately 4000 in the municipality

Compilation of building stock



Table

DCDB_Buildings

OBJECTID *	Shape *	AREA_	PERIMETER	BLDG_	BLDG_ID	BLDG_A_UID	SRC_SL_CODE	BLDG_NM_E	BLDG_NM_G	SRC_CODE	BLDG_CODE	BLDG_HGT_CODE	LOCK_ID	PHASE_ID	OBJECT_ID	Shape_Length	Shape_Area
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2	Polygon	<Null>	52.594581	67	77	0	4			1	1300	1	0	0	69	52.5939	160.948701
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4	Polygon	<Null>	46.329641	73	83	0	4			1	1300	1	0	0	75	46.329465	116.420948
5	Polygon	<Null>	51.714962	87	100	0	4			1	1300	1	0	0	90	51.714617	126.987424
6	Polygon	<Null>	53.883443	88	101	0	4			1	1300	1	0	0	91	53.881226	135.469426
7	Polygon	<Null>	23.260652	91	104	0	4			1	1300	1	0	0	94	23.261455	27.676253
8	Polygon	<Null>	41.827955	99	113	0	4			1	1300	1	0	0	102	41.82955	93.362283
9	Polygon	<Null>	43.559798	101	115	0	4			1	1301	1	0	0	104	43.557113	75.672758
10	Polygon	<Null>	63.411874	108	124	0	4			1	1300	1	0	0	112	63.411227	225.630263
11	Polygon	<Null>	30.340689	116	135	0	4			1	1301	1	0	0	120	30.340711	49.989133
12	Polygon	<Null>	77.959181	186	231	0	4			1	1300	1	0	0	200	77.96094	363.114992
13	Polygon	<Null>	16.207469	189	234	0	4			1	1300	1	0	0	203	16.208042	15.641616
14	Polygon	<Null>	81.539957	196	244	0	4			1	1301	1	0	0	210	81.538058	236.890564
15	Polygon	<Null>	82.361863	197	245	0	4			1	1300	1	0	0	211	82.362065	244.134826
16	Polygon	<Null>	67.137778	199	248	0	4			1	1301	1	0	0	213	67.138978	269.995181
17	Polygon	<Null>	22.012077	200	249	0	4			1	1301	1	0	0	214	22.015427	22.170164
18	Polygon	<Null>	101.767555	201	251	0	4			1	1301	1	0	0	216	101.772881	396.126586
19	Polygon	<Null>	68.327719	204	256	0	4			1	1301	1	0	0	219	68.323982	259.428275
20	Polygon	<Null>	69.759429	205	257	0	4			1	1300	1	0	0	220	69.756101	279.639214
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22	Polygon	<Null>	17.921363	209	261	0	4			1	1300	1	0	0	224	17.921835	19.349018
23	Polygon	<Null>	43.705725	210	267	0	4			1	1300	1	0	0	226	43.707622	95.798597
24	Polygon	<Null>	69.930323	213	285	0	4			1	1301	1	0	0	233	69.931015	296.52878
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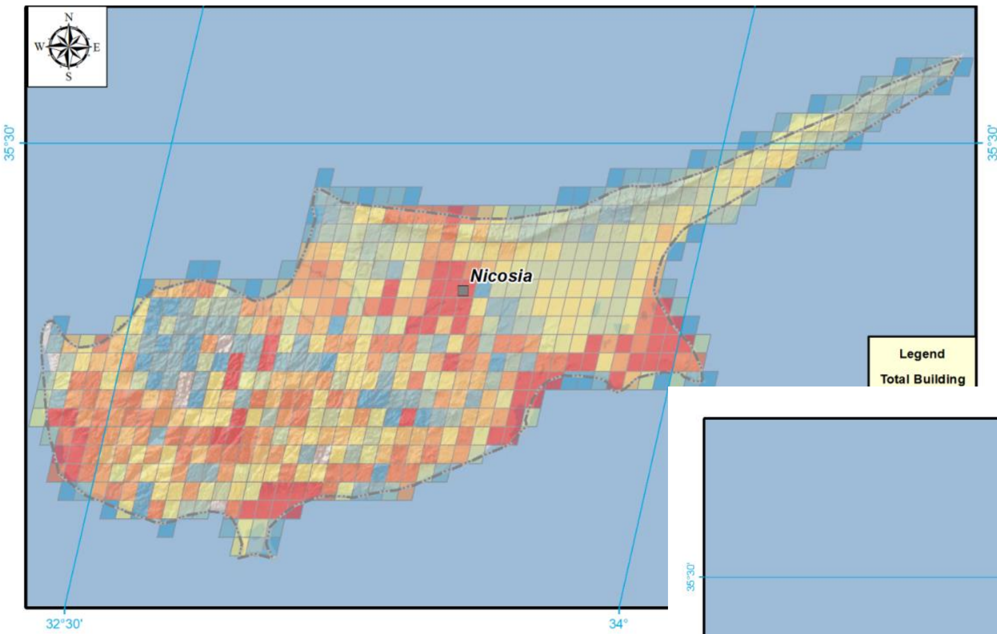
45	Polygon	<Null>	16.562425	308	414	0	4			1	1300	1	0	0	337	16.562525	15.859837

(0 out of 198204 Selected)

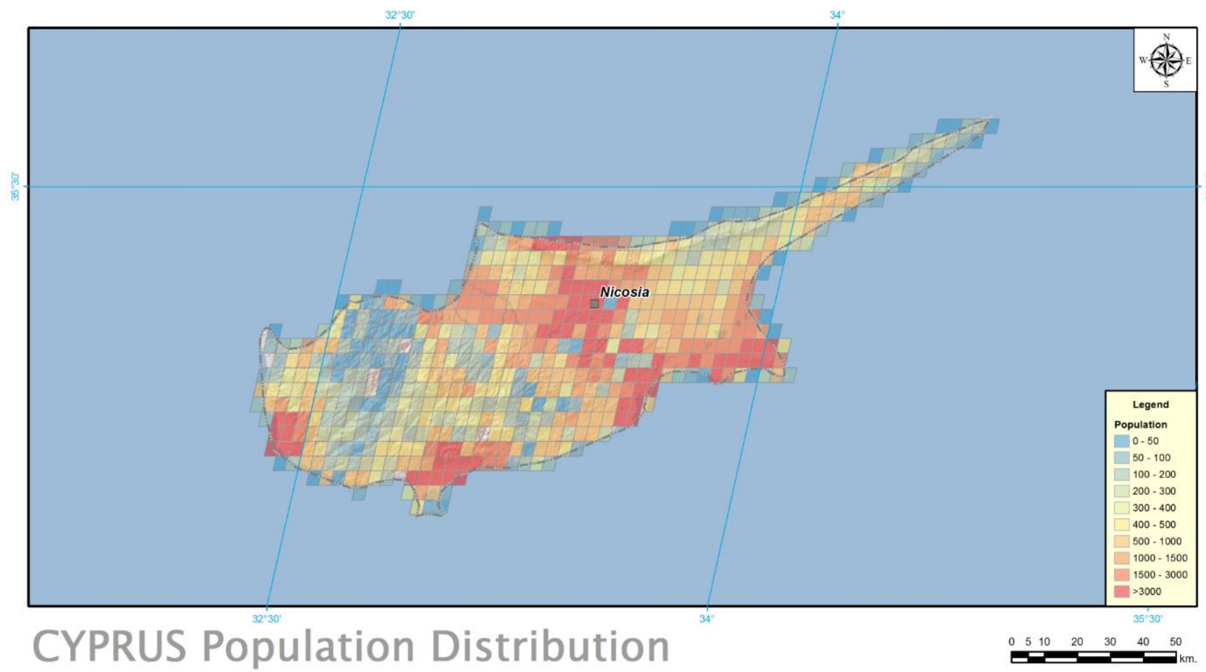
Buildings were allocated into grid cells to be compatible with ELER

(κάναβος 1km^2)

Databases



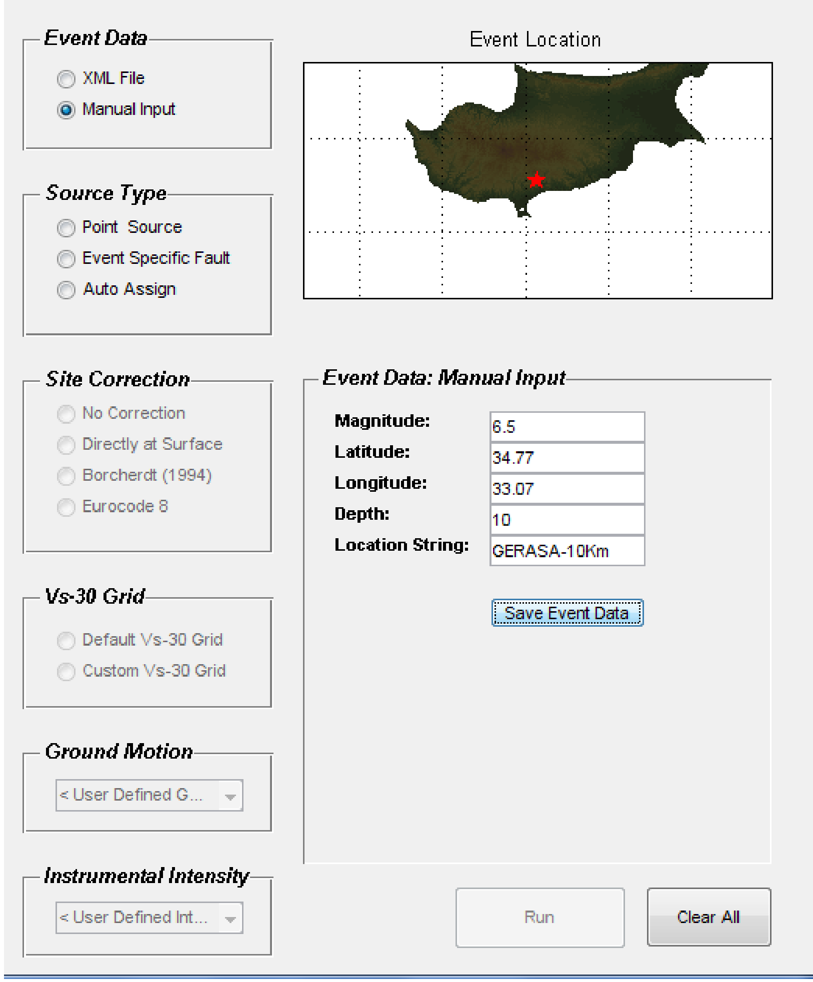
CYPRUS Total Building Distributio



CYPRUS Population Distribution

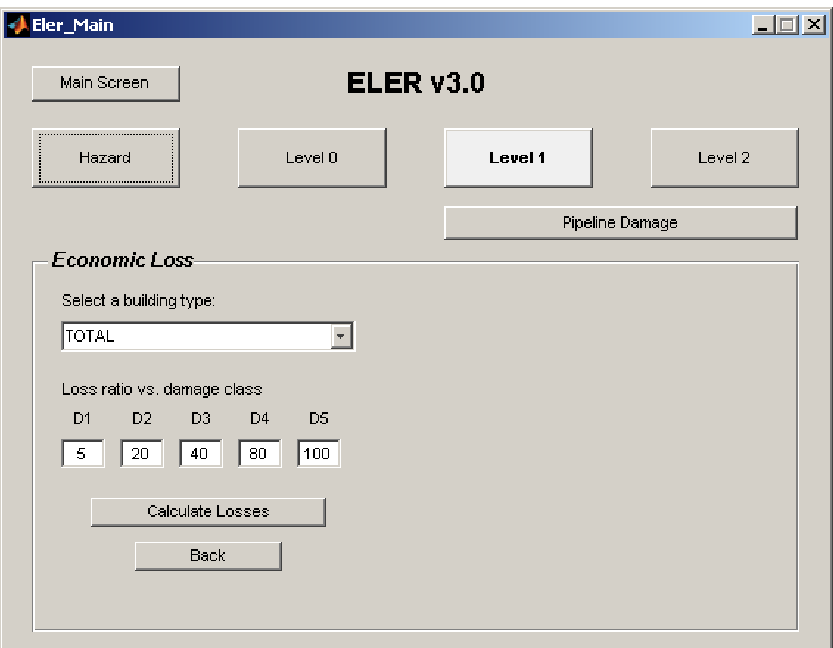
Risk Assessment methodology

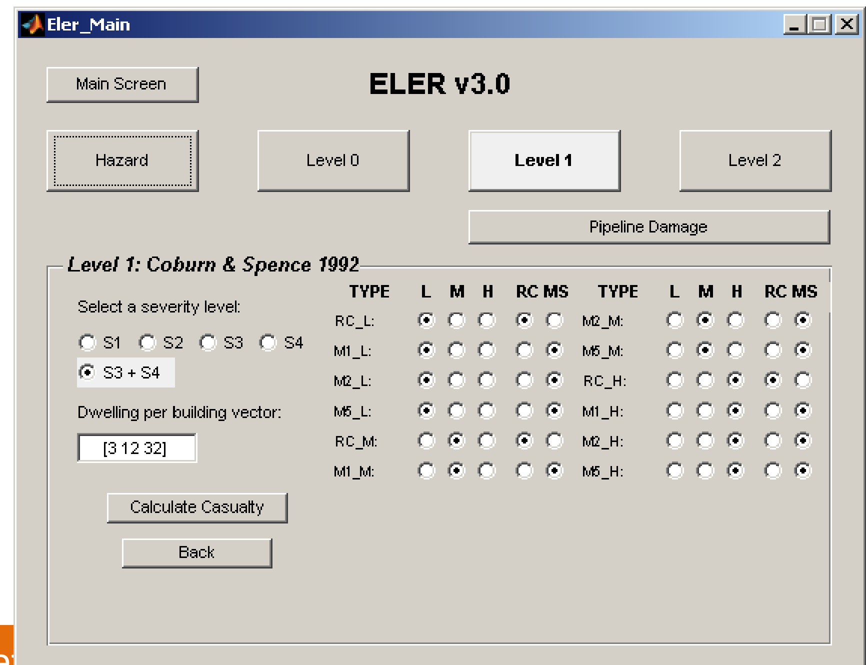
- For a given earthquake magnitude and epicenter information, estimation of the spatial distribution of selected ground motion attenuation equations with selected parameters (MMI or PGA) through region specific ground motion prediction equations and using shear wave velocity distributions or other site descriptors.
- Estimation of the building damage (fragility curves) and human casualty at different levels of sophistication that commensurate with the availability of inventory of human built environment
- Estimation of direct economic losses stemming from building damages using damage indices per damage level (grades)



Risk Assessment methodology

For the application of the methodology, a software was developed (ELER-Earthquake Loss Estimation Routine) as part of the funded research regional program EMME (Earthquake Model for the Middle East) for the the rapid estimation of earthquake shaking and losses in the Euro-Mediterranean region. The methodology that is used in this software is capable of developing scenario earthquake based loss assessments.



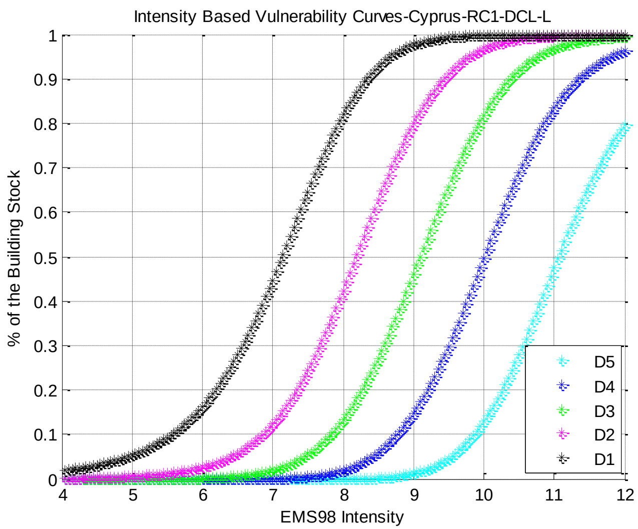


Risk Assessment methodology

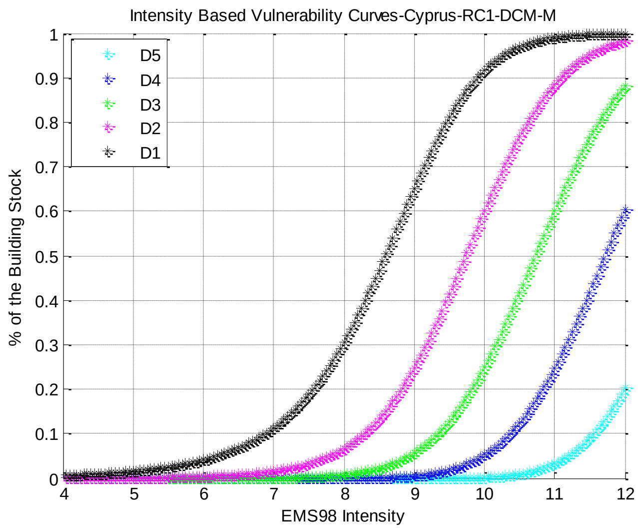
	LEVEL 0	LEVEL 1	LEVEL 2
HAZARD & INVENTORY	**Shakemap** (Point Source/Extended Source based on Seismotectonic Database +Vs30 →EMS98)	**Shakemap** (Point Source/Extended Source based on Seismotectonic Database +Vs30 →EMS98)	**Ground Motion Map** (Point Source/Extended Source based on rapid inversion +observed GM values +Vs30 →EMS98)
	City Locations + Landscan Population Distribution	Building Inventory (types and storey numbers) + Landscan Population Distribution	Building Inventory (types and storey numbers) + Landscan Population Distribution
BUILDING DAMAGE & CASUALTY	N/A	Building Damage using EMS98 Intensity based Building Vulnerability with Uncertainties.	Building Damage using Spectral Displacement based Building Vulnerability with Uncertainties.
	Regionally Adjusted Fatality vs EMS98 Relationships	Building Damage related Casualty Distribution	Building Damage related Casualty Distribution

Seismic Vulnerability

- Vulnerability curves for Level 1 assessment were derived based on EMS-98 (do not account for specific structural characteristic of RC buildings in Cyprus but rather general typical ones) and are used for a preliminary assessment of the risk in monetary terms at city or country level
- Hazard is expressed in the form of MMI attenuation laws



RC_No seismic_low rise



RC_Modern Seismic_low rise

Seismic Vulnerability-EMS98

Grade 1: Negligible to Slight Damage

Grade 2: Moderate damage

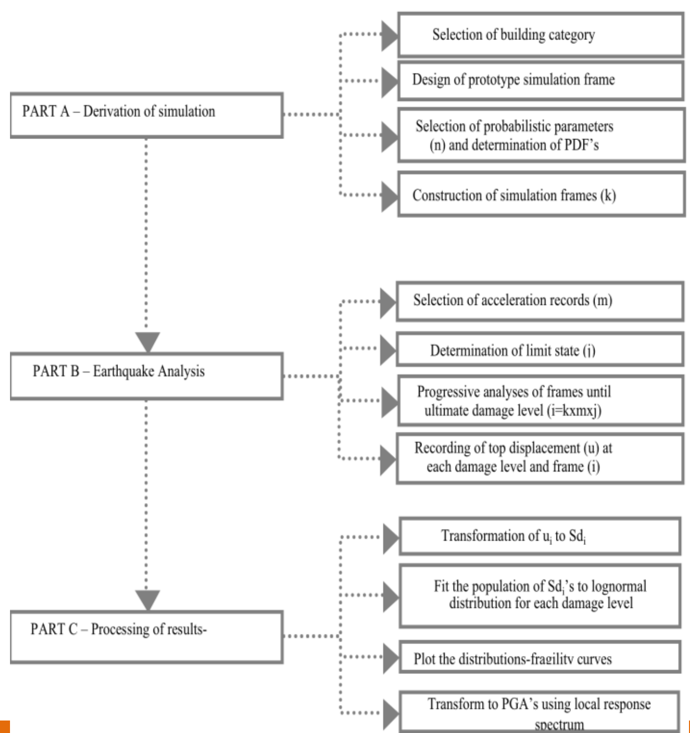
Grade 3: Substantial to Heavy Damage

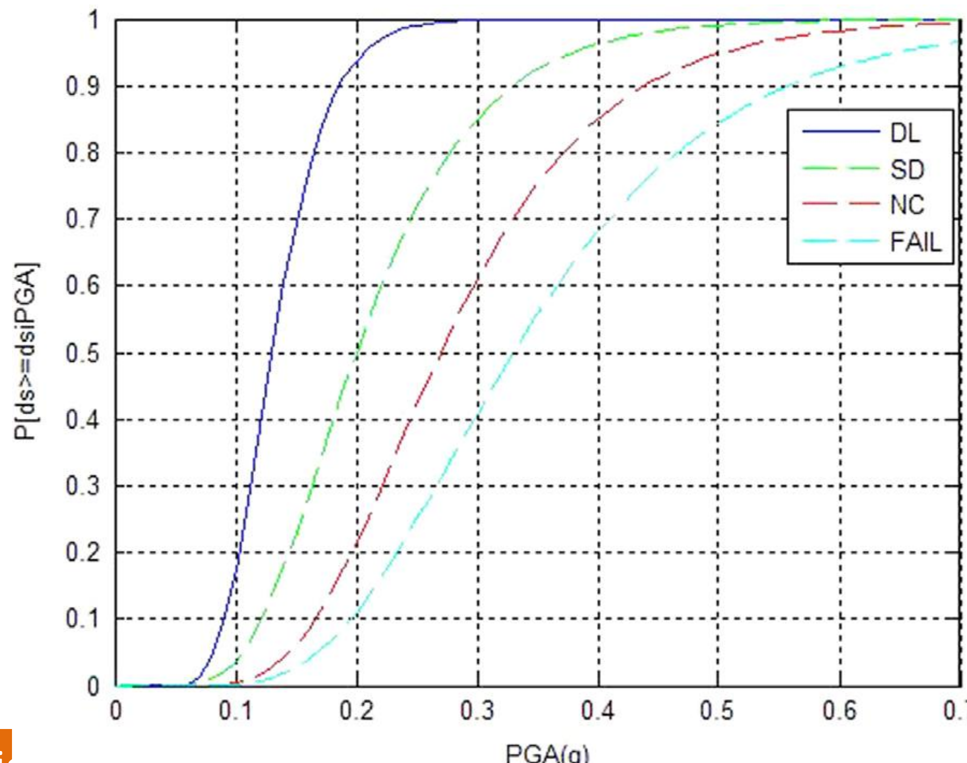
Grade 4: Very Heavy Damage

Grade 5: Destruction

Seismic Vulnerability-Fragility curves

- Fragility curves describe the relationship between the probability of being or exceeding a particular (structurally defined and representative of the building stock) damage state and the seismic hazard (PGA) and are used for detailed risk assessment (capacity demand diagram methods)-Level 2





Seismic Hazard

- For Level 2 assessment hazard is expressed in the form of local response spectra
- The derived spectra for the 2 zones defined in the Microzonation study were substituted into the software and can be used for detailed assessment at city level

Figure 4: Seismic zonation of Limassol municipality based on the Microzona

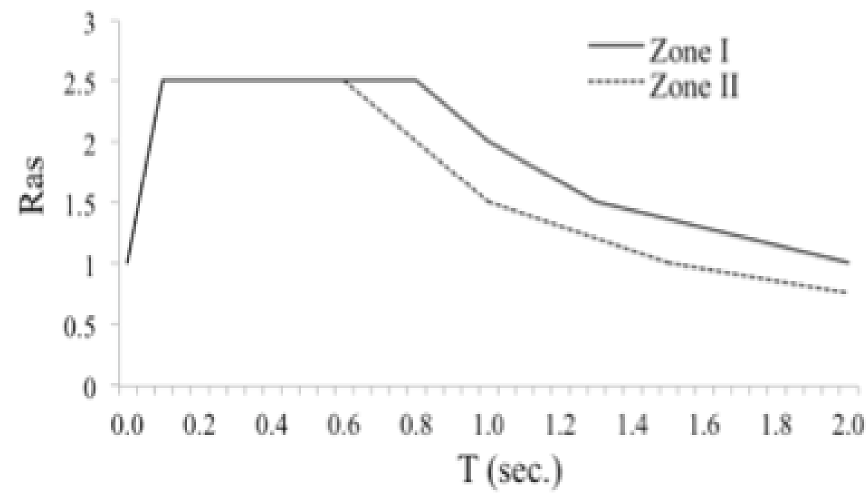
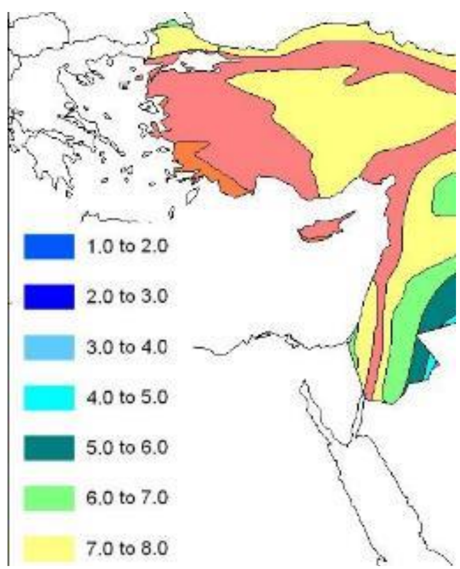
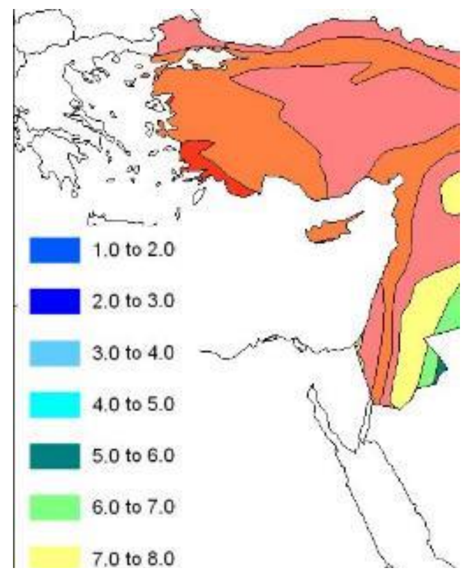


Figure 5: Normalised response spectrum for each of the two seismic zones included in Limassol Microzonation study for Limassol Municipality

Risk Assessment Scenarios

- Level 1 assessment for country level
- 2 seismic hazard scenarios were used (design with 475 year return period and maximum credible earthquake with 2475 y.)
- MMI were calculated for each scenario using local seismotectonic and geological conditions (MMI=8 and 10)





EMS-98

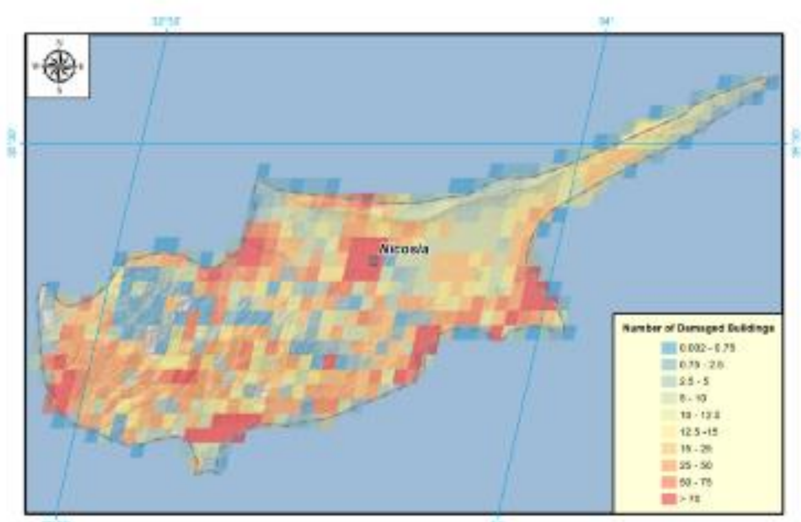
Intensity	F	I	II	III	IV	V	VI	VII	VIII
Effects	Felt	Not felt	Scarcely felt	Weak	Largely observed	Strong	Slightly damaging	Damaging	Heavily damaging

Risk Assessment Scenarios

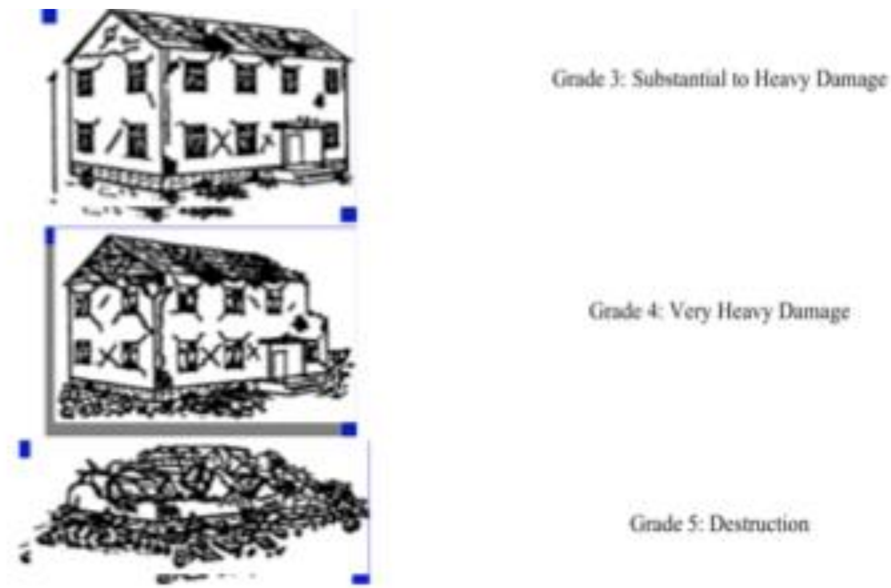
- The predictions regarding the seismic hazard for the RP=475yrs earthquake show good correlation with the design hazard map for Cyprus included in the National Annex of Eurocode 8.
- The existing design hazard map proposes a PGA=0.25g for this area. As expected lower intensities are predicted for the remaining part of the island (mainland) which is at a greater distance from the fault.

Scenario 1

- For the design earthquake the distribution of damage is shown below
- ≈ 12% of buildings with DG4+DG5 (≈ 45000 buildings)
- ≈ 20% with DG3
- As a 1st estimate 5.000 inhabitants are expected to be relocated

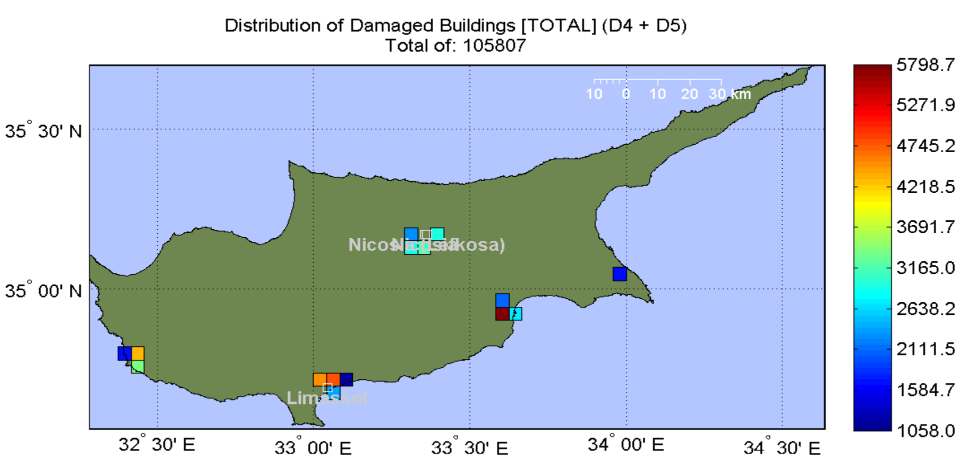


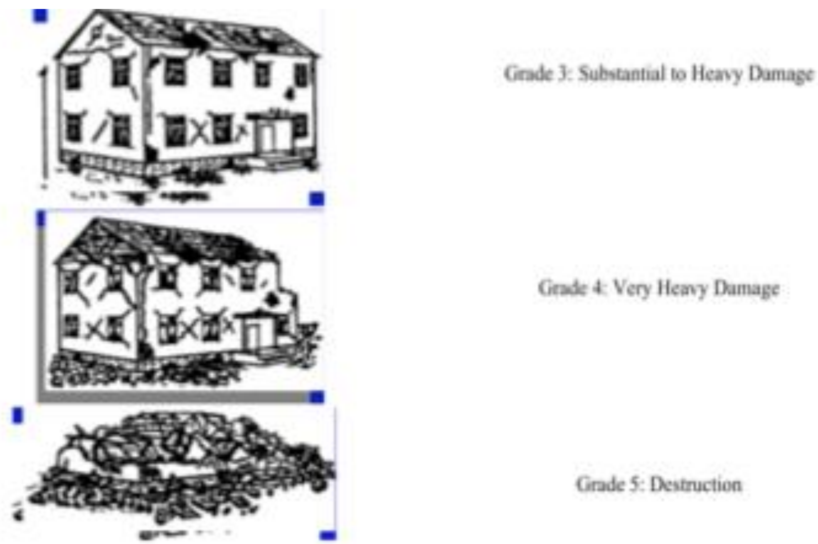
CYPRUS D4+D5 Damage Distribution
Vs30 = 300 m/s RP = 475 yrs



Scenario 2

- For the maximum credible earthquake the distribution of damage is shown below
- ≈ 30% of buildings with DG4+DG5
- ≈ 25% with DG3
- As a 1st estimate 20.000 inhabitants are expected to be relocated

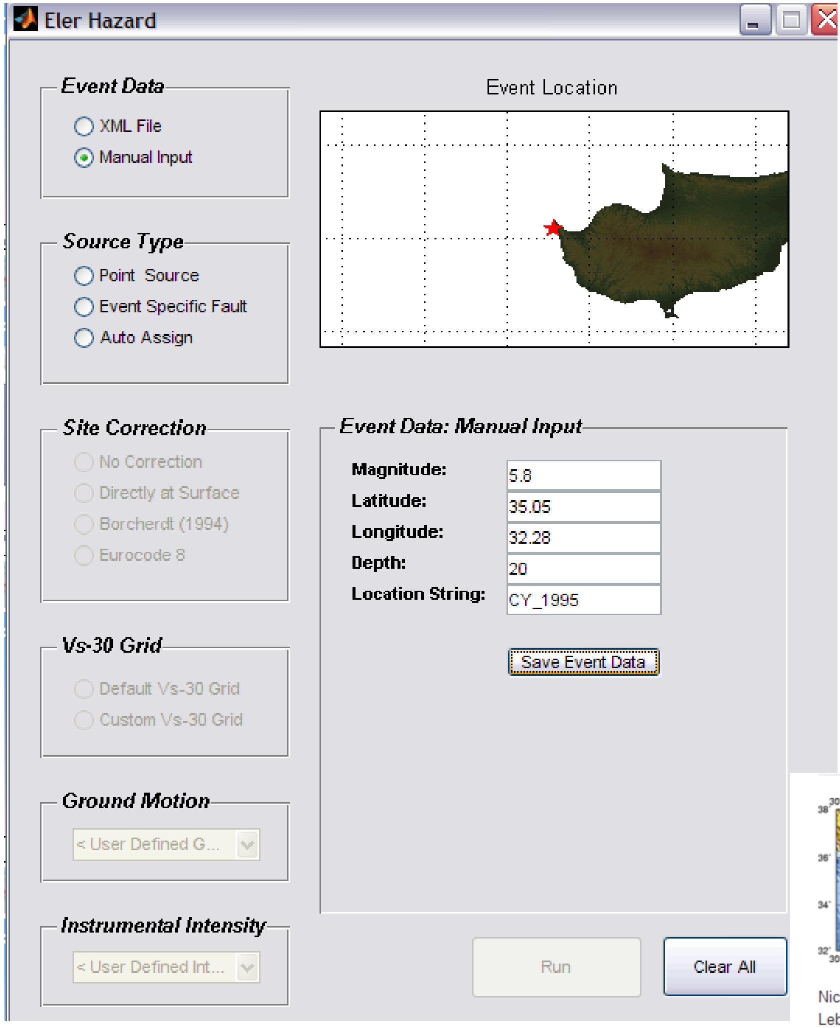


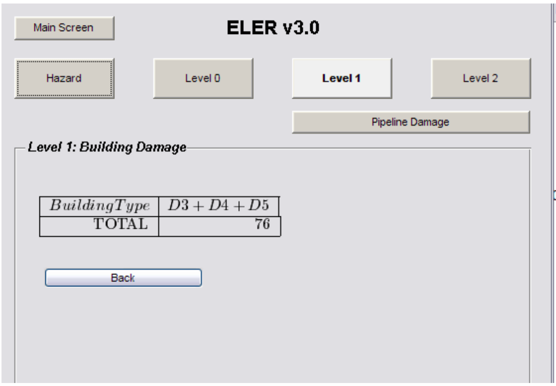


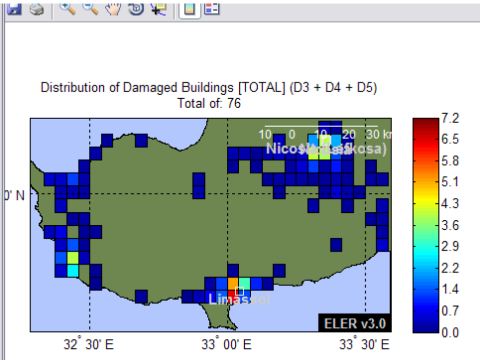
Risk Assessment methodology

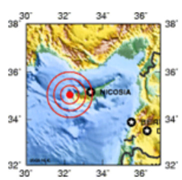
- Level 2 assessment focused on Limassol municipality using very detailed building inventory for the area. It was concluded that for the 475 yrs scenario included in the design hazard map for Cyprus (PGA=0.25g along the coast) approximately 6000 buildings will suffer extreme damage in the city of Limassol.
- The results verified closely the level 1 assessment

Simulation of 1995 Paphos earthquake





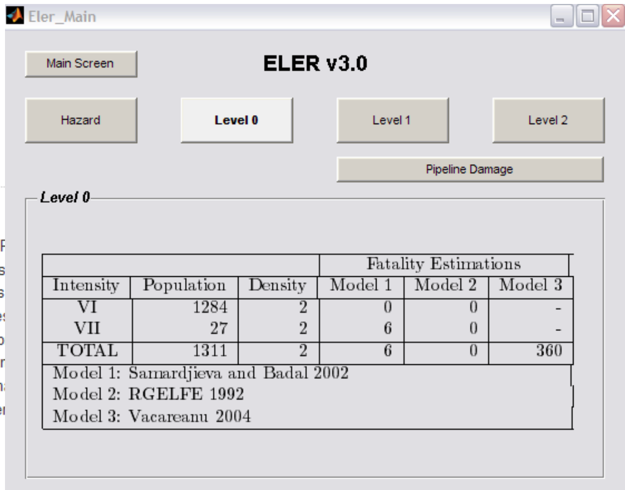




M5.9 - Cyprus, 1995

Two people killed and five injured in the F… area. Fifty houses destroyed, 70 serious… and 500 slightly damaged in the Paphos… areas. Twenty masonry houses were de… Arodhes. Felt (VII) at Arodhes, Peristero… Polis; (VI) at Kathikas, Peyia and Strou… Kykkou Monastery; (IV) at Larnaca, Lim… Nicosia; (III) at Paralimni. Felt throughout Cyprus. Also felt in northe… Lebanon.

From Significant Earthquakes of the World 1995.



Thank you for your attention