Technical University of
Civil Engineering Bucharest

# SEISMIC RISK IN ROMANIA. ASSESSMENT AND AWARENESS

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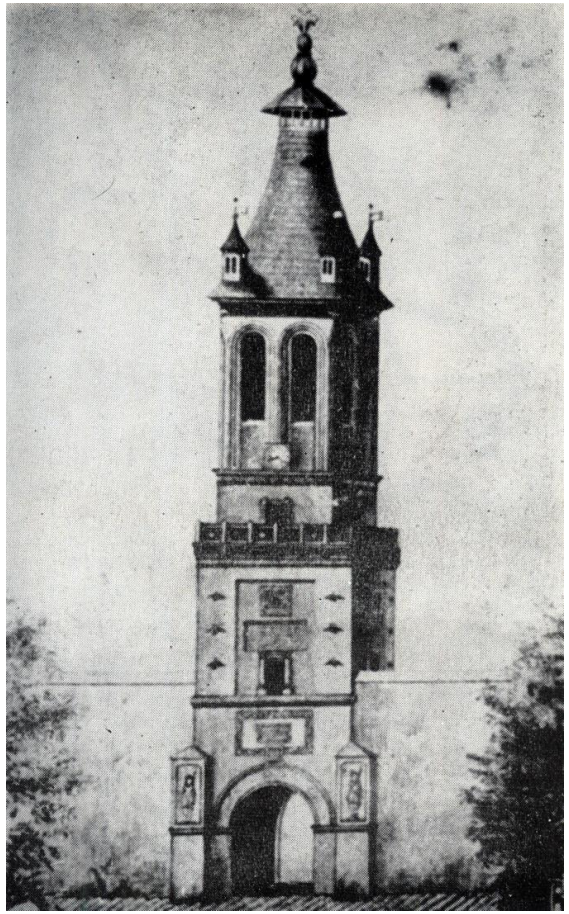
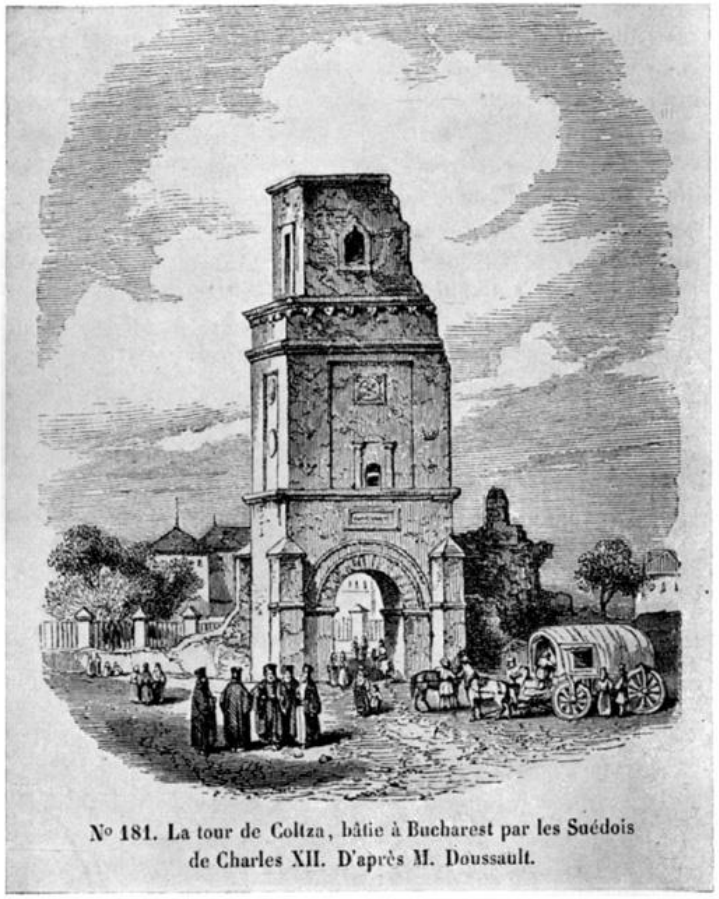
- Major earthquakes in Romania
- Seismic hazard
- Building exposure and fragility functions
- Seismic risk in Romania & Bucharest
- Seismic risk awareness in Bucharest
- Conclusions
  - Acknowledgement

# Major earthquakes in Romania

October 26, 1802 – Mw=7.9



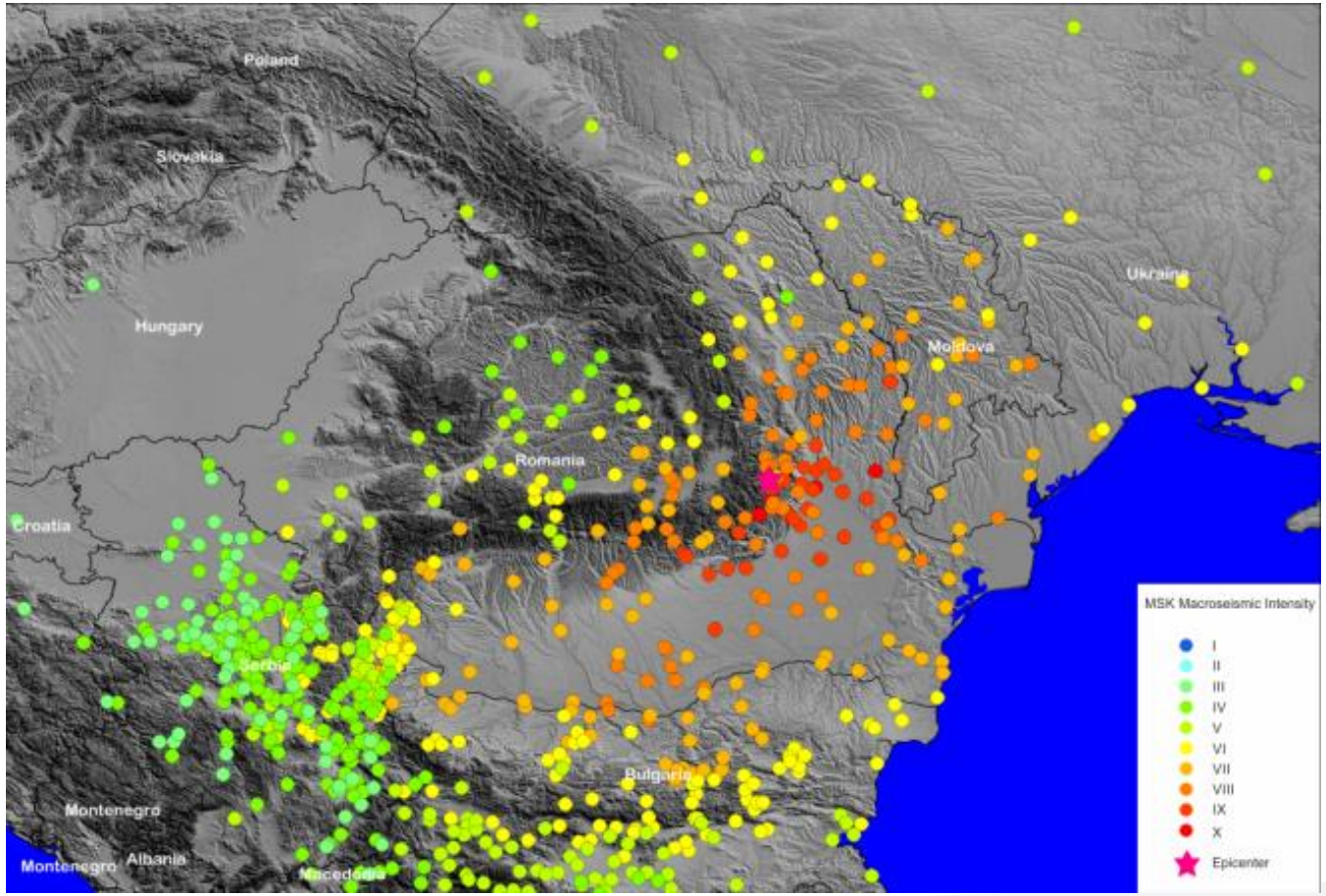


N° 181. La tour de Coltza, bâtie à Bucharest par les Suédois de Charles XII. D'après M. Doussault.

http://en.wikipedia.org/wiki/1802_Vrancea_earthquake

# Major earthquakes in Romania

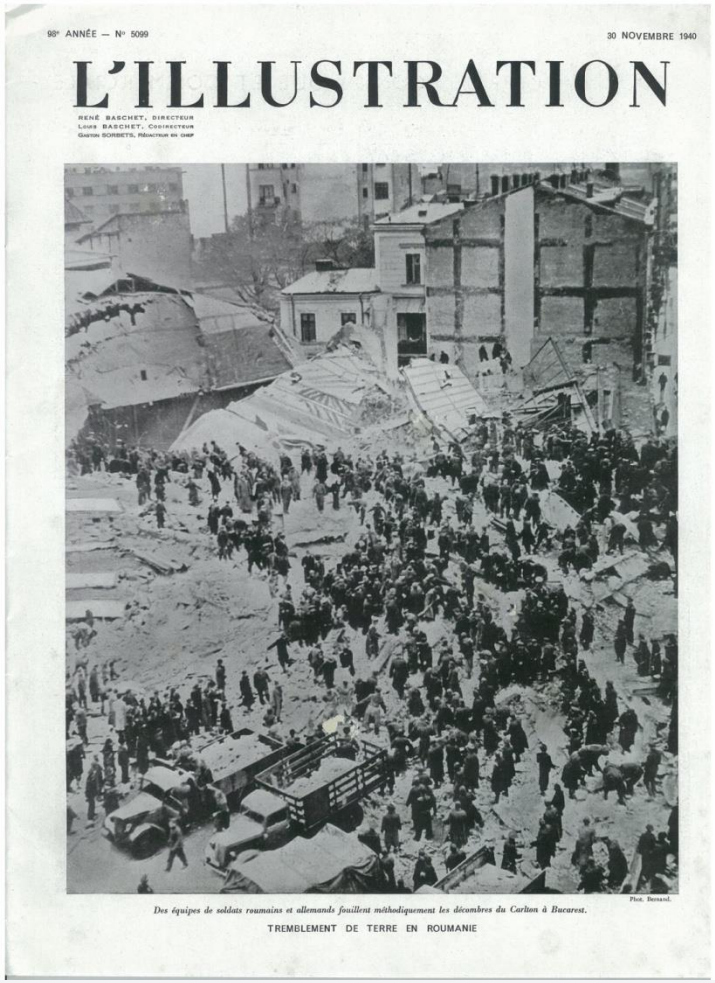
November 10, 1940, Mw=7.7, h=150 km




MSK macroseismic intensities

# Major earthquakes in Romania

November 10, 1940, Mw=7.7, h=150 km


98e ANNÉE — N° 5099 30 NOVEMBRE 1940

L'ILLUSTRATION

RENÉ BASCHET, DIRECTEUR
LOUIS BASCHET, CODIRECTEUR
GASTON SORBETS, RÉDACTEUR EN CHEF

Des équipes de soldats roumains et allemands fouillent méthodiquement les décombres du Carlton à Bucarest.

TREMBLEMENT DE TERRE EN ROUMANIE

Carlton Building (l'Illustration, 1940)



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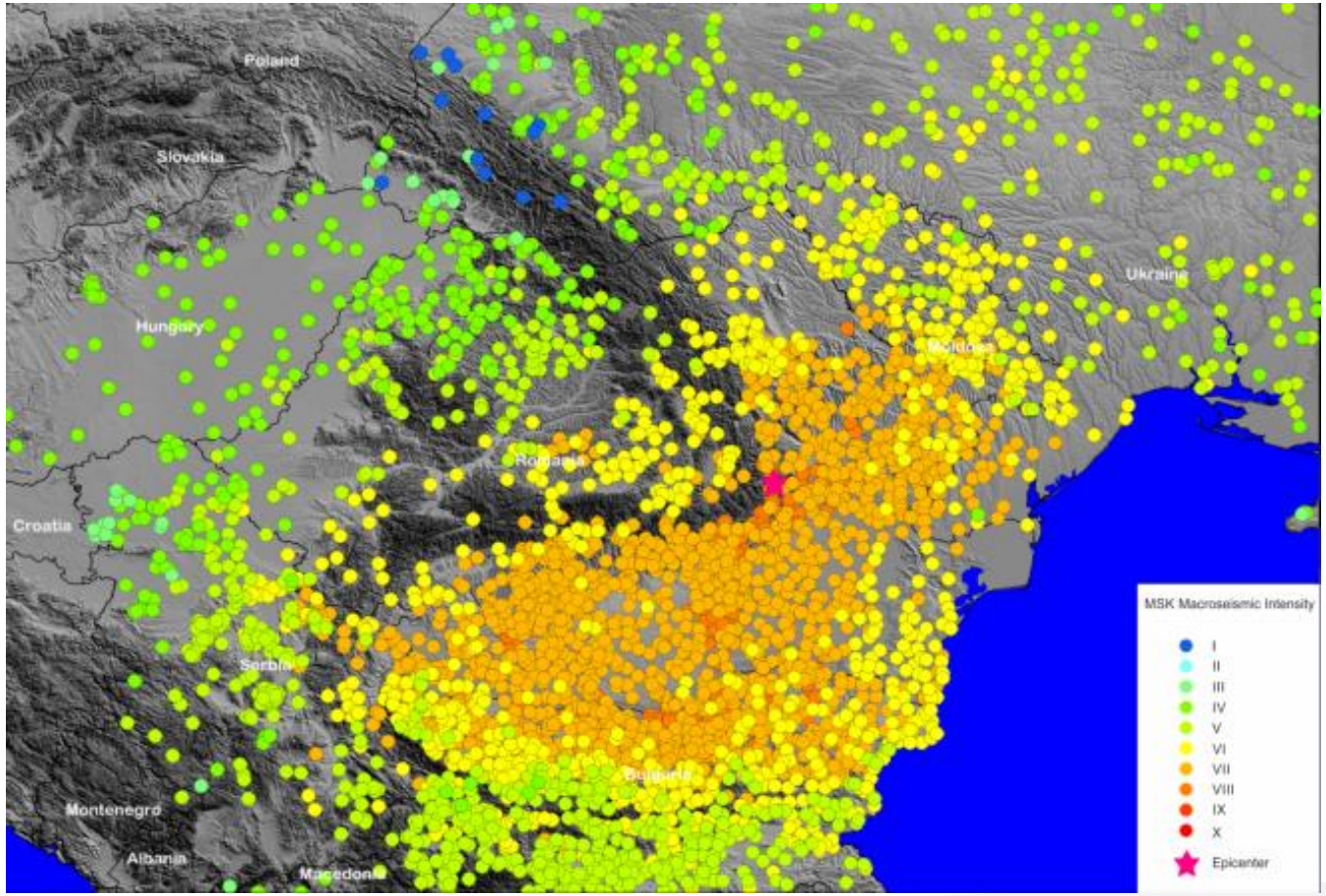
# Major earthquakes in Romania

March 4, 1977, Mw=7.4, h=94 km




MSK macroseismic intensities

# Major earthquakes in Romania

March 4, 1977, Mw=7.4, h=94 km

- 1578 deaths (1424 in Bucharest)
- 11221 injured (7598 in Bucharest)
- 32 collapsed buildings in Bucharest
- 33000 housing units destroyed or severely damaged
- Total losses: 2.05 bn USD (in excess of 6% of GDP)

(Source: World Bank Report)

# Major earthquakes in Romania

March 4, 1977, Mw=7.4, h=94 km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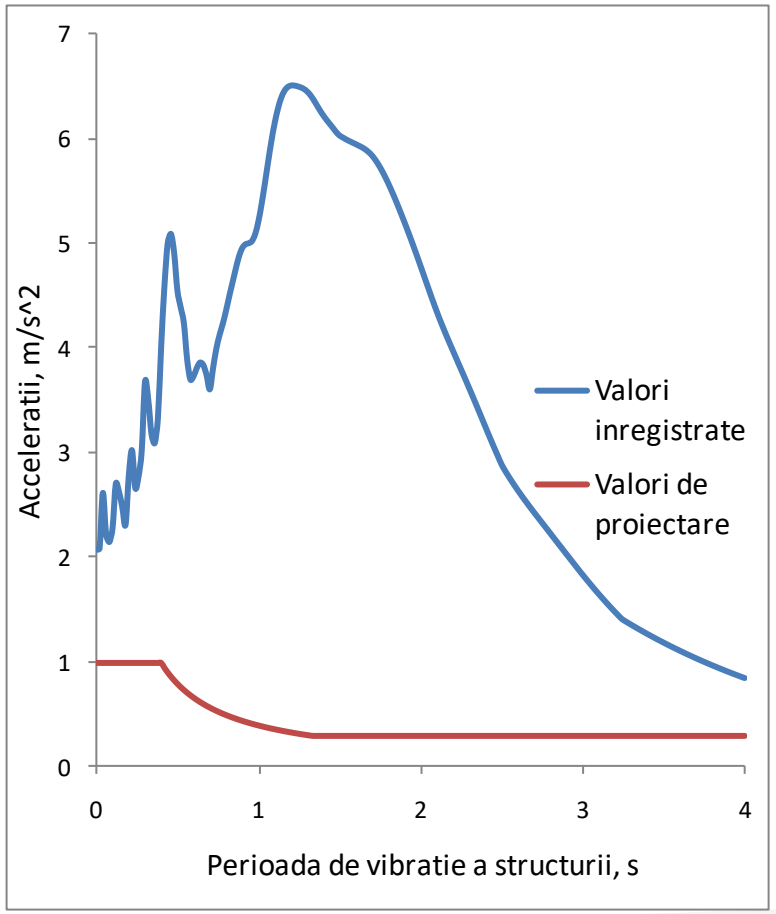
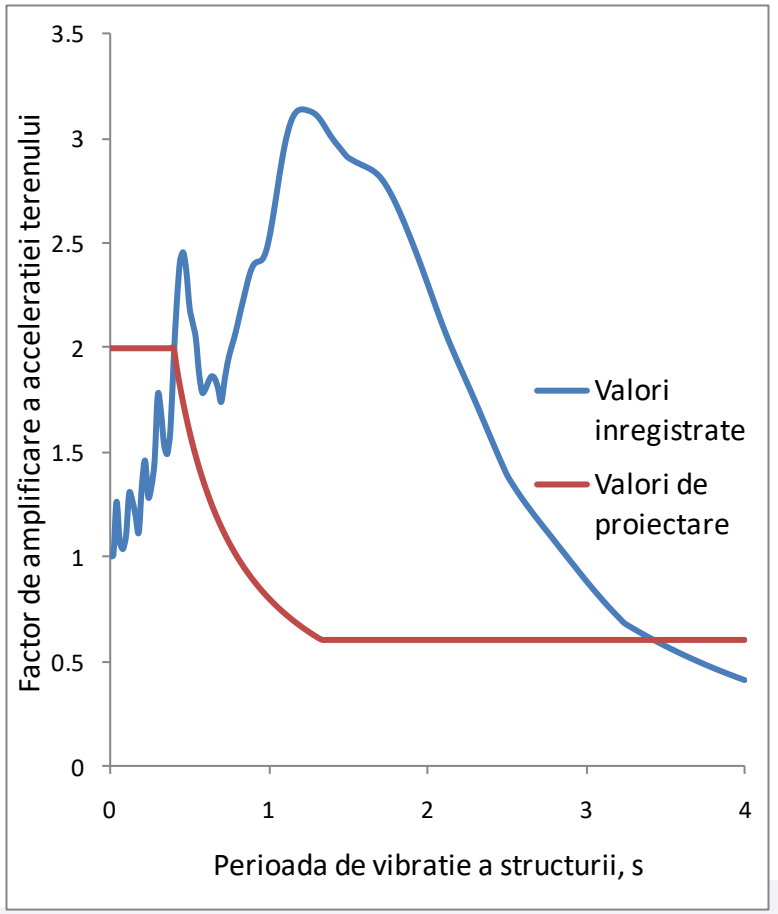
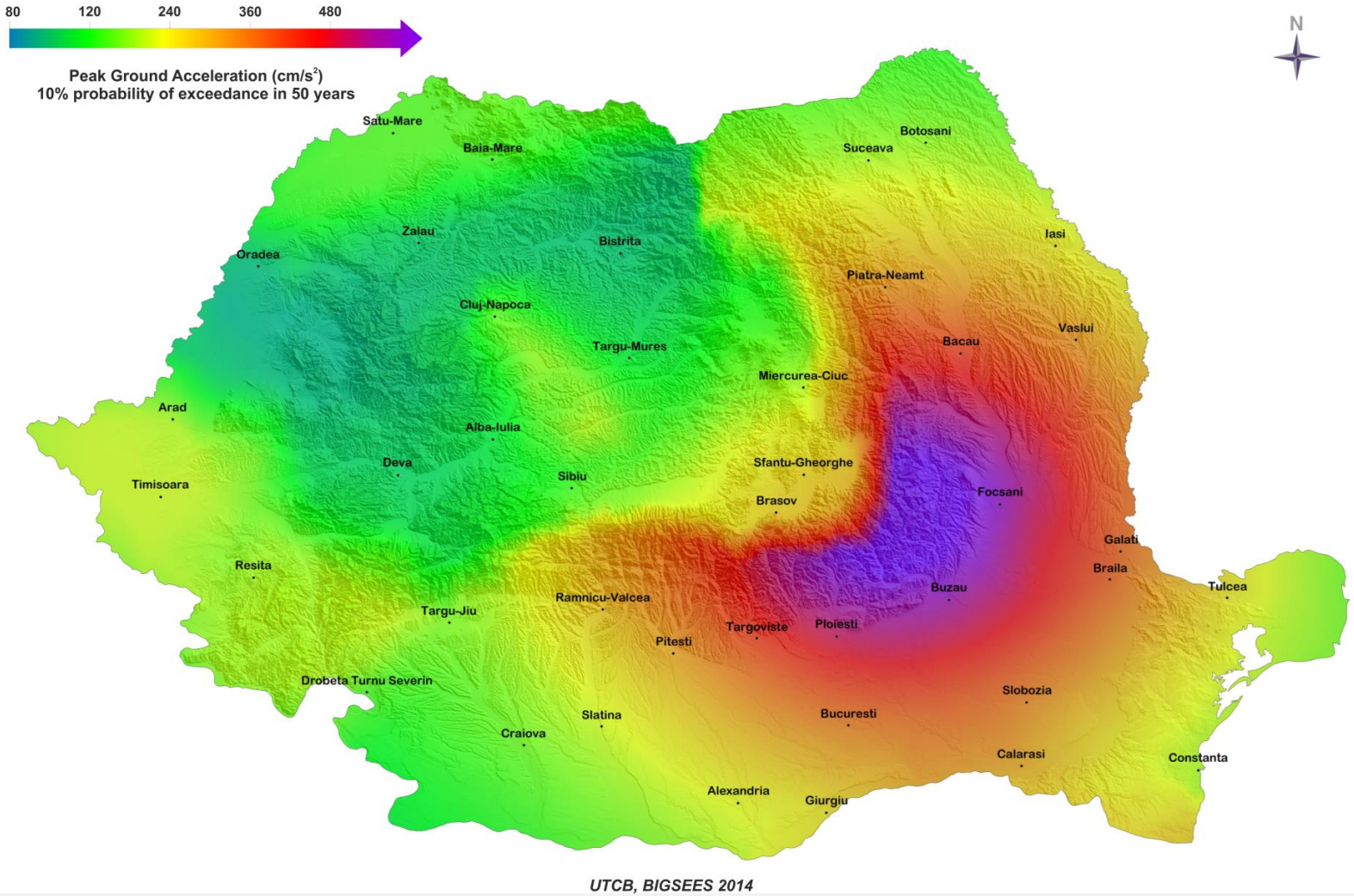



Digitized recorded ground motion (left), acceleration response spectra (centre) and normalized acceleration response spectra (right) – blue – recorded values; red – design values

# Seismic hazard of Romania

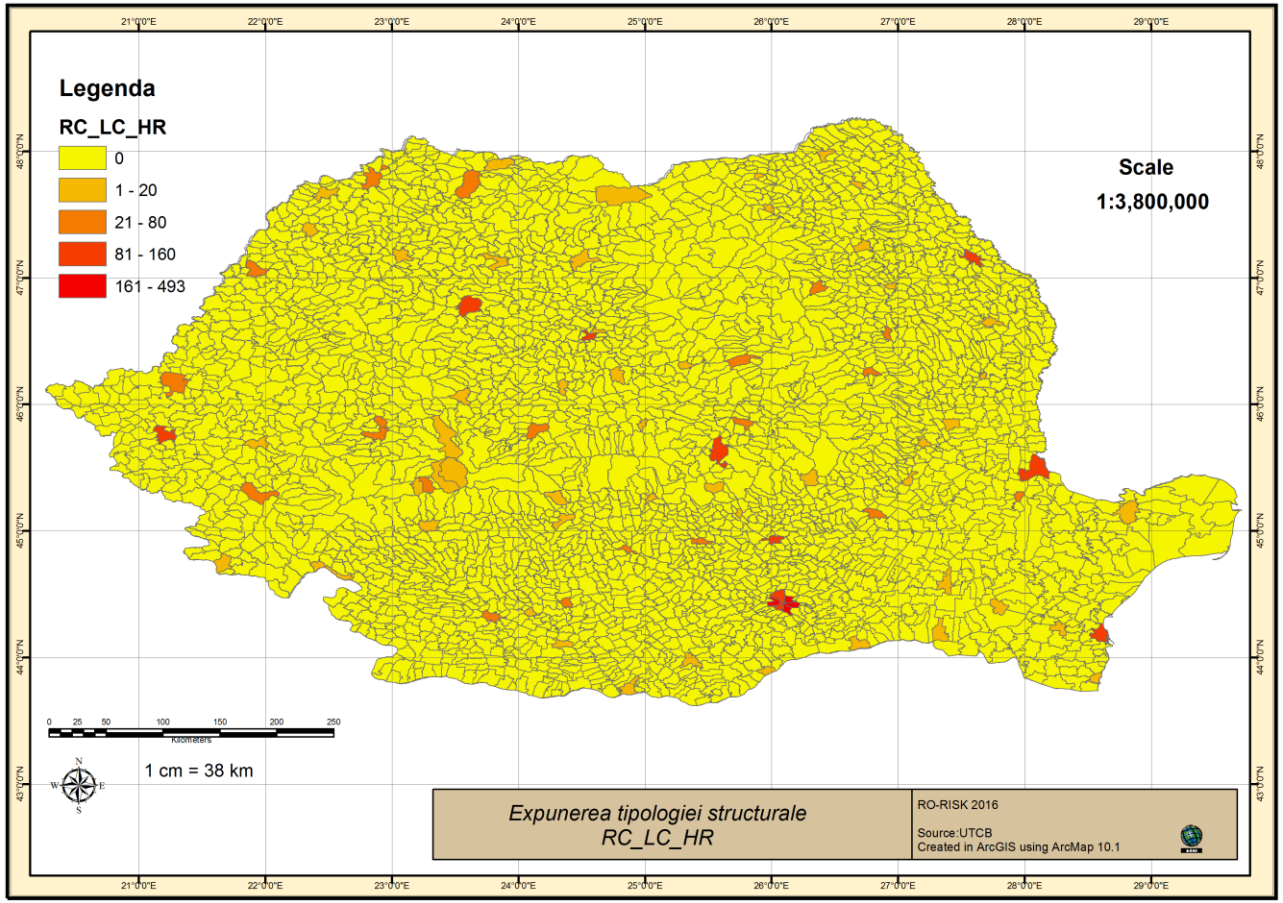


# Exposure

Exposure data - available from the latest census of 2011 (Arion et al., 2018)

| | 1992 Census | 2002 Census | 2011 Census |
|---|---|---|---|
| Population | 23.286.794 | 22.628.665 | 20.121.641 |
| No. of buildings | 4.482.119 | 4.837.215 | 5.341.908 |
| Housing units | 7.666.181 | 8.111.391 | 8.723.699 |
| GDP (current US$ Billions) | 25,12 | 46,18 | 185,36 |

# Building exposure




Distribution of number of reinforced concrete high-rise buildings designed according low seismic code by census unit
(RO-RISK Project)



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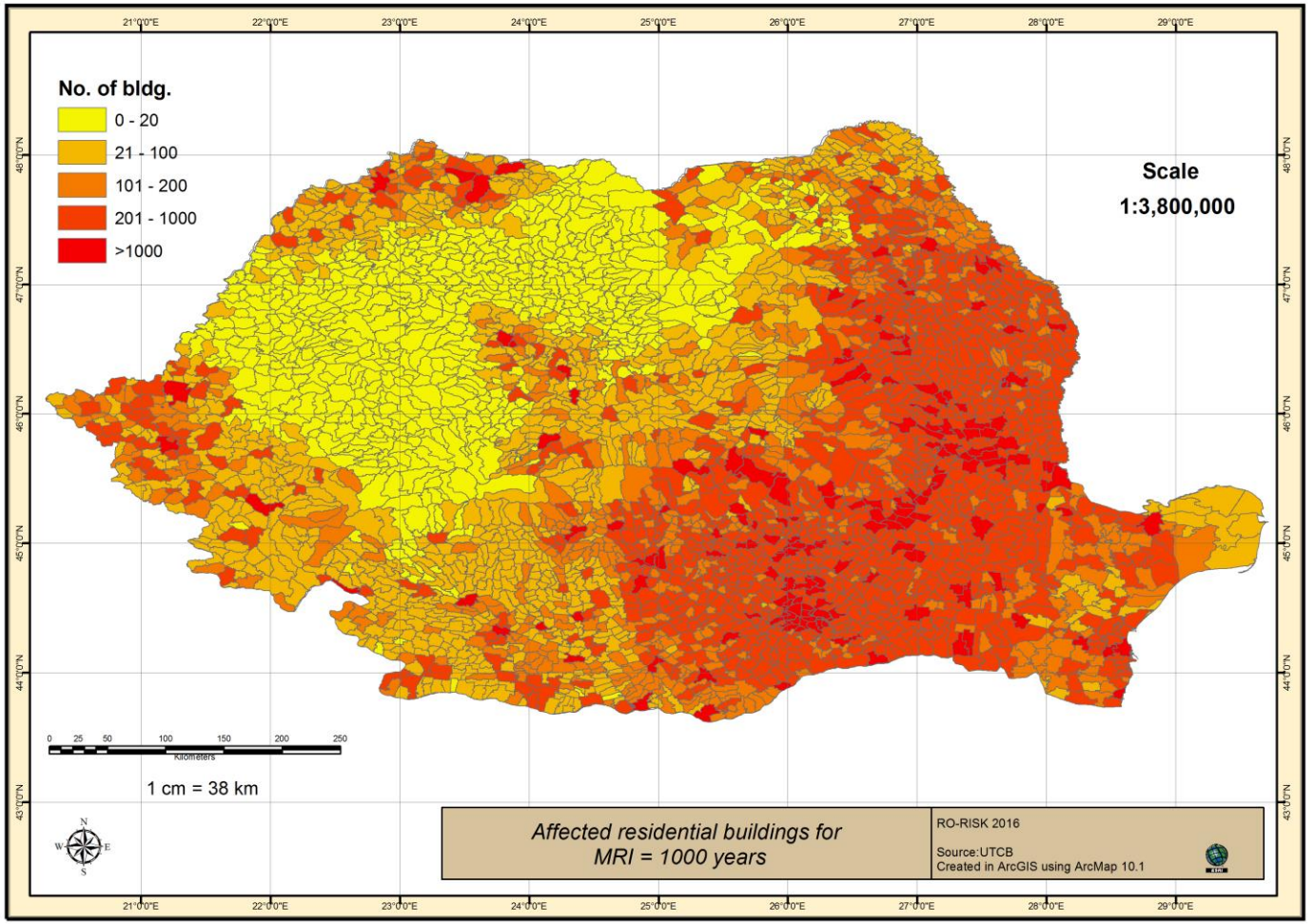
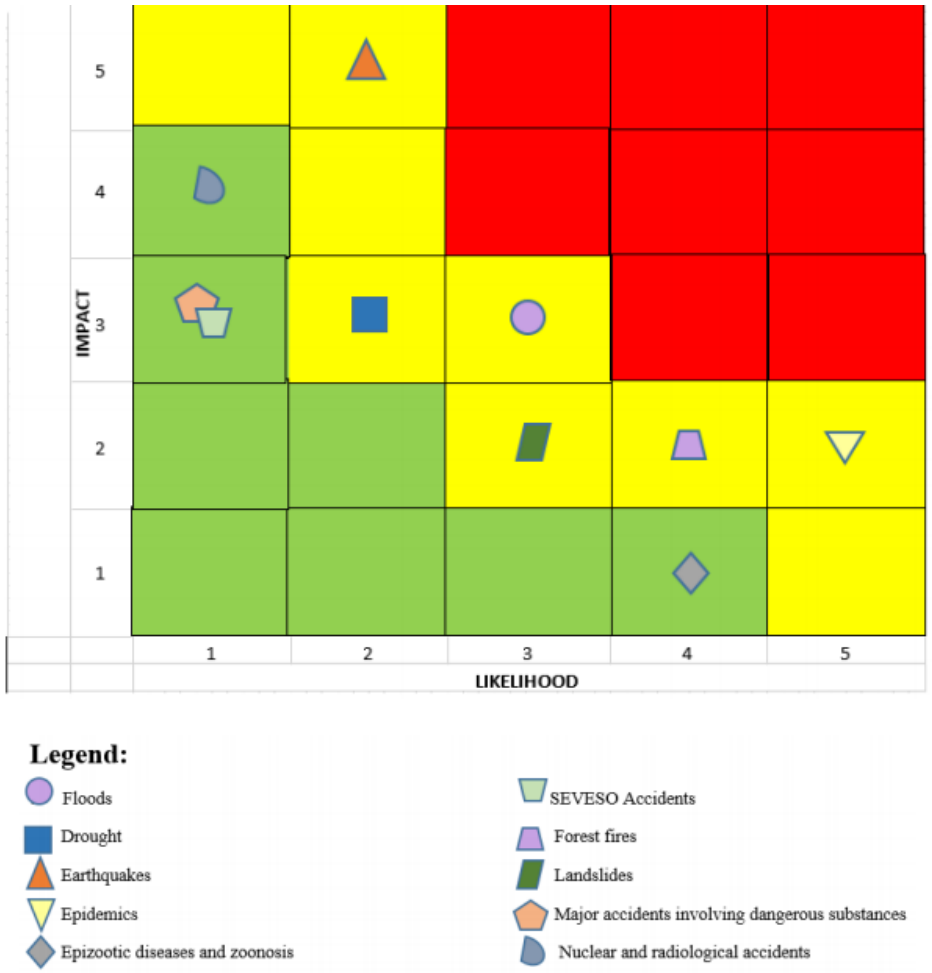
# Seismic risk in Romania




Distribution of number of damaged buildings for an earthquake scenario with 1000 years MRP (RO-RISK Project)

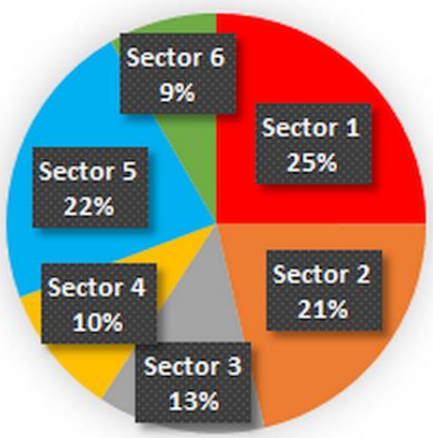
# Seismic risk in Romania



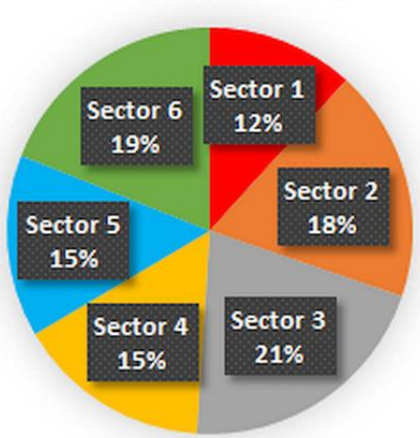

Risk matrix for Romania (RO-RISK Project)
(https://www.igsu.ro/index.php?pagina=analiza_riscuri)

# Building exposure in Bucharest

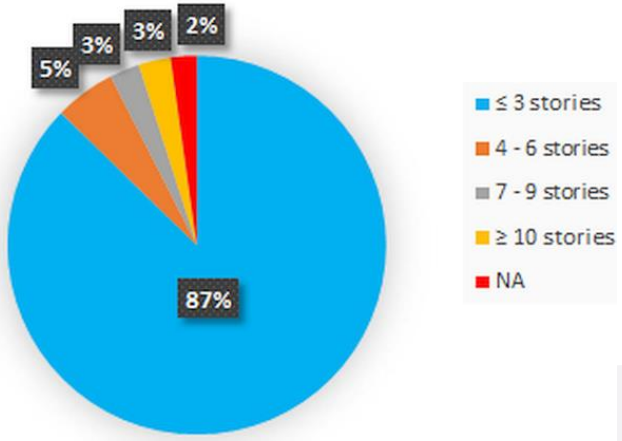
**Share of buildings**



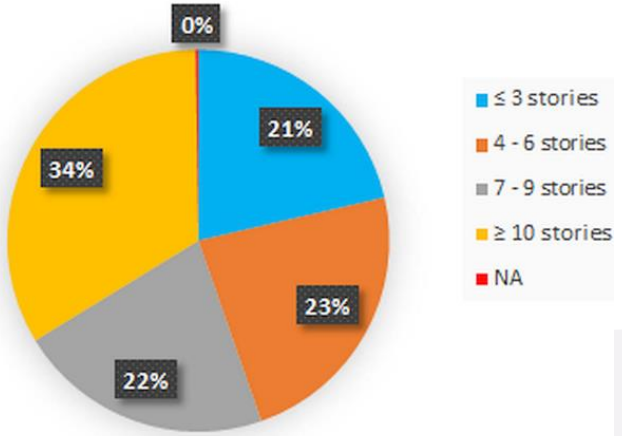

**Share of population**




**No. of stories**




**Population**



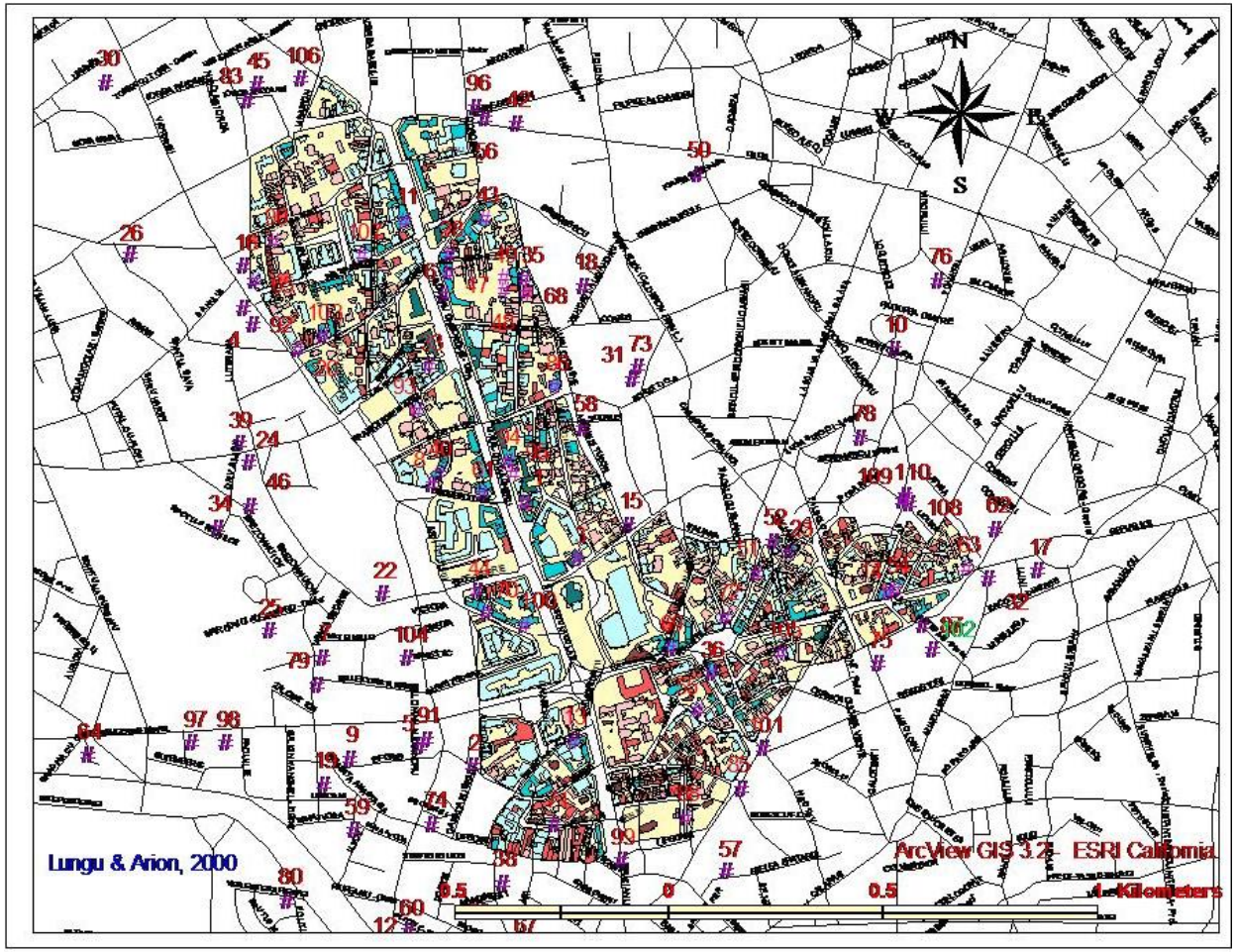



Pavel & Vacareanu, 2016 - IJDRR

# Building exposure in Bucharest

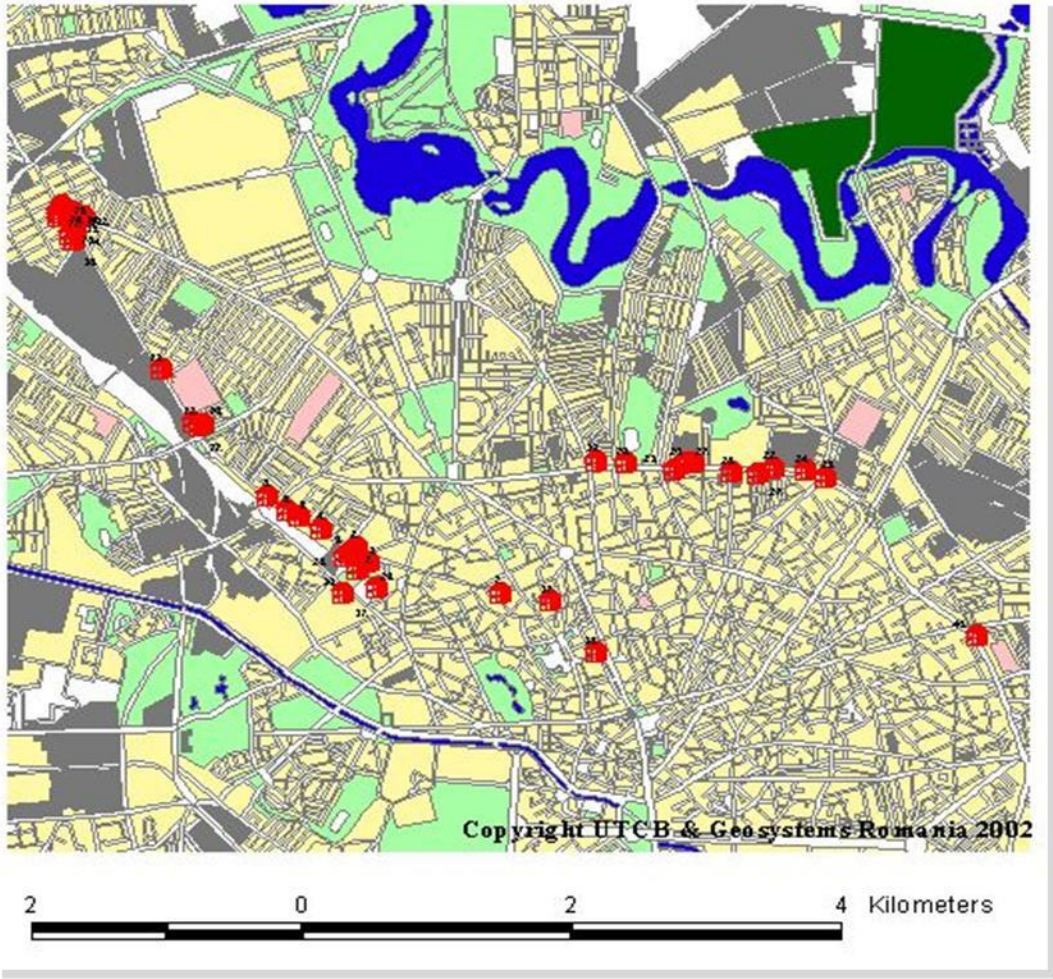
- Main characteristics of existing residential building stock of Bucharest (Pavel and Vacareanu, 2016; Pavel et al. 2017):
  - More than 60% of the existing building stock - built prior to Vrancea 1977 earthquake
  - Around 5% of the number of residential buildings have more than nine stories in height, the majority being in Districts 2, 3 and 6 (District is equivalent to Sector)

# Building exposure in Bucharest



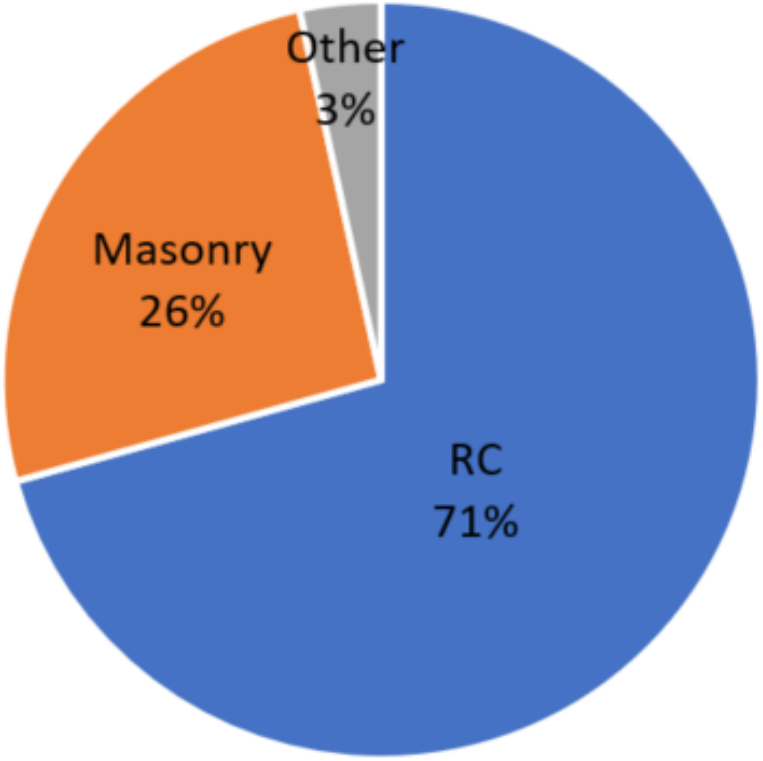

Identified seismic risk class I residential buildings in Bucharest

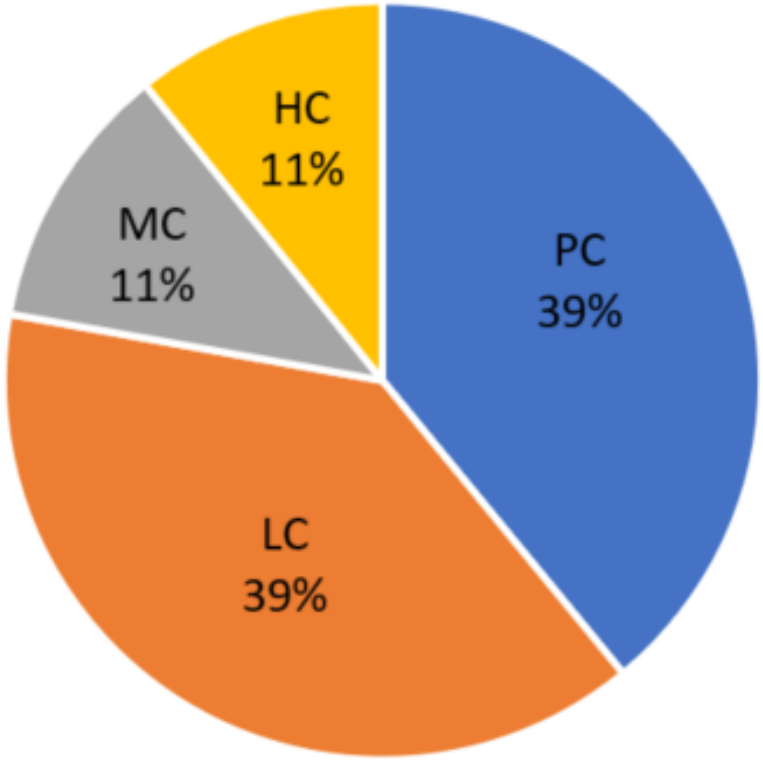
# Building exposure in Bucharest

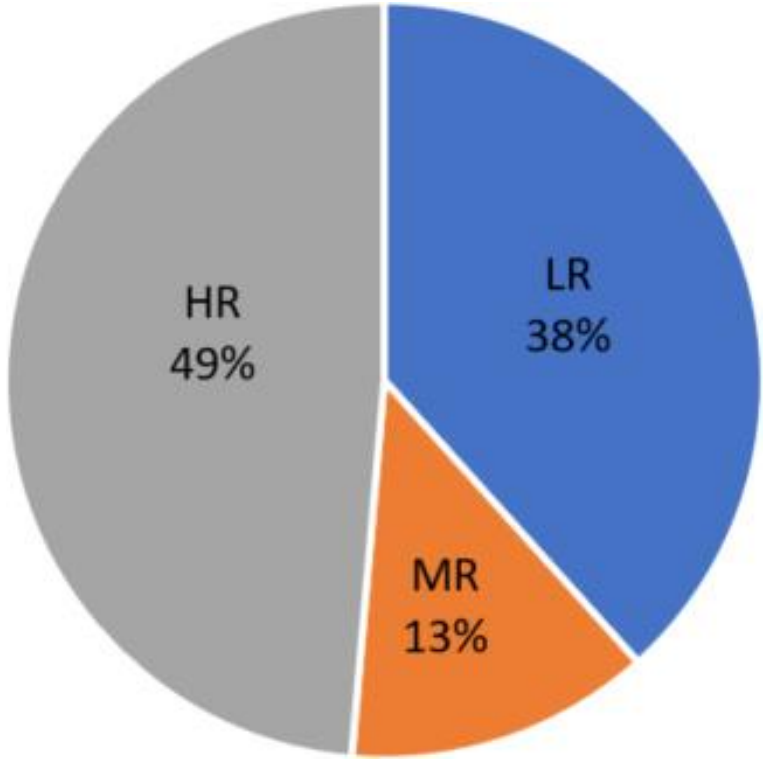



Soft and weak groundfloor residential buildings in Bucharest

# Seismic risk in Bucharest



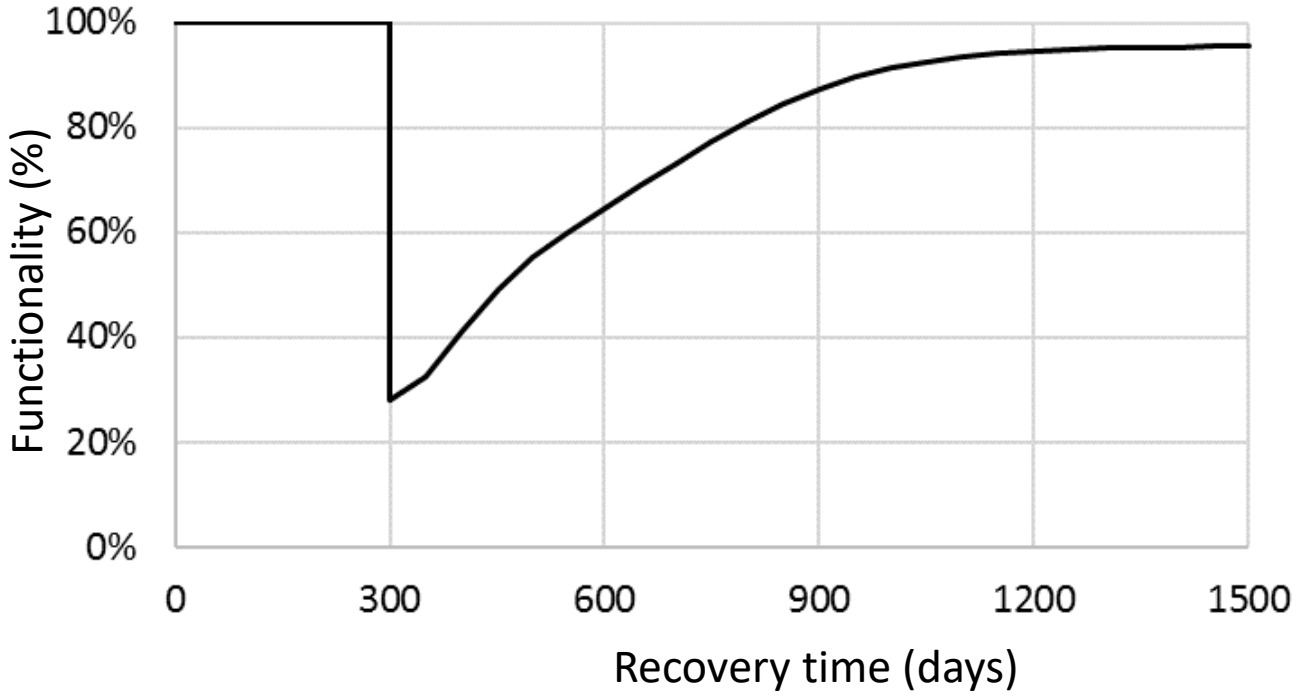




Relative contributions to total direct losses for a Mw 7.5 Vrancea earthquake function of building material (left), seismic design (centre) and height (right) using HAZUS approach (Pavel et al., 2018)

# Seismic resilience of Bucharest

**Earthquake scenario**

- Source: Vrancea intermediate
- Magnitude $M_W$ = 7,5
- Focal depth $h$ = 90 km
- Epicentral distance $d$ = 120 km




Note: Functionality parameter: number of housing units in Bucharest

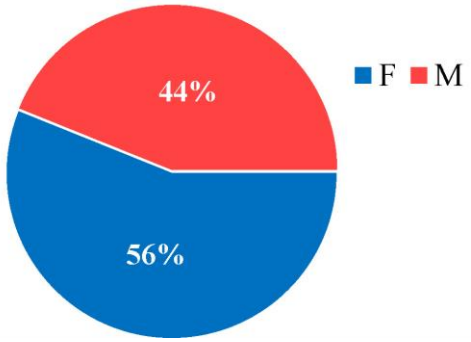
# Seismic risk & resilience in Bucharest

- Direct losses for residential buildings in Bucharest for an EQ scenario with 1000 years MRP can be as high as 8% of the GDP of Romania
- Mean economic losses are in the range 5 – 13 bill. €
- Time necessary for restoring 95 % of the pre-earthquake housing capacity (Burton et al. 2014) - between 550 days for $M_W$ = 7.0 scenario and over 2000 days for $M_W$ = 8.0 scenario

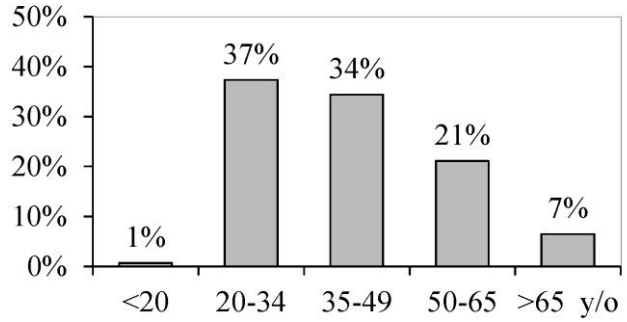
# Seismic risk awareness in Bucharest

- February to September 2016 - Survey to investigate the risk awareness, preparedness and expectations of Bucharest population (CoBPEE Project); 1000 respondents to online and paper questionnaires
- Questions grouped into four parts quantifying: level of education and awareness regarding the occurrence of a major earthquake in Romania; importance of structural safety; level of damage/losses expected by population after a major earthquake; level of post-earthquake community involvement

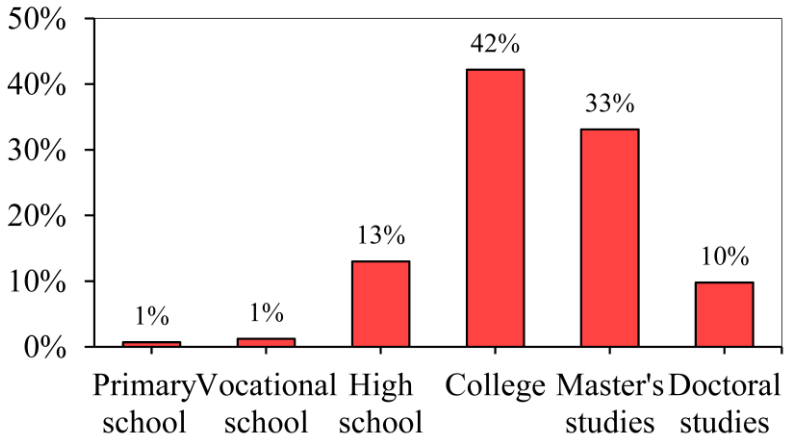
# Seismic risk awareness in Bucharest



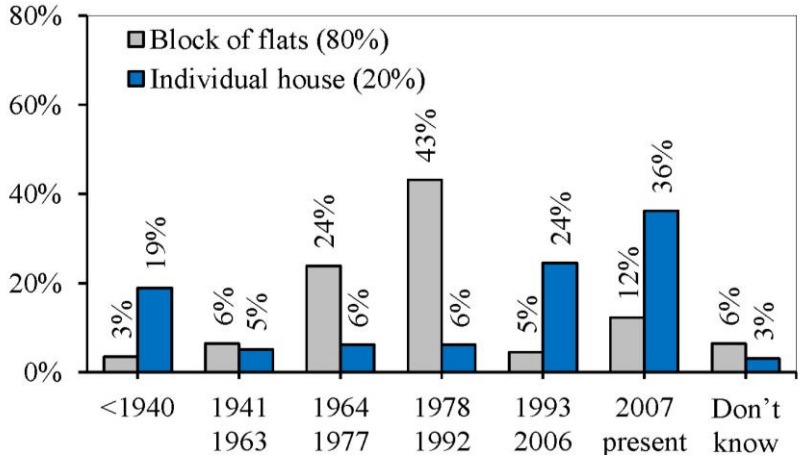

Sex distribution of respondents




Age distribution of respondents




Education distribution of respondents



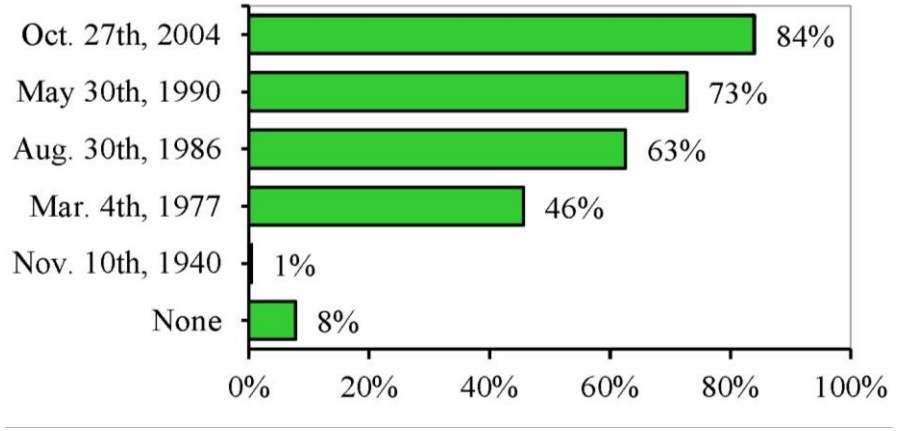

Distribution of individual houses and blocks of flats with year of construction



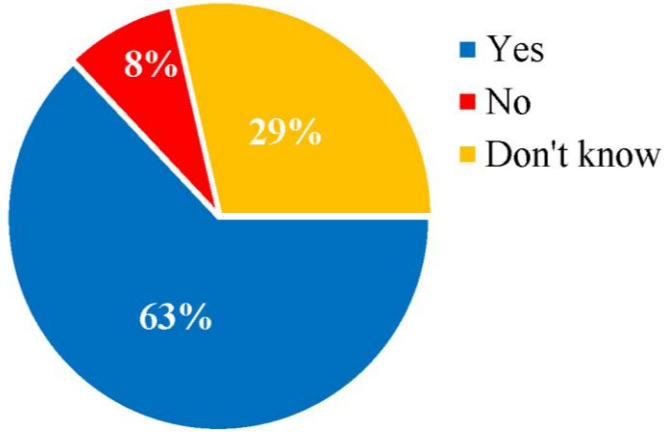
I. Calotescu, F. Pavel and R. Vacareanu (2018). Earthquake Risk Awareness in Bucharest, Romania: Public Survey, in R. Vacareanu and C. Ionescu (eds.), Seismic Hazard and Risk Assessment, Springer Natural Hazards

# Seismic risk awareness in Bucharest

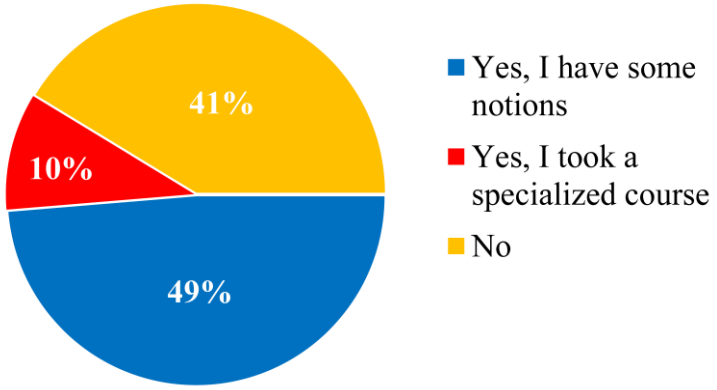
Vrancea earthquakes felt by respondents



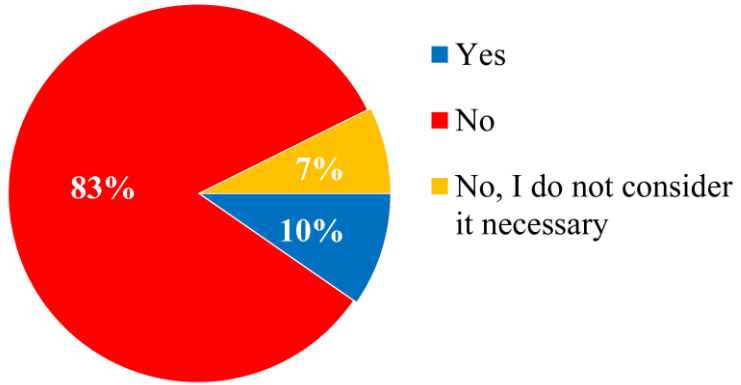

Do you believe there is a risk of occurrence of a major earthquake in Romania in the coming years?




Do you know how to perform first aid?




Do you have a meeting place with your family in case of a major earthquake?



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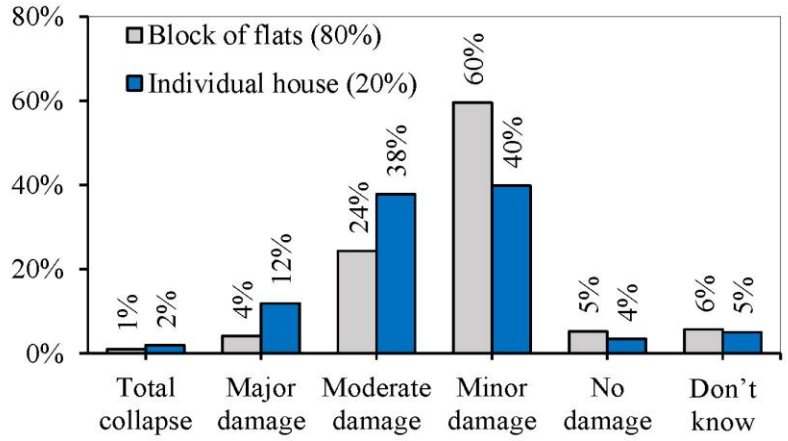
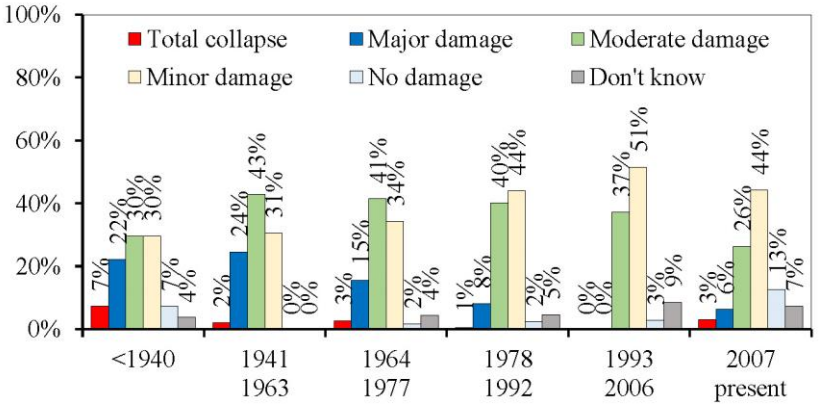
# Seismic risk awareness in Bucharest

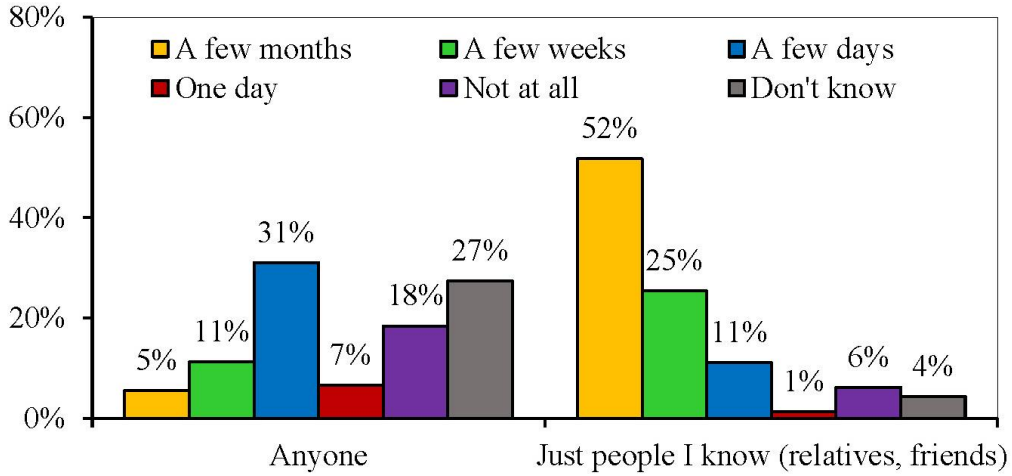
Expectation of respondents related to seismic damage to their buildings




Expectation of respondents related to damage degree vs. year of construction for blocks of flats




After a major earthquake, to whom would you be willing to provide shelter for a short period of time?

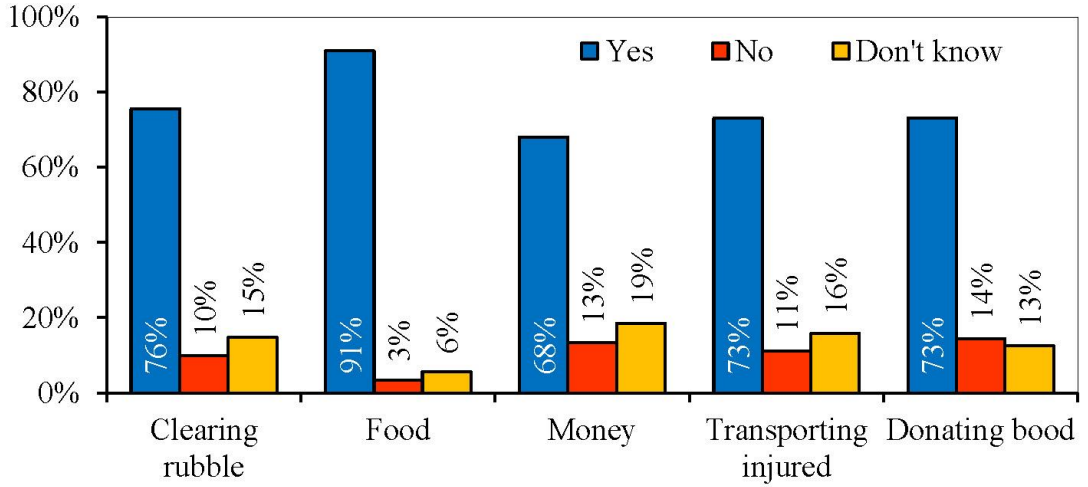




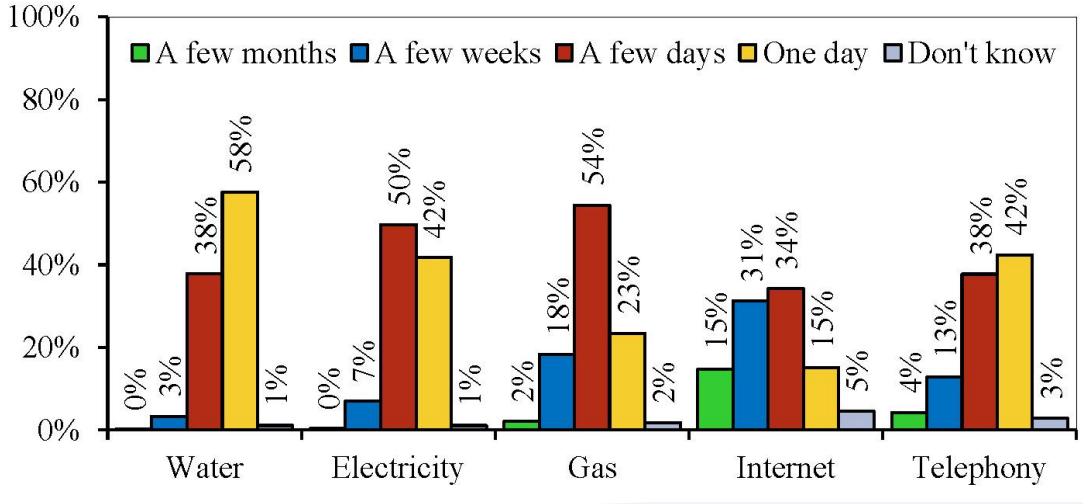

I. Calotescu, F. Pavel and R. Vacareanu (2018). Earthquake Risk Awareness in Bucharest, Romania: Public Survey, in R. Vacareanu and C. Ionescu (eds.), Seismic Hazard and Risk Assessment, Springer Natural Hazards

# Seismic risk awareness in Bucharest

After a major earthquake, what type of humanitarian assistance would you offer?




After a major earthquake, what period of time would you find it acceptable for water, gas, internet or telephone provision/services to be restored?



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# Conclusions

- Seismic resilience – a paradigm shift absolutely needed in Romania
- Quest for seismic resilience
- Insurance premiums – tool for performance based design and seismic rehabilitation, not used so far
- Involvement of reinsurance companies and industry – weak, so far
- Increase public awareness – daunting task

# Conclusions

- Program for seismic retrofitting of residential buildings – hard to implement
- Program for seismic retrofitting of public buildings – more focus and visibility; World Bank support is highly valuable and fully acknowledged
- Seismic risk of Bucharest – very high; social and economic impact – very high; mitigation, possible
- An approach similar to *National Earthquake Hazards Reduction Program (NEHRP) - A research and implementation partnership* – is definitely needed

# Acknowledgements


- Full gratitude to Romanian and Japanese taxpayers
- Results presented - obtained in the research projects: **BIGSEES** (BrIdging the Gap between Seismology and Earthquake Engineering: From the Seismicity of Romania towards a refined implementation of Seismic Action EN 1998-1 in earthquake resistant design of buildings), **COBPEE** (Community Based Performance Earthquake Engineering) and **RO-RISK** (Disaster risk assessment at national level)

# Acknowledgements


- Members of BIGSEES, COBPEE and RO-RISK teams acknowledge the support of Ministry of National Education, Emergency Situations Department, General Inspectorate for Emergency Situations and European Social Fund
- The author conveys his full gratitude to Alanna Simpson for the kind invitation and outstanding support and to Maryia Markhvida for the perfect organization of the Session - Seismic Risk in Multifamily Apartment Buildings: Engineering, Social, Financial, and Policy Implications


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# Thank you!

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