World Conference on Disaster Reduction
18-22 January 2005, Kobe, Hyogo, Japan

Seismic risk mitigation in the Romania-

Synergy from international projects

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(ii) Fragility of existing building stock and evolution of codes for earthquake resistance of buildings

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(i) *Recurrence of subcustral seismic hazard in Romania and experience of the 1977 seismic disaster*

"Nowhere else in the world is a center of population so exposed to earthquakes originating repeatedly from the same source"

Charles Richter. 15 March 1977,
Letter to the Romanian government

World Map of Natural Hazards prepared by the Münich Re, 1998 indicates for Bucharest: "Large city with Mexico-city effect"

1000 yr catalogue of subcrustral Vrancea earthquakes

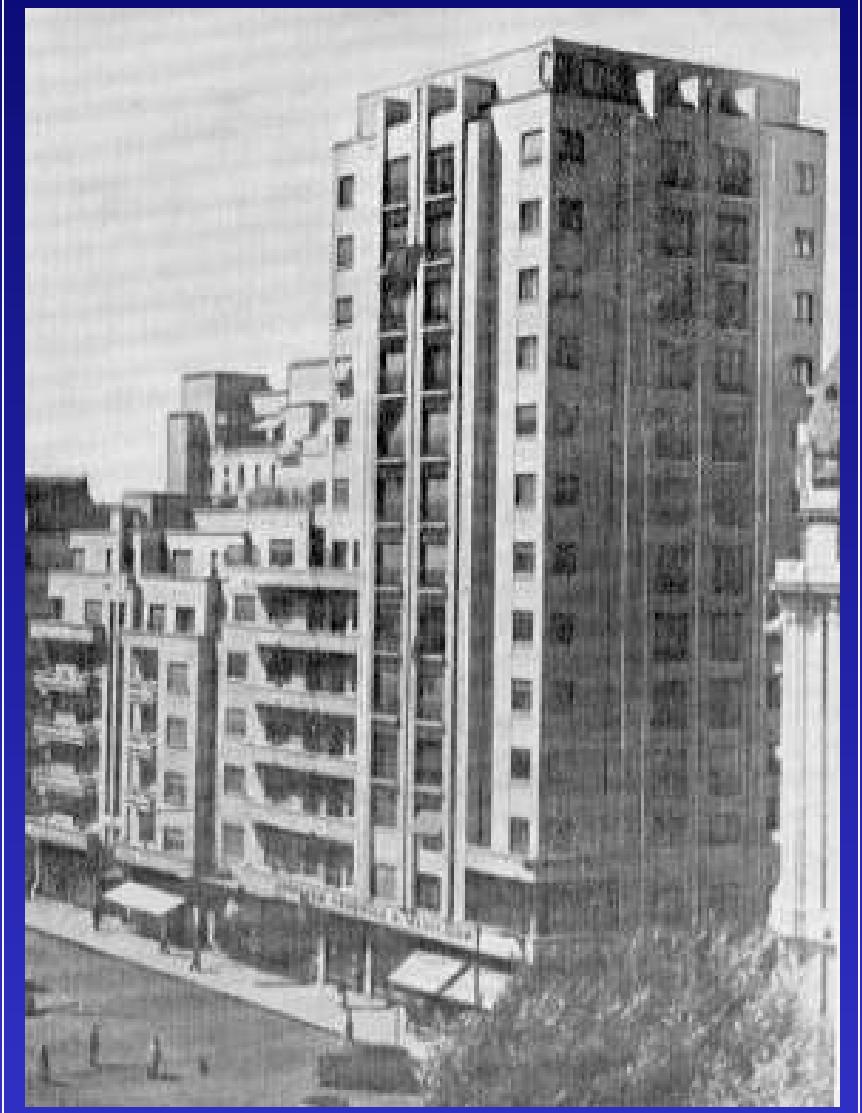
- *Major historical events and major 20 century earthquakes*

Event	Epicentral intensity I_o	Focus depth. km	Moment magnitude M_w	Obs
1802, October 26	> 9		7.9	Largest Vrancea event ever occurred
1829, November 20	IV < 8			
1838, June 23	8			
1940, November 10	9	150	7.7	Largest seismic losses ever experienced
1977, March 4	8/9	109	7.5	
1986, August 30	7/8	133	7.2	

November 10th, 1940 earthquake

$M_w = 7.7$

$h \cong 150$ km



Collapse of the Carlton building–the tallest RC building in Bucharest:

- 11 storey,
- h = 47 m,
- 130 death

March 4, 1977 earthquake

M_w = 7.5 ; h = 109 km

Killed 1,578 people (1424 in Bucharest)

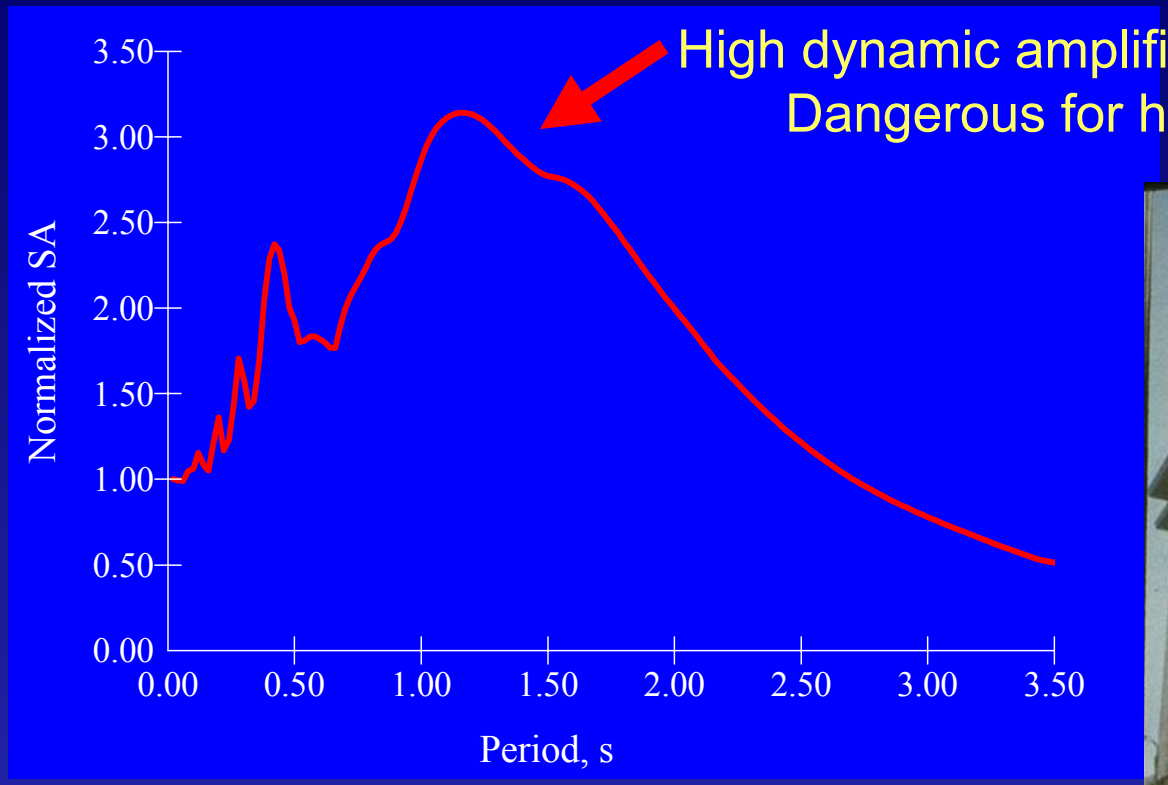
Injured 11,221 people (7598 in Bucharest)

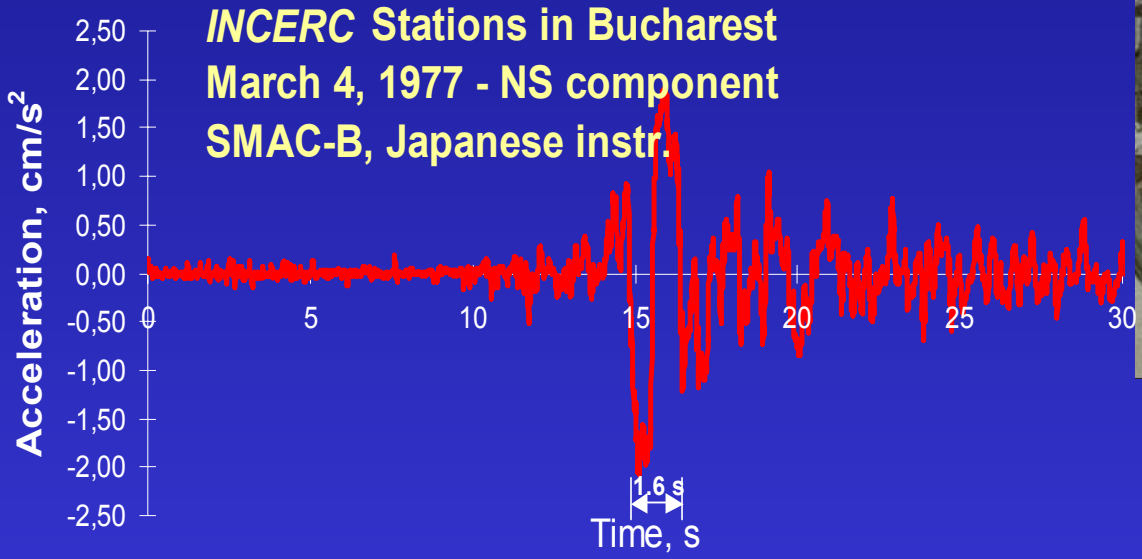
- Destroyed or seriously damaged 33,000 housing units and caused lesser damage to 182,000 other dwellings
- Destroyed 11 hospitals and damaged 448 others hospitals, etc.

The World Bank estimation of losses (Report 16.P-2240-RO, 1978):

- **Total losses in Romania : 2.05 billion USD (100%)**
  - **Construction losses : 1.42 (70%)**
  - **Building and housing losses : 1.02 (50%)**

High dynamic amplification at high periods.
Dangerous for high-rise buildings.

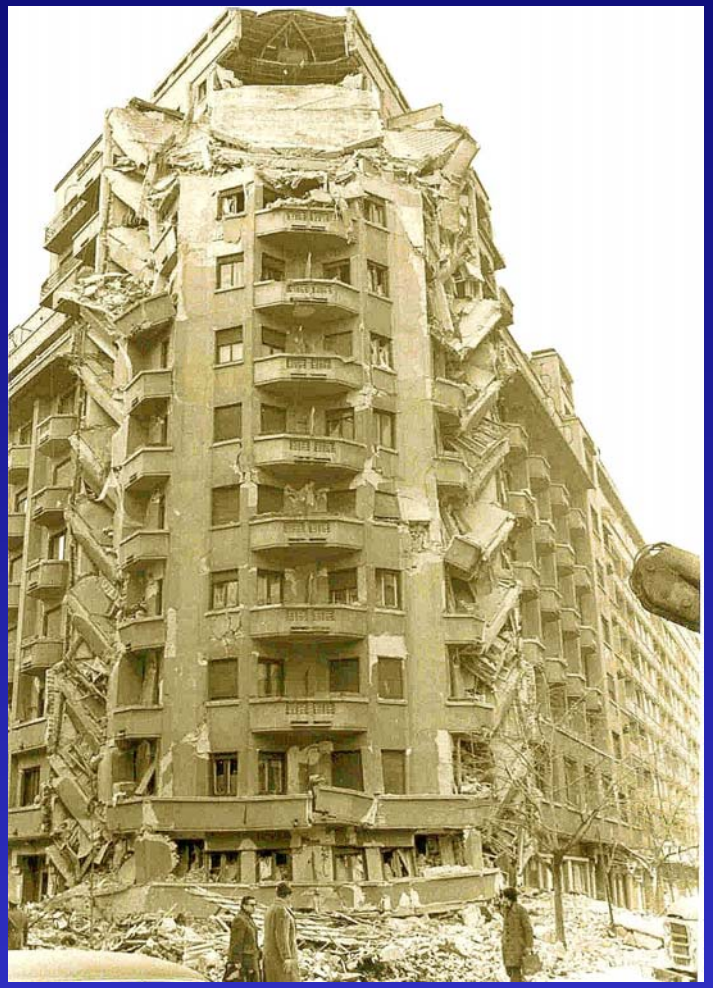




32 tall buildings
completely collapsed.

1977 earthquake in Bucharest

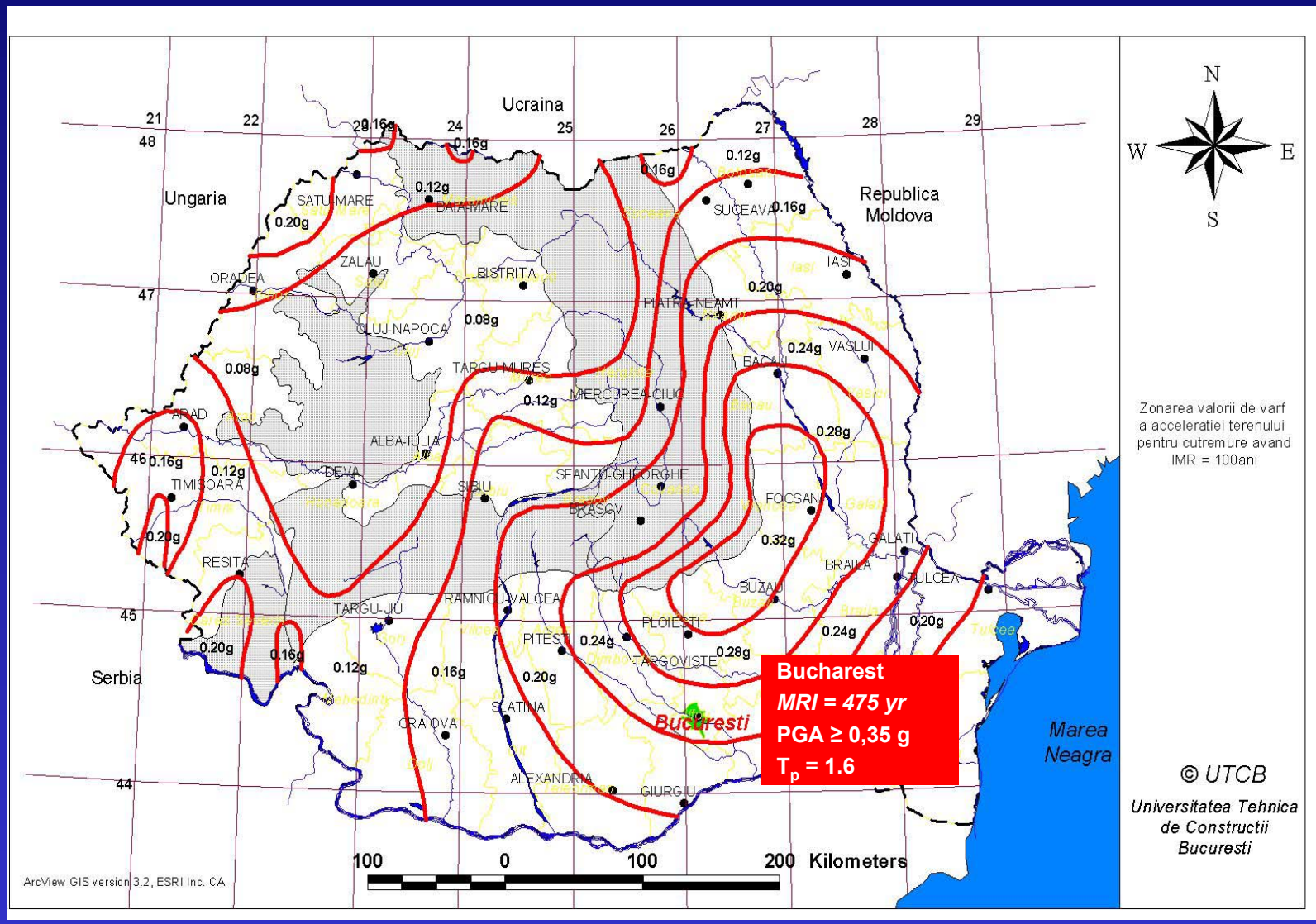
1977 earthquake in Bucharest



1944, W W II

1977 earthquake in Bucharest

Probabilistic zonation of peak ground acceleration for design P100-2004 code proposal: *MRI =100 yr*



Fragility of existing building stock in Romania

Two international lessons unlearnt from the 1977 disaster:

1

"A systematic evaluation should be made of all buildings in Bucharest erected prior to the adoption of earthquake design requirements and a hazard abatement plan should be developed."

From:

"Observation on the behaviour of buildings in the Romanian earthquake of March 4, 1977" by G. Fattal, E. Simiu and Ch. Cluver. Edited as the NBS Special Publication 490, US Dept of Commerce, National Bureau of Standards, Sept 1977.

2

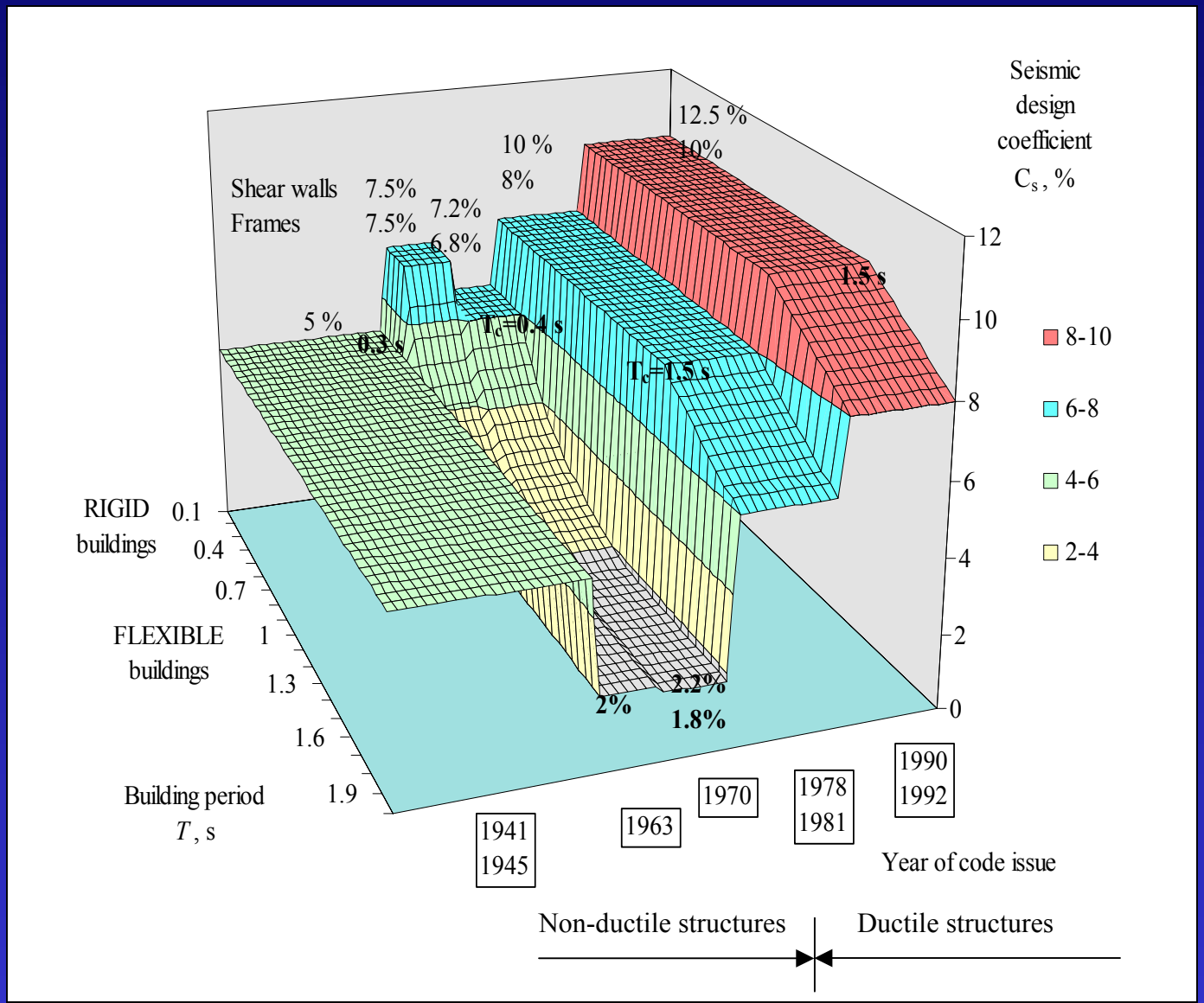
"Tentative provisions for consolidation solutions would preferably be developed urgently".

From:

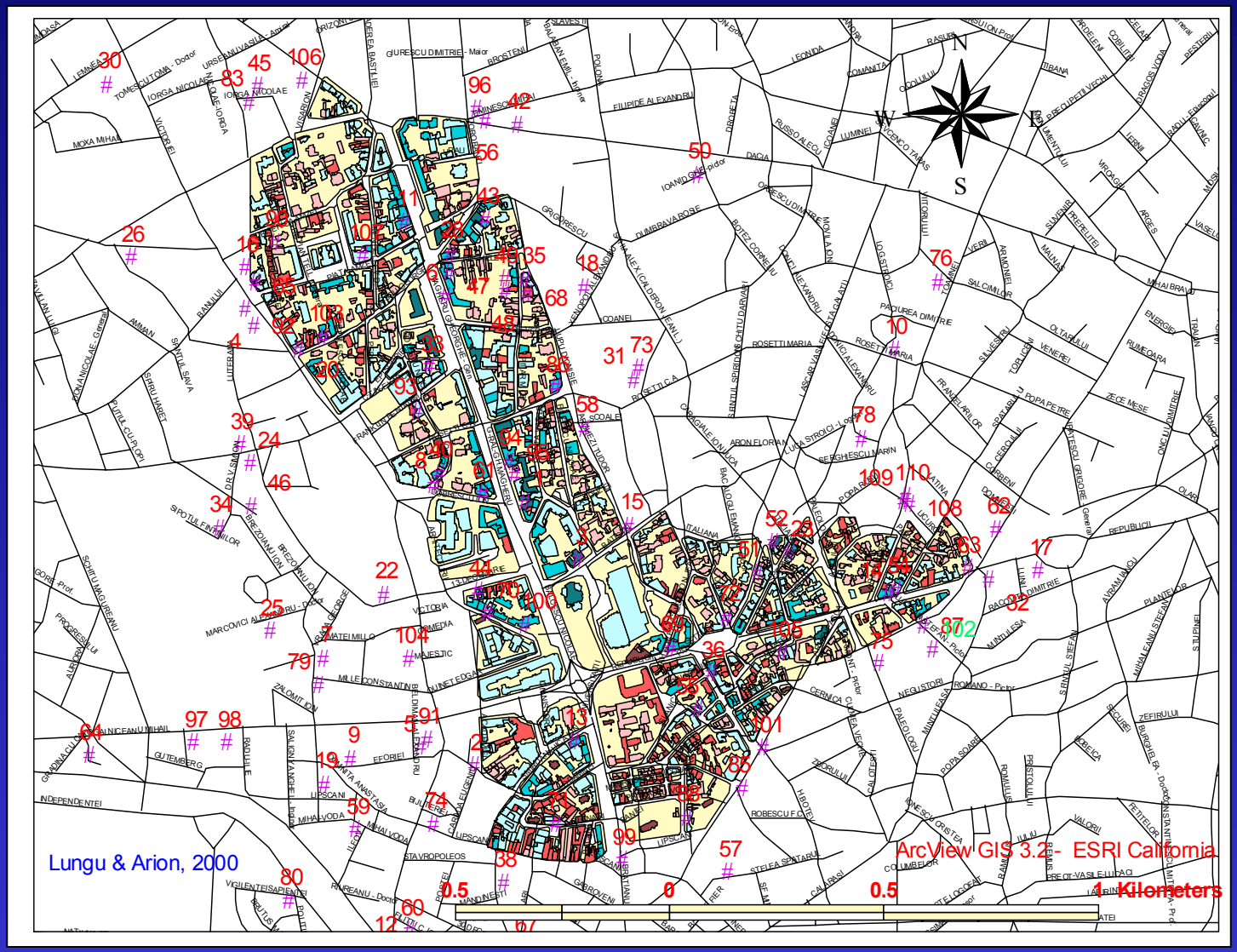
"The Romanian earthquake. Survey report by Survey group of experts and specialists dispatched by the Government of Japan (K. Nakano). Edited by JICA, Japan International Cooperation Agency, June 1977.

Evolution of codes for earthquake resistance of building

Seismic design coefficient in Bucharest, 1940-2004



Central Bucharest: 123 buildings built prior to 1945 and identified as having seismic risk of class 1 in case of a strong earthquake, *Mw*≥7.5



Vulnerable school buildings

-from *Ministry of Education and Research* of Romania-

City	Number of vulnerable schools			Total
	Requiring technical assessment	Having a technical report	Having technical documents	
Bacau	1	-	-	1
Barlad	11	-	-	11
Brasov	7	2	-	9
Bucharest	13	7	2	22
Constanta	-	-	1	1
Craiova	2	-	5	7
Galati	1	2	-	3
Giurgiu	2	-	-	2
Iasi	3	5	-	8
Pitesti	-	1	1	2
Ploiesti	1	5	-	6
Sibiu	3	1	-	4
Vaslui	10	-	-	10
Total	**54**	**23**	**9**	**86**

Vulnerable hospital buildings

-from *Ministry of Health and Family* of Romania-

CITY	Number of vulnerable hospitals				Total
	Severely damaged. Requiring immediate technical assessment	Having a technical report	Approved project for retrofitting	Retrofitting in work	
Bacau	3				3
Barlad				2	2
Bucharest	13	16	6	10	45
Buzau	9				9
Constanta	7				7
Craiova	4				4
Focsani			2		2
Galati		6	2	1	9
Giurgiu		1			1
Iasi	21	17	2	5	45
Pitesti	2	7			9
Ploiesti	2				2
Sibiu	1				1
Targu-Mures	2				2
Vaslui	4			1	5
Total	**68**	**47**	**12**	**19**	**146**

International and national programmes for seismic risk mitigation on Romania

Objectives:

1. ***Strengthening*** *of "seismic risk class 1" buildings:*
   Legislation + Construction work;

2. ***Upgrading*** *of the code for seismic design of buildings and structures;*

3. *Seismic* ***instrumentation***

Strengthening of 9 storey residential building in central Bucharest, 2003

December 2004:

4 buildings are fully retrofitted
8 buildings are under retrofitting
16 buildings have retrofitting projects ready
8 buildings are on the waiting list for retrofitting

Upgrading the code for seismic design of buildings and structures

*The draft of the New code for earthquake resistance of **new** structures, P100-2004, following EUROCODE 8 format, was just issued (Jan 2004)*

*The draft of the New code for earthquake resistance of **existing** buildings and structures: to be prepared !*

RISK U.E. Project

An advanced approach to earthquake risk scenarios with applications to different European towns

Europe inventory database and typology

Classification of buildings occupancy

Code	Occupancy category	Importance & exposure category		
		1	2	3
B	***GENERAL BUILDING STOCK***			
B1	***Residential***			
1.1	Single family dwelling (house)			x
1.2	Multi family dwelling (apartment bldg.)			
1.3	Low-rise (1-2)			x
1.4	Mid-rise (3-7)			x
1.5	High-rise (8+)		x[1)]	x
1.6	Institutional dormitory		x[1)]	x
B2	***Commercial***			
2.1	Supermarkets, Malls		x[2)]	x
2.2	Offices		x[2)]	x
2.3	Services			x
2.4	Hotels, Motels		x[2)]	x
2.5	Restaurants, Bars			x
2.6	Parking			x
2.7	Warehouse			x
B3	***Cultural***			
3.1	Museums		x[3)]	x
3.2	Theatres, Cinemas		x[2)]	x
3.3	Public event buildings		x[2)]	x
3.4	Stadiums		x[2)]	x

1) Buildings with capacity greater than 150 people
2) Buildings with capacity greater than 300 people or where more than 300 people congregate in one area

Europe building typology matrix, *BTM*

Label	Building type description	Height description			Code level*			
		Name	No. of stories	Height h, m	N	L	M	H
RC	***Reinforced concrete structures***							
RC1	Concrete moment frames	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
RC2	Concrete shear walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
RC3	Concrete frames with unreinforced masonry infill walls							
3.1	Regularly infilled frames	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
3.2	Irregularly frames (i.e., irregular structural system, irregular infills, soft/weak story)	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
RC4	RC Dual systems (RC frames and walls)	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
RC5	Precast Concrete Tilt-Up Walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				
RC6	Precast Concrete Frames with Concrete shear walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	h ≤ 9 9 < h ≤ 21 h > 21				

***Code level**

N - no code;
L - low-code (designed with unique arbitrary base shear seismic coefficient);
M - moderate-code;
H - high-code (code comparable with Eurocode 8)

Population and yearly GDP of seven towns

Town	Inhabitants	Population density, persons/km^2	Population growth, 20th century*	GDP/person (approx.) *Euro*
Barcelona	1,503,451	15,176	1970↓	22,000
Bitola	79,456	12,600	1990→	1,620
Bucharest	2,011,305	10,806	1989→	1,980
Catania	333,075	6,125	1971-1991 ↓	9,000-15,000
Nice	342,738	4,766	1980→	20,000
Sofia	1,133,183	4,680	1985↓	1,630
Thessaloniki	1,048,151	21,600	1991→	15,290

Vulnerability and typology of European buildings stock

versus

Seismic codes inter-benchmark periods

Town	Seismic codes inter-benchmark periods		
	Pre-code	Low-code	Moderate code
Barcelona	*79%*	*21%*	*--*
Bitola	*48%*	*29%*	*23%*
Bucharest	*30%*	*30%*	*40%*
Catania	*92%*	*-*	*8%*
Nice	*75%*		*25%*
Sofia	*Data not available*		
Thessaloniki	*20%*	*50%*	*30%*

JICA technical cooperation project (2002-2007)

"Reduction of seismic risk for buildings and structures in Romania"

- *Project signed in **2002**, when 100 years of diplomatic relations between Japan and Romania were celebrated*

Partnership of 3 institutions:

NCSRR, National Center for Seismic Risk Reduction

UTCB, Technical University of Civil Engineering Bucharest

INCERC, National Institute for Building Research, Bucharest

under the authority of: *MTCT, Ministry of Transports, Constructions and Tourism*

Total cost of the project 5.27 mill. USD (equipment cost 2.7 mill. USD)

- 24 Romanian young students/engineer to be trained in Japan
- 34 Japanese short term and long term experts in Romania

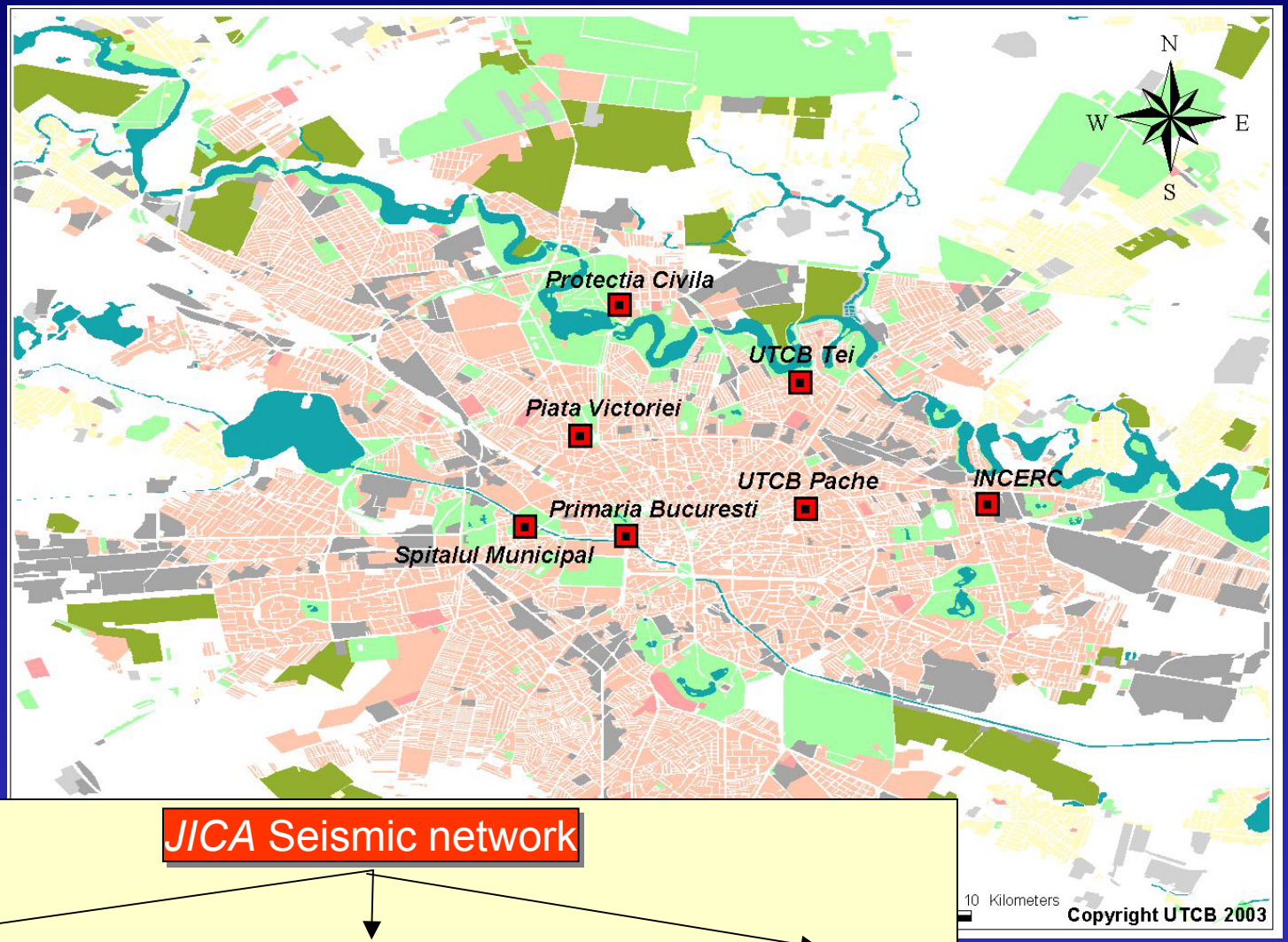
Structure testing equipment - Reaction frame

- ✓Maximum weight of tested specimens - 7t
- ✓Maximum dimensions of the tested specimens - 2.5m by 3 m
- ✓Reaction frame 9.7m x 7.6m

Equipments for soil testing and investigation

- ✓Triaxial testing equipment
- ✓Drilling equipment
- ✓SPT/CPT testing equipment

Bucharest - Location of borehole instrumented sites



JICA Seismic network

Free field, outside Bucharest 6 ETNA accelerometers

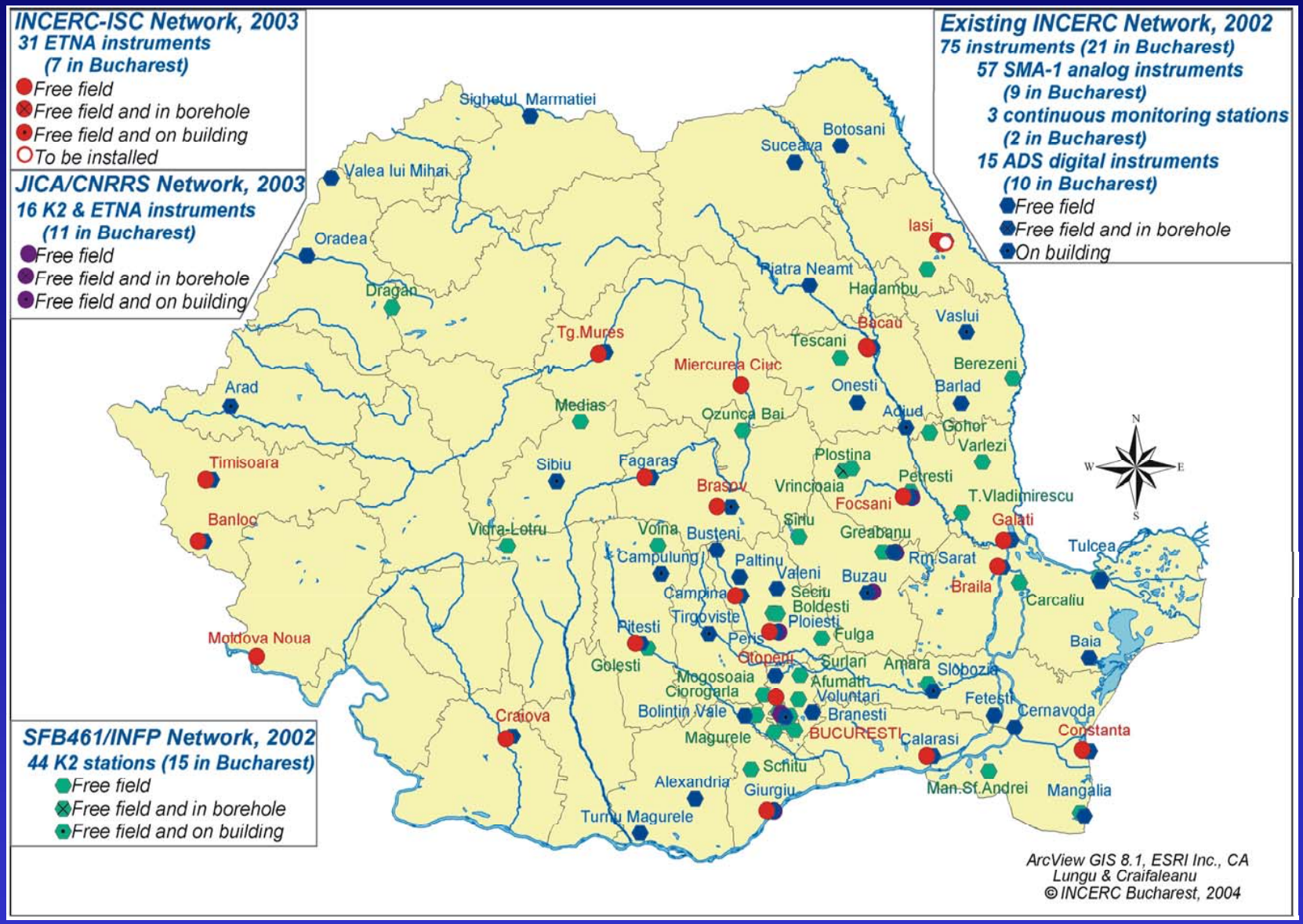
7 Boreholes in Bucharest: K2 station+3 sensors/station (1surface +2 in borehole/station)

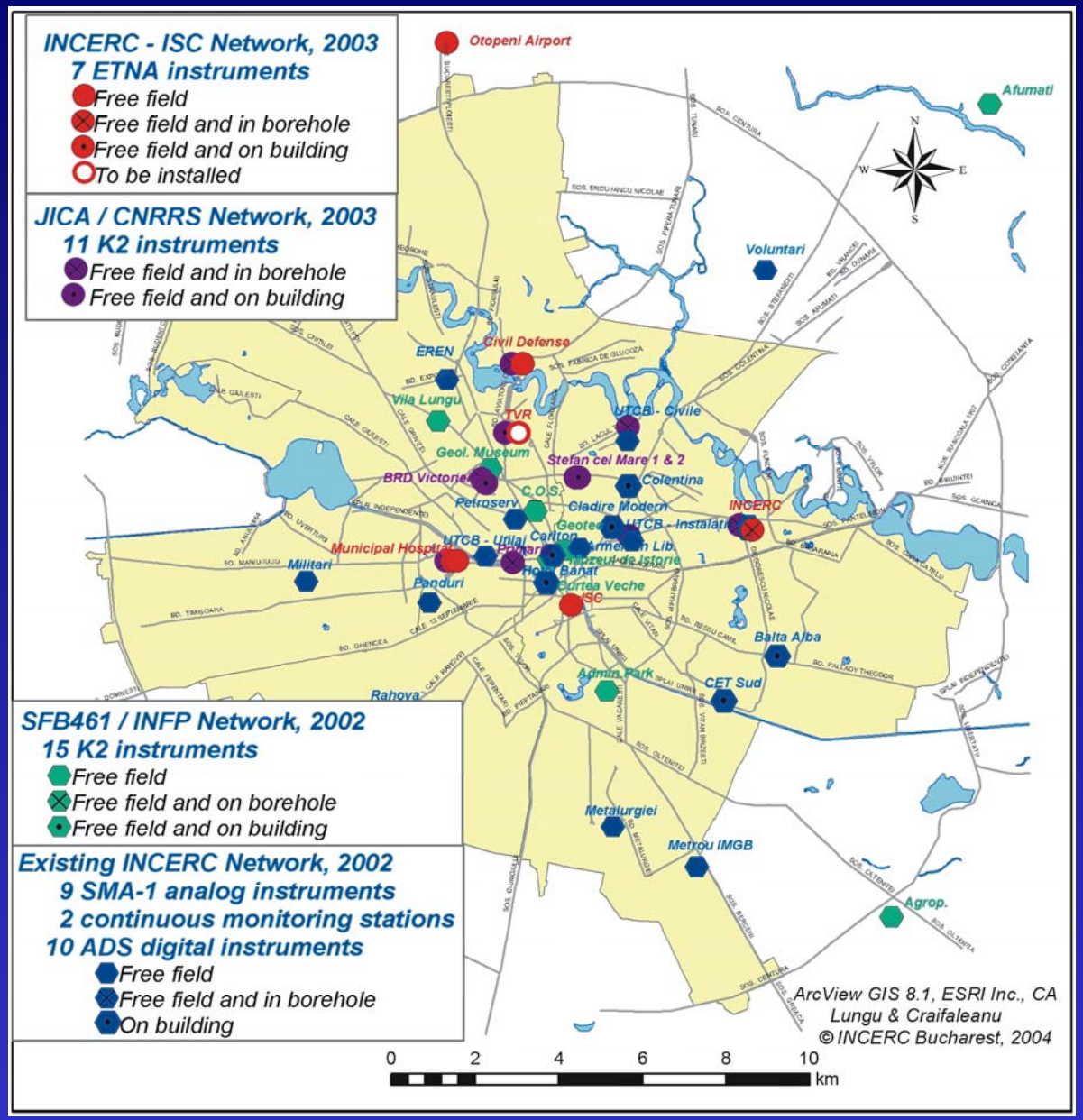
Buildings in Bucharest 4 K2 stations

SFB 461, German Science Foundation Project (1996-2007): Strong Earthquakes - Challenge for Geosciences and Civil Engineering

- Collaborative research work of *7 Romanian institutions and 6 Departments of Karlsruhe University*
- Strong impact on *seismic instrumentation* of Romania
- *Two* International Earthquake Conferences in Bucharest
- *Synergetic effects* on major international earthquake projects in Romania: JICA, World Bank, etc.
- Extension of bilateral *cooperation at regional level*: Turkey , Republic of Moldavia, Bulgaria, FYROM etc.

Romania seismic instruments: *More then 100 digital instruments*

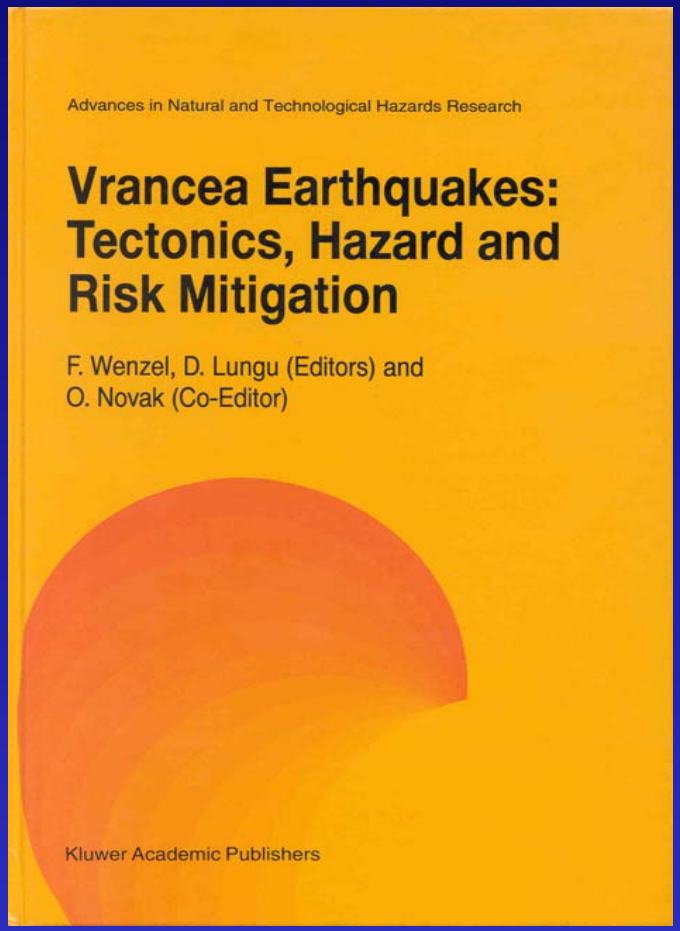


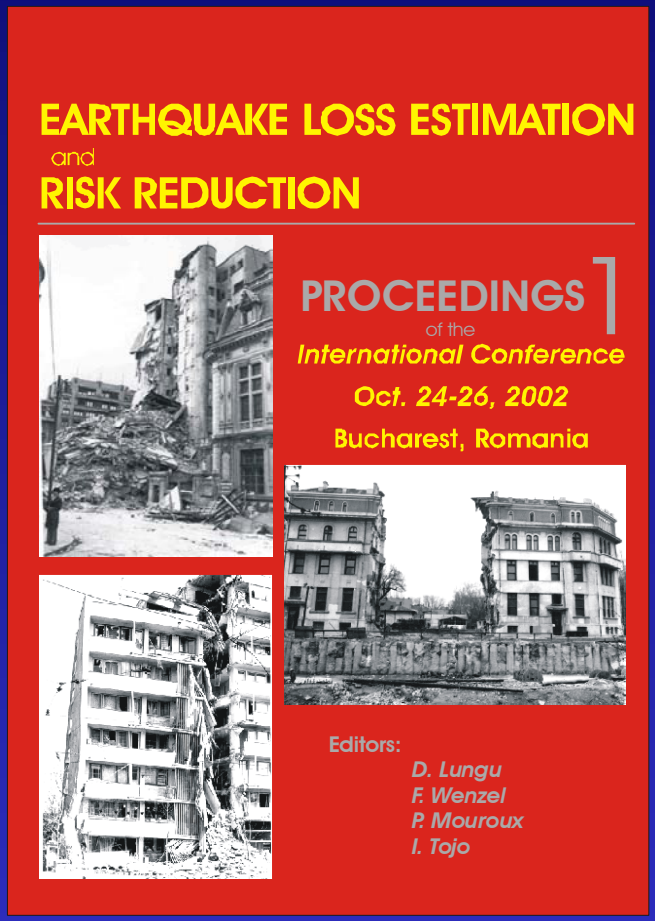


Bucharest Seismic networks:

More then 40 digital instruments

Two International Earthquake Conferences in Bucharest





- More than 60 foreign participants in 2002 in Bucharest
- 2 vol. Proceedings, 786 pages

NATO project in Romania (2005-2008)

Partners institutions:

- Middle East Technical University, Ankara, Turkey
- Institute for Geophysics and Geology, Moldavian Academy of Science, Kishinev, Republic of Moldova
- National Building Research Institute, *INCERC,* Bucharest, Romania
- Central Lab. for Seismic Mechanics & Earthquake Eng., Sofia, Bulgaria

Deterministic seismic zonation maps for countries affected by **Vrancea** earthquakes

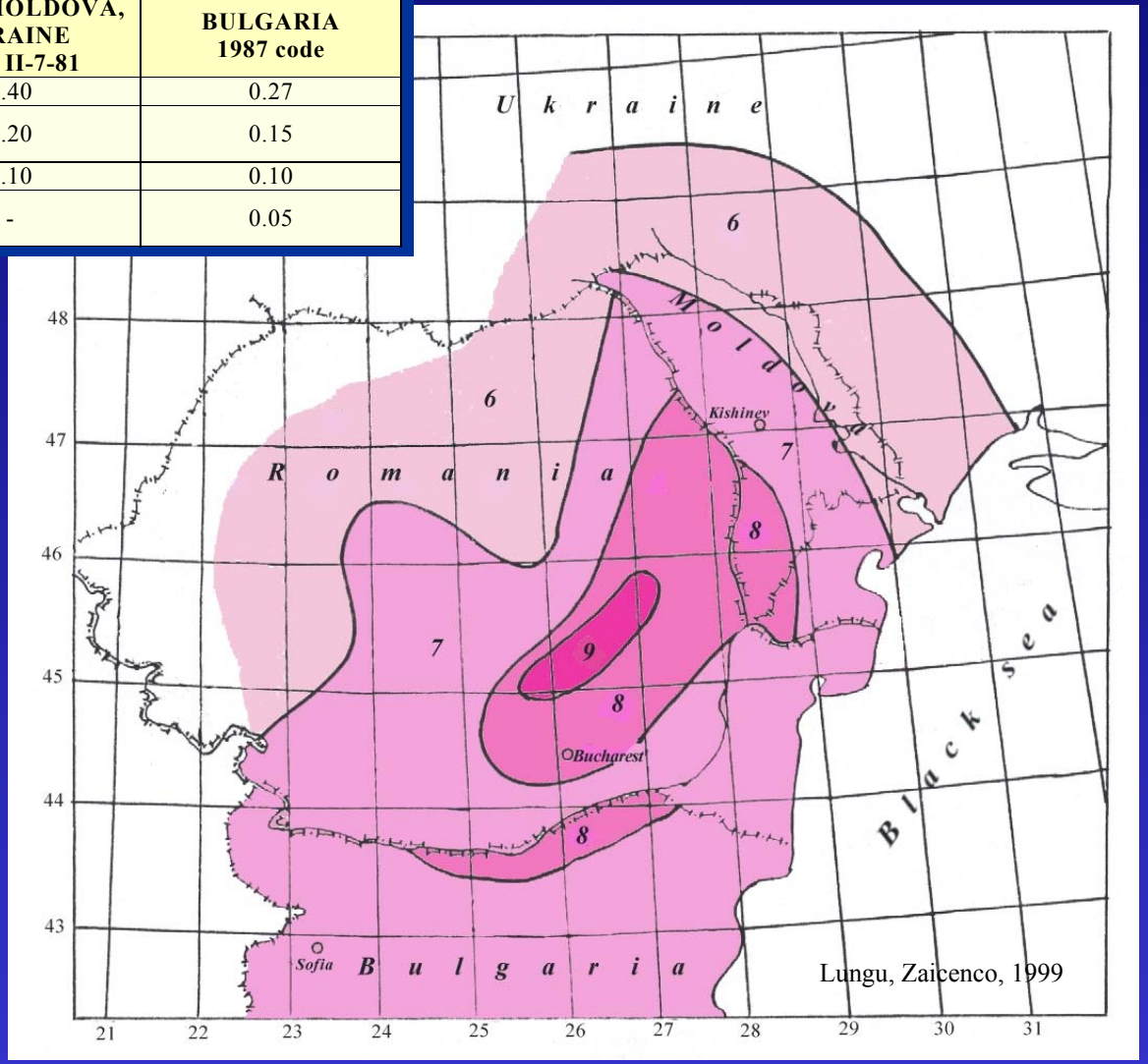
MSK Intensity	PGA/g		
	ROMANIA P100-92& SR 11100/1-93	Rep. of MOLDOVA, UKRAINE SNIP II-7-81	BULGARIA 1987 code
IX	0.32	0.40	0.27
VIII	0.25 0.20	0.20	0.15
VII	0.16	0.10	0.10
V	0.12 0.08	-	0.05

MRI - mean recurrence interval of earthquake magnitude is:

Romania: *50 yr, 1992*
100 yr, 2004

Republic of Moldova: *50 yr*

Bulgaria: *1000 yr*



Lungu, Zaicenco, 1999

World Bank project in Romania (2005-2009)

Component A:

Strengthening of Disaster management capacity ~5%

Component B:

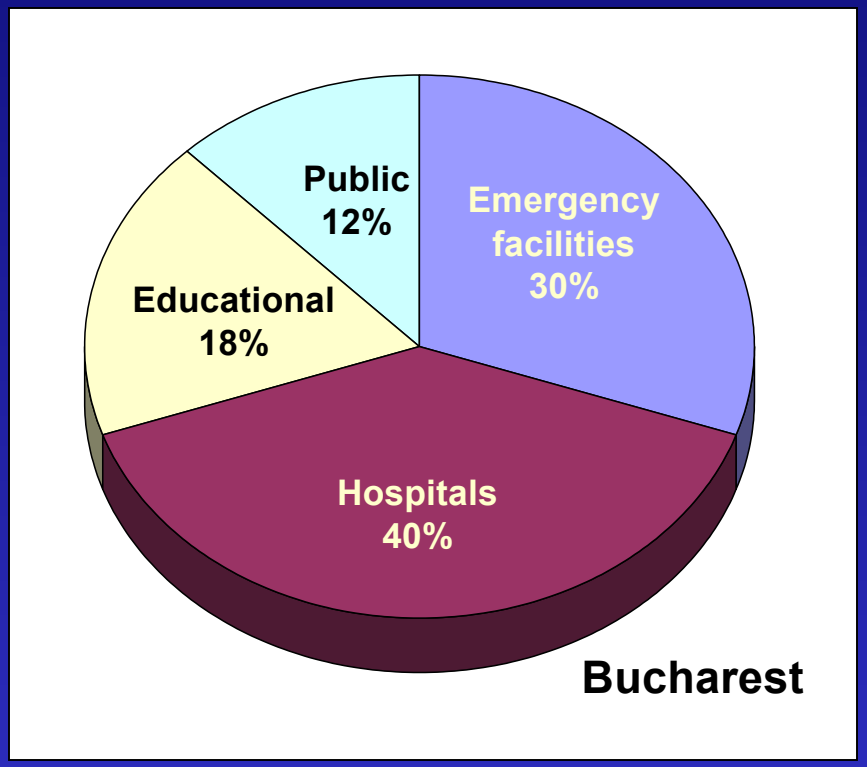
Earthquake Risk Reduction ~35%

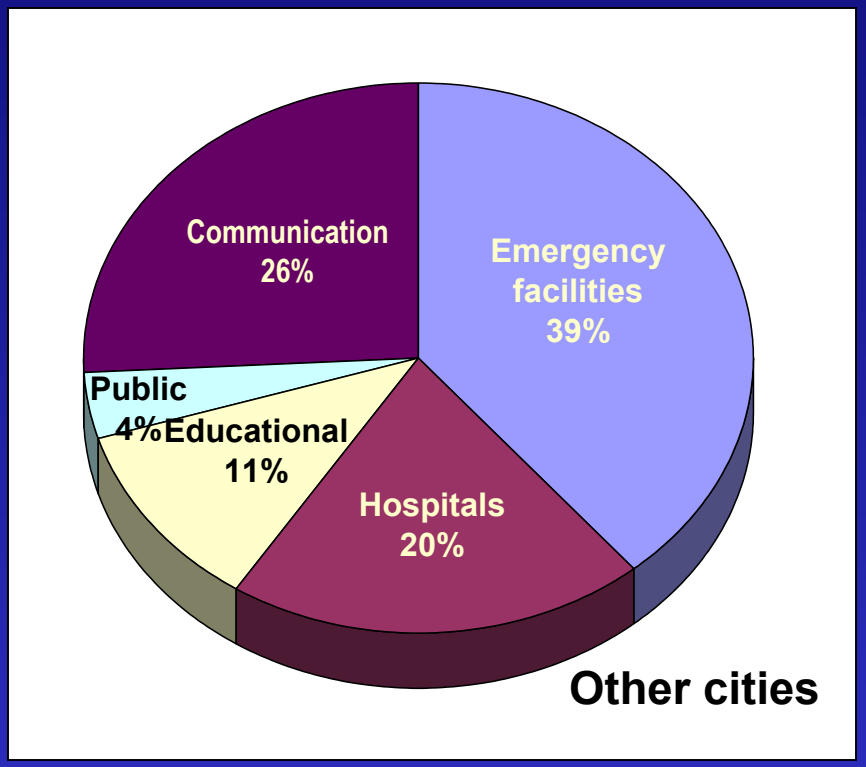
Subcomponents:

- ***Strengthening of high priority buildings and lifelines***
- ***Design & supervision***
- ***Building code review and study of code enforcement***
- ***Professional training in cost effective retrofitting***

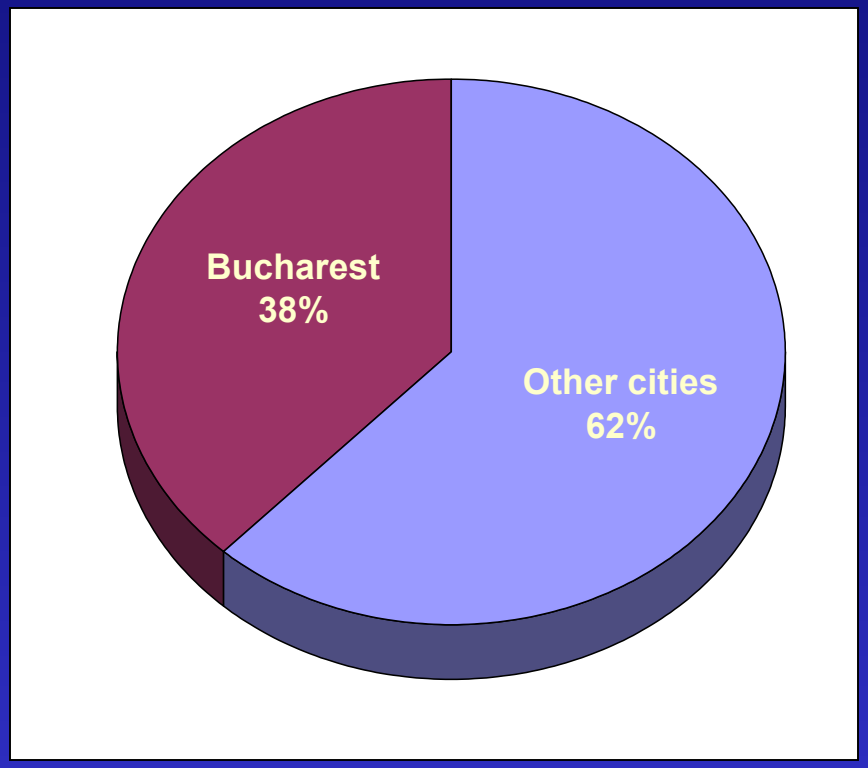
Components C D& E: ***Flood, Pollution & Project Management 60%***

Distribution of buildings with occupancy

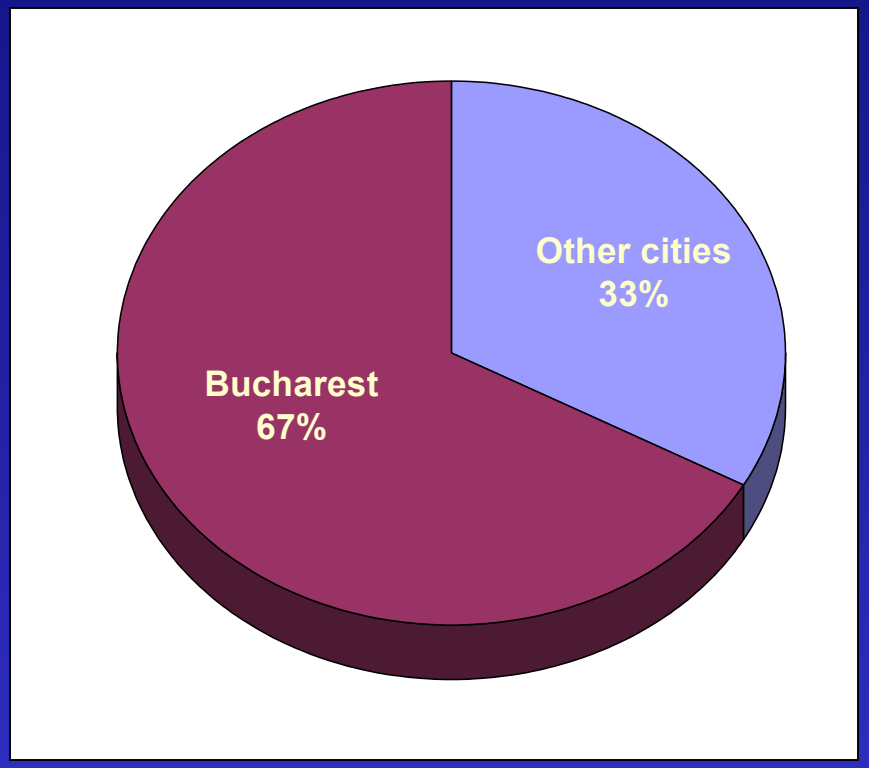




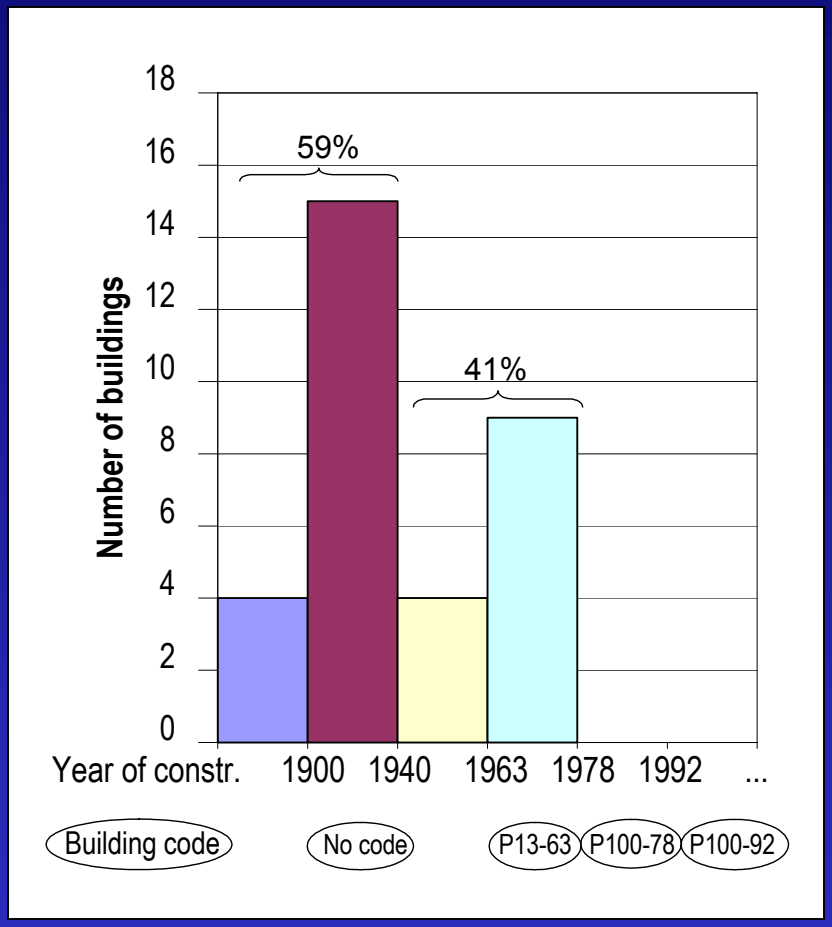
Distribution of number of buildings to be retrofitted

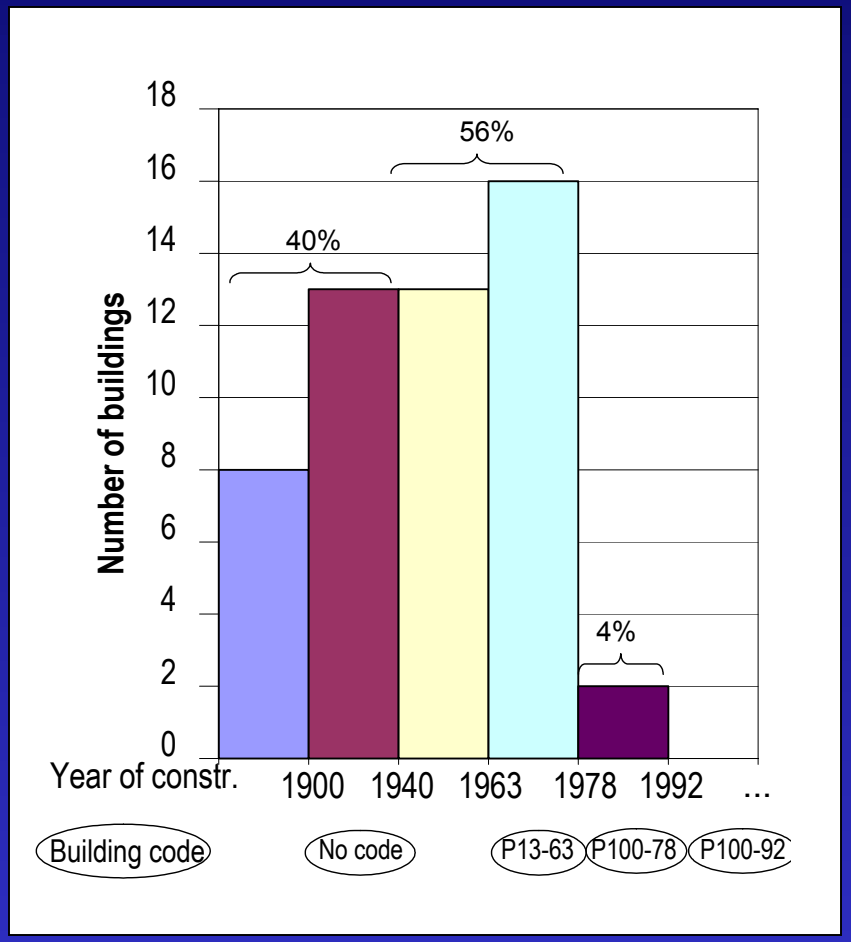


Distribution of cost for buildings to be retrofitted



Distribution of buildings with year of construction





World Bank report

"Preventable Losses: Saving Lives and Property through Hazard Risk Management"

Strategic Framework for reducing the Social and Economic Impact of Earthquake, Flood and Landslide Hazards in the Europe and Central Asia Region

Draft, May 2004

- ***Romania*** *is regarded as one the most seismically active countries in Europe*
- ***Bucharest*** *is one of the 10 most vulnerable cities in the world.*

Recommendations for Romania:

- ***Upgrade the legal framework*** *for hazard specific management;*
- ***Review the existing buildings code*** *for the retrofitting of vulnerable buildings;*
- *Conduct a* ***comprehensive public awareness campaign*** *for the earthquake risk;*
- ***Invest in hazard mitigation*** *activities in order to reduce the risks caused by earthquakes;*
- ***Develop financing strategy*** *for catastrophic events.*