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EARTHQUAKE HAZARD RELATED ELEMENTS FOR DISASTER PREPAREDNESS PLANNING

J. T. PETROVSKI and Z. V. MILUTINOVIC

Institute of Earthquake Engineering and Engineering Seismology, Section for Risk and Disaster Management, University "St. Cyril and Methodius", 73 Salvador Aliende Street, P.O. Box 101, Skopje, Republic of Macedonia

ABSTRACT

Earthquake hazard related elements for disaster preparedness planning and emergency response have been formulated for the Republic of Macedonia based on detail analysis of seismic hazard for three level of expected shaking, of large scale, moderate and disaster preparedness earthquake scenario from ten dominant source zones, separately. Assessment of vulnerability and seismic risk parameters has been performed for five dominant elements at risk of population and housing, public buildings essential for post-disaster relief operations, water supply and transportation systems. Homeless population and human casualties have been estimated for the considered three hazard levels as well as remaining existing and required standby facilities as a basic elements for planning of disaster preparedness. Considering country exposure to dominant natural and man-made disasters it has been concluded that earthquake effects expressed in terms of physical and functional losses and human casualties are overwhelming the effects of other disasters like floods, landslides, wildfires and considered man-made disasters.

KEYWORDS

earthquake hazard; vulnerability; seismic risk of buildings and population; disaster preparedness

SEISMICITY AND SEISMIC HAZARD ANALYSIS

Earthquakes from ten seismic source zones (Fig. 1 and Tab. 1) have historically affecting the territory of Macedonia. Earthquakes with magnitude 6.0 to 7.8 have been experienced throughout the country. For the last 25 years more than 40 damaging earthquakes from epicenters in Macedonia have been recorded. Historically the strongest earthquakes occurred in Pehcevo-Kresna (1904, M=7.8) and Valandovo-Dojran (1931, M=6.7) seismic source zones. During the last 50 years few destructive and even catastrophic earthquakes have been affecting the country. In the recent time the City of Skopje (1963, M=6.1, I=IX-X MCS) was devastated; 80.7% of total building area (including dwelling houses) was destroyed or heavily damaged, 75.5% of inhabitants were left homeless, direct economic losses were estimated at 15% of the GNP of former Yugoslavia for the year of 1963.

Seismic hazard analysis was performed through source-by-source approach for three selected return periods, corresponding to : (1) LSE, large scale earthquake, expected to occur within 50 years return period and 10% exceedence probability; (2) MSE, moderate scale earthquake expected to occur within 10 years return period

and 10% exceedence probability; (3) DPE, disaster preparedness earthquake, expected to occur within 5 years return period and 10% exceedence probability. The seismic hazard estimates for DPE and LSE earthquake scenario, dominating Western and Eastern Macedonia are presented in Figs 2 and 3, respectively.

SEISMIC RISK OF BUILDINGS

The seismic risk for prevailing traditional and modern residential and public buildings was estimated based on developed vulnerability functions (Petrovski and Milutinovic, 1987, 1994, 1995) as presented in Figs. 4 and 5 and considered earthquake hazard scenarios. Estimates on damaged and collapsed housing area and corresponding homeless population by dominant seismic source zones are summarized in Figs. 6 and 7. The overall damaged and collapsed building potential inherent to residential and public buildings is presented in Table 2 for prevailing seven categories of use and considered hazard scenarios.

The public buildings, in particular schools and tourism buildings are possessing the highest risk level ranging from 33 to 83% with temporary or permanent loss of function, out of which 19 to 49% are permanent physical losses of collapsed buildings. Medical buildings are less vulnerable, but yet with unacceptable risk level for intended post-disaster use. Functional losses of medical buildings, including hospitals and clinics, might be expected in the range of 19% for DPE up to 67% for LSE earthquake scenarios.

The estimated overall residential buildings risk level and associated population homelessness and casualty is found to be very high, even considering significant changes in earthquake resistant construction after 1963, Skopje earthquake in the entire country. Total functional loss of residential buildings is estimated in the range of 28% for DPE up to 74.1% for LSE earthquake scenarios, out of which permanent physical losses shall be accounted in the range of 8.3% to 40.2%, respectively (Petrovski and Milutinovic, 1994, 1995).

ELEMENTS FOR DISASTER PREPAREDNESS PLANING

Based on the performed analysis of the effects of nonsequential earthquake exposure the estimate on requirements for shelter and care of homeless population as well as hospitalization and medical care are defined as a basic elements for disaster preparedness planning on a regional and country level. Also, estimated nondamaged housing, medical and other public facilities in adequate balance with demanded facilities will give additional requirements of standby facilities and supplies for temporary shelter and medical care of the affected population.

As an example the elements for disaster preparedness of Western Macedonia are given in Table 3 and 4 through presentation of homeless, available non-damaged housing area and additionally required shelter capacity as standby facilities. It has been found that governing figure for planning of additional facilities for shelter is 73,405 inhabitants (Tab. 4) and 1,700 inhabitants for hospitalization and medical care, which is not covered with available facilities in the affected region and neighbor municipalities, and thus standby facilities and emergency supplies should be provided.

Considering other regions in the country with high concentration of population, like City of Skopje and with expected more severe exposure, like Eastern Macedonia, it could be concluded that under present low economic strength the Republic of Macedonia, like other developing countries, cannot sustain the preparedness level for large scale and moderate scale earthquake scenarios. Even for disaster preparedness scale earthquake scenario, as a minimum demand level, the country's ability will be exceeded, and substantial international assistance will be required during emergency and rehabilitation period.

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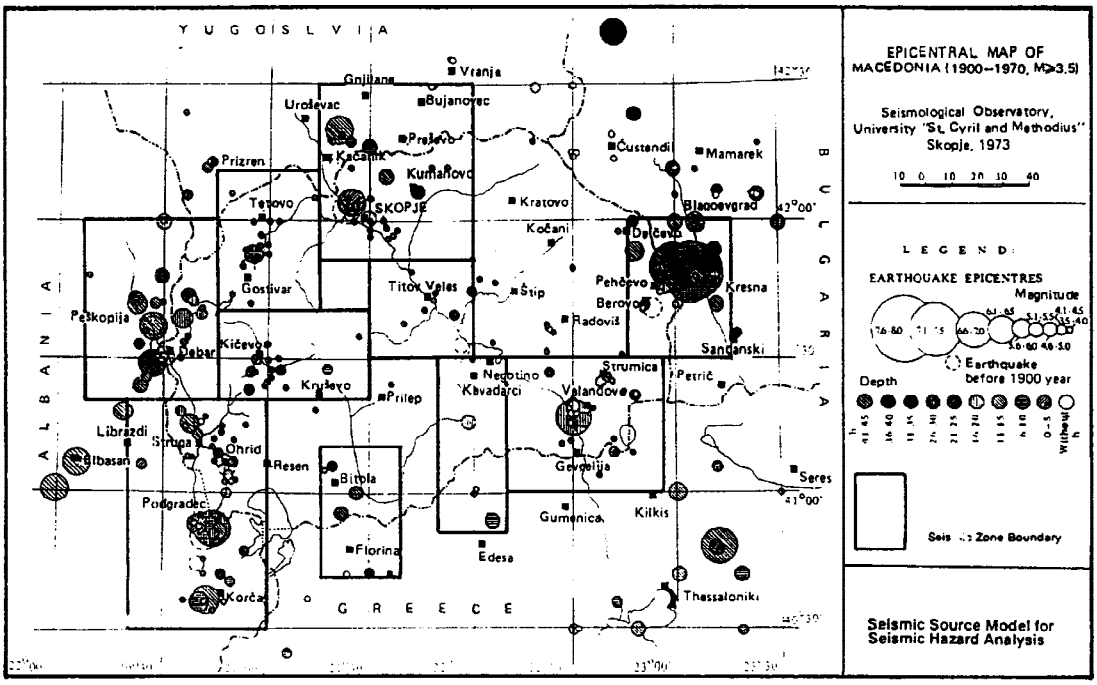
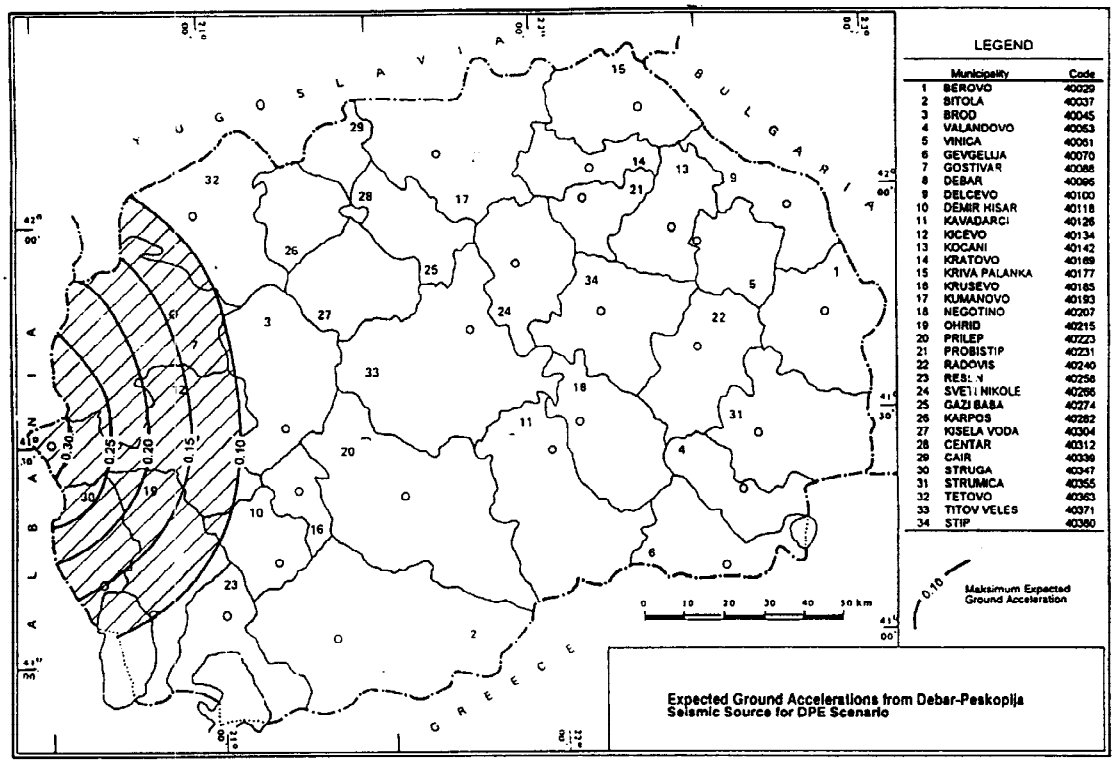


Fig. 1 Seismic source zones for seismic hazard analysis

Table 1. Major earthquakes occuring in the Republic of Macedonia

Seismic Zone	Date, GMT (d/m/y)	Time (h/m)	Coordinates		M (occurred)	I	max M (expected)
			ϕ (N)	λ (E)			
Skopje-Vitina	26.07.1963	04:17	42.0	21.4	6.1	9	6.5
Tetovo-Gostivar	12.03.1960	11:54	41.9	20.9	5.7	8	6.1
Debar-Peskopija	30.11.1967	07:23	41.4	20.5	6.6	9	6.9
Ohrid-Korca	18.02.1911	21:35	40.9	20.8	6.7	9	6.9
Valandovo-Dojran	08.03.1931	01:50	41.3	22.5	6.7	10	6.9
Pehcevo-Kresna	04.04.1904	10:25	41.8	23.1	7.8	10	7.9
Titov Veles	14.09.1922	16:37	41.7	21.4	5.5	7-8	5.8
Kicevo-Krusevo	21.10.1988	02:18	41.3	21.0	4.4	6-7	5.8
Bitola-Florina	14.09.1920	02:09	41.0	21.4	5.3	7	5.7
Tikves-Mrezicko	09.07.1955	23:53	40.9	22.1	5.1	7-8	6.0



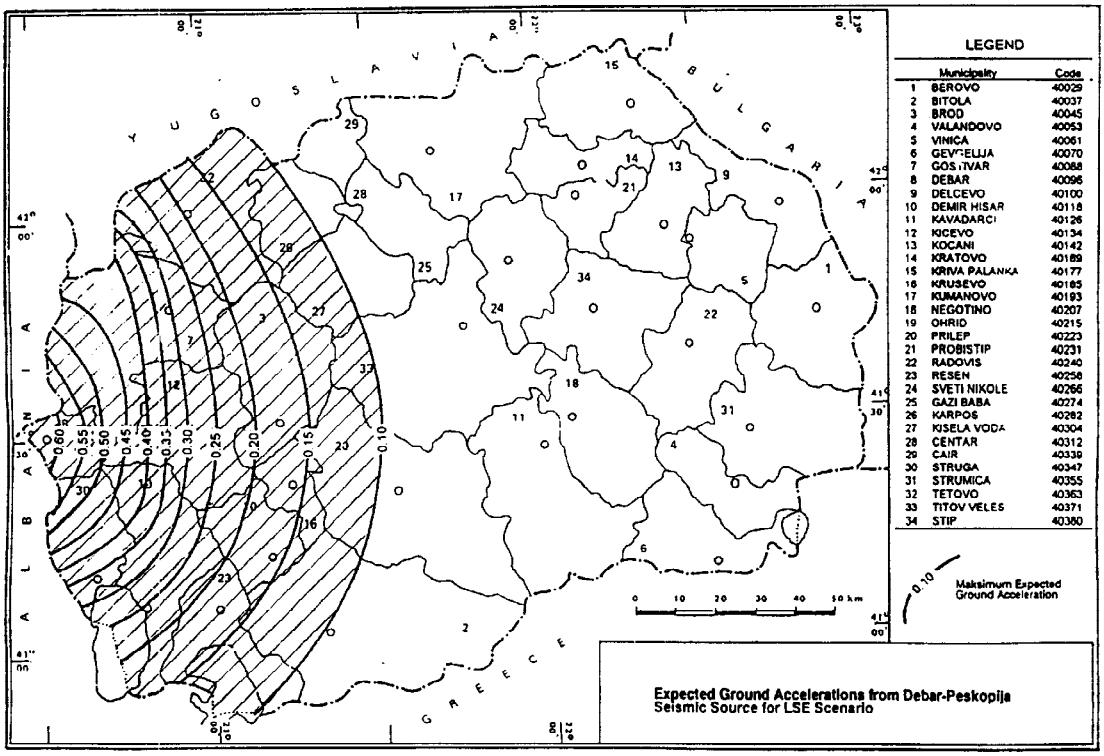
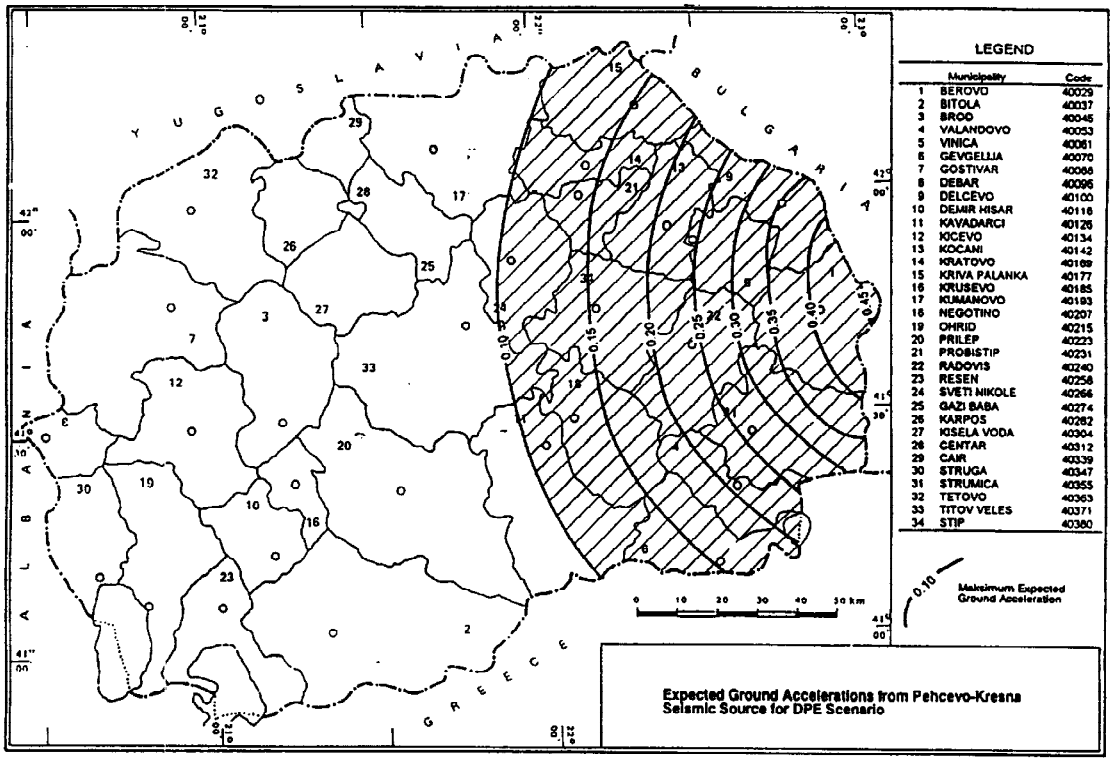


Fig. 2 Expected ground accelerations from Debar-Peskopija seismic source zone for DPE and LSE earthquake scenario



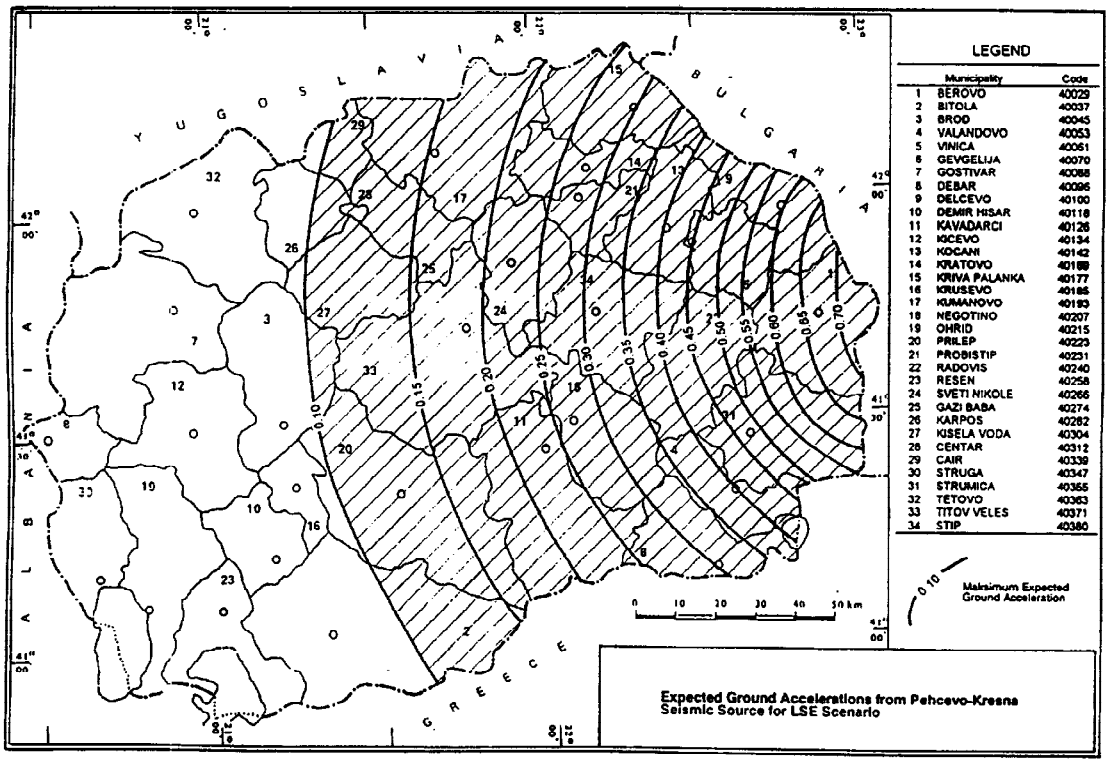
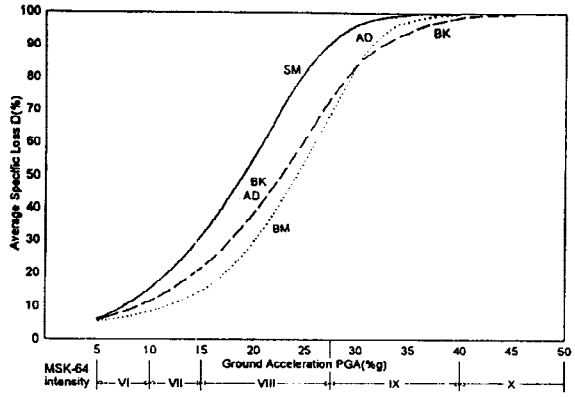
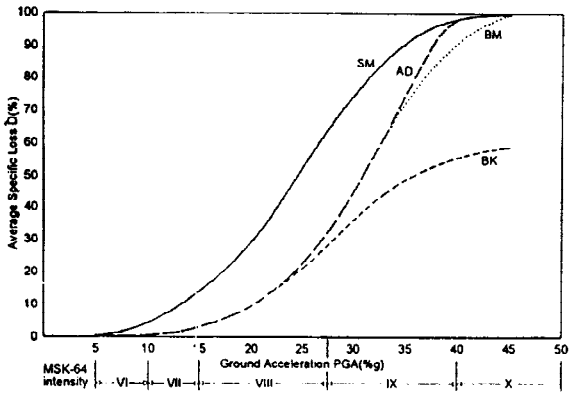


Fig. 3 Expected ground accelerations from Pehcevo-Kresna seismic source zone for DPE and LSE earthquake scenario

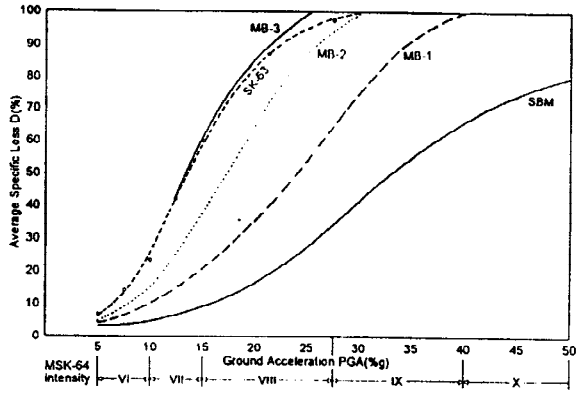


a. Damaged and Collapsed Buildings

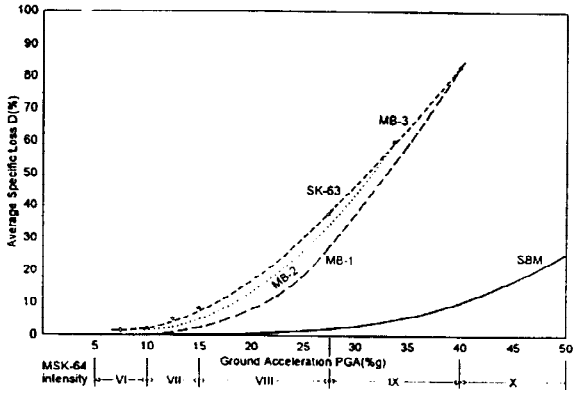


b. Collapsed Buildings

Fig. 4. Average empirical vulnerability function for rural buildings
SM: stone masonry; BM: brick masonry; BK: wood frame with adobe;



a. Damaged and Collapsed Buildings



b. Collapsed Buildings

Fig. 5. Average analitical vulnerability function for brick masonry buildings and comparison with EVF after Skopje 1963 earthquake
MB-1: average quality, 1-2 stories; MB-2: low quality 1-2 stories; MB-3: average quality, 3-5 stories; SMB: confined masonry;

Table 2. Expected average percent of damaged and collapsed building gross floor area

Buildings Use	DPE Scenario			MSE Scenario			LSE Scenario		
	D	C	D+C	D	C	D+C	D	C	D+C
1 School Buildings	17.9	19.0	26.9	28.6	23.7	52.3	30.7	49.0	79.7
2 Hotels and Motels	22.3	6.4	28.7	35.0	20.5	55.5	32.7	41.7	78.9
3 Resort Buildings	24.2	8.5	32.7	36.4	22.7	59.1	37.7	45.4	83.1
4 Hospitals and Clinics	14.9	1.9	16.8	29.1	8.5	37.7	41.1	23.6	64.7
5 Medical Centers	16.5	2.3	18.8	31.3	8.2	39.5	40.6	25.9	66.9
6 Medical Units	14.1	1.8	15.9	29.0	6.6	35.6	41.9	21.0	62.9
7 Residential Buildings*	19.8	8.3	28.1*	30.3	20.3	50.6	34.5	40.2	74.7

D = Damaged Buildings
C = Collapsed Buildings
D+C = Damaged and Collapsed Buildings

* Estimates are calculated according to total residential area (40275731 m^2) estimated from the 1991 Census data

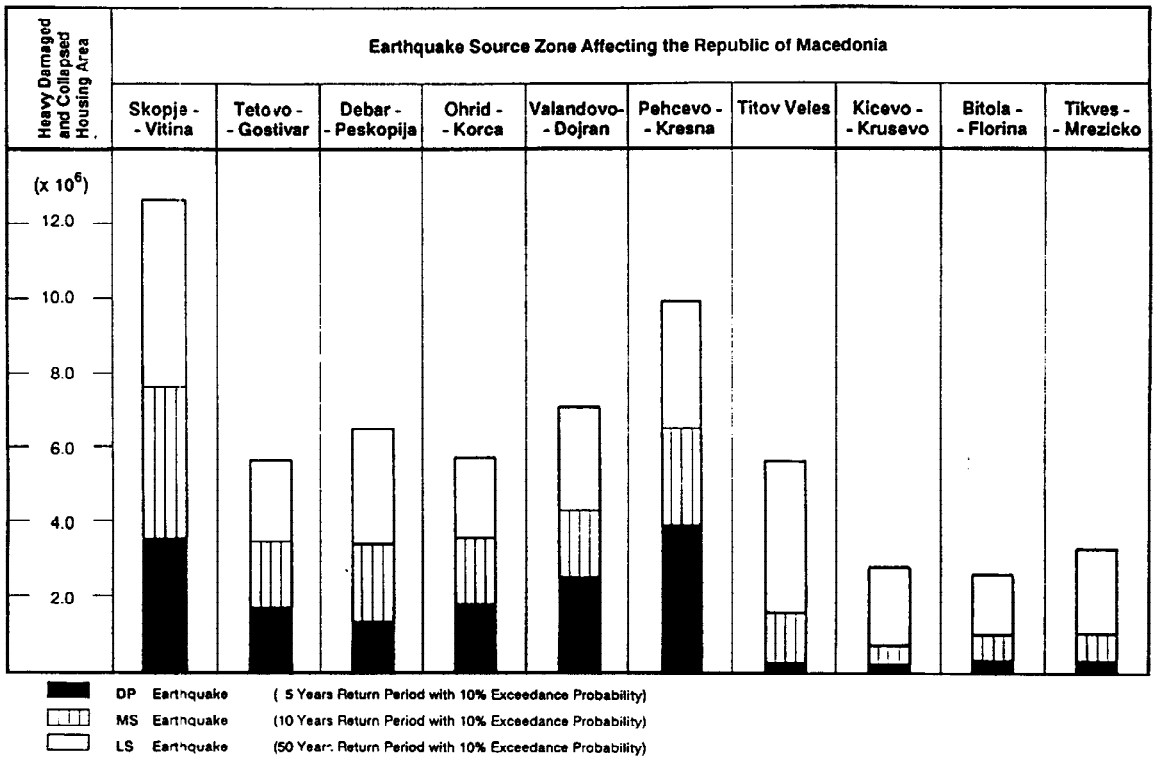


Fig. 6. Summary estimates on heavily damaged and collapsed housing area by dominant seismic source zones affecting the Republic of Macedonia

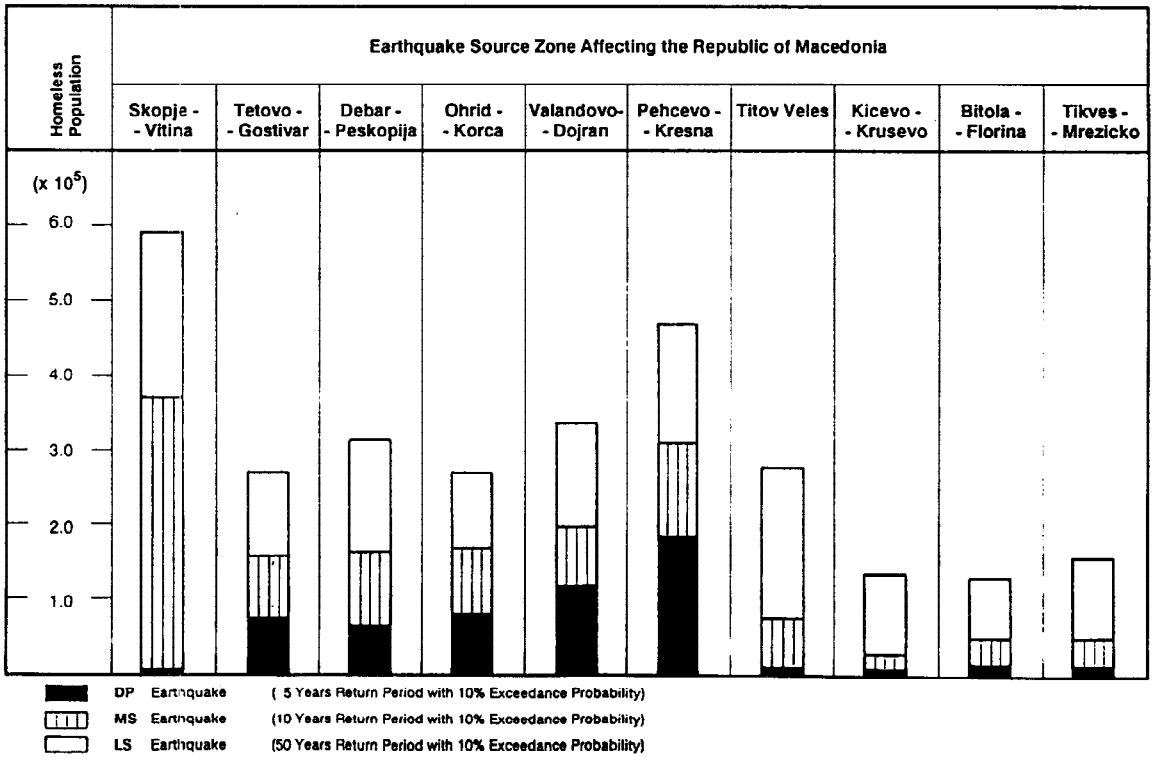


Fig. 7. Summary estimates on homeless population by dominant seismic source zones affecting the Republic of Macedonia (earthquake occurrence at 24:00h)

Table 3. Estimated non damaged housing area in Western Macedonia by municipalities, regions and earthquake zones for DPE earthquake scenario

Municipality	Seismic Source					Preparedness Elements
	Skopje-Vitina	Tetovo-Gostivar	Ohrid-Korca	Debar-Peskopeja	Kicevo-Krusevo	
Gostivar	1.689.977	1.118.434	1.689.977	1.411.977	1.689.977	1.182.434
Tetovo	2.922.097	2.393.646	3.068.910	2.861.348	3.068.910	2.393.646
Subtotal	4.613.074	3.676.080	4.758.887	4.273.325	4.758.887	3.676.080
Debar	425.198	425.198	391.868	168.560	425.198	165.560
Ohrid	1.851.426	1.851.426	1.232.583	1.716.383	1.851.426	1.232.583
Struga	1.599.374	1.599.374	1.078.834	1.367.575	1.599.374	1.078.834
Subtotal	3.875.998	3.875.998	2.703.285	3.252.518	3.875.998	2.703.285
Brod	223.262	223.262	209.715	205.516	202.725	202.725
D. Hisar	301.035	301.035	260.473	282.915	301.035	260.473
Kicevo	1.195.024	1.141.937	1.111.418	1.007.707	1.113.201	1.007.707
Subtotal	1.719.321	1.666.234	1.581.606	1.496.138	1.616.961	1.496.138
Total	10.208.393	9.118.312	9.043.778	**9.021.981**	10.251.846	**9.021.981**
Skopje	7.730.013	9.860.156	10.273.309	10.273.309	10.273.309	7.730.030

Municipal Level Regional Level **9.021.981** Headquarters Level

Table 4. Required shelter capacity for homeless population in Western Macedonia

Municipality	Homeless Population	Emergency Available Shelter					Required Shelter No.	Available Turist Camps No.
		Hotels		Children&Workers		Total No.		
		%	No.	%	No.			
Gostivar	34185	72	217	72	1260	1476	32709	-
Tetovo	39028	80	723	-	-	723	38305	-
Subtotal	73213	-	940	-	1260	2200	71013	-
Debar	15376	42	26	-	-	26	15350	-
Ohrid	20915	68	2170	68	5218	7388	13527	3016
Struga	19773	68	2064	68	4669	6733	13040	5424
Subtotal	42754	-	4234	-	9887	14121	28633	8440
Brod	1059	91	27	-	-	27	1032	-
D. Hisar	1522	89	34	-	-	34	1488	-
Kicevo	8346	84	112	-	-	112	8234	-
Subtotal	9956	-	173	-	-	173	9783	-
TOTAL								
1. Tetovo-Gostivar	75605	-	940	-	1260	2200	73405	-
2. Debar Peskopija	69917	-	199	-	-	199	69718	-
3. Ohrid-Korca	48732	-	5415	-	18315	23640	25092	13670