SEISMIC VULNERABILITY OF THE MEGA CITY OF TEHRAN

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SUMMARY

Tehran is a city with about 10 million people living or commuting in and out of it on a daily bases. History of the region indicates strong earthquakes of magnitude 7.0 and higher with approximately 158 years as a return period. With the constant treat of strong earthquakes, municipality of Tehran and the scientific body has joined together to prepare and implement a comprehensive plan for different aspects of the earthquake reduction policies throughout the city.

This paper focuses only on the vulnerability analysis of the city. The policy framework for this analysis involves: study of the seismotectonics of the region, geotechnical aspects, structural performance and lifelines in the metropolitan of Tehran. All together 14 different seismic vulnerability indexes are defined for the city and then a relative vulnerability is specified for each of the 20 sub-divisions, now 22. This paper provides a brief discussion of the analyzed data as well as the obtained results.

INTRODUCTION

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In this regard, this paper looks into the general seismic vulnerability of the city considering different relevant aspects of the phenomenon based on rapid analysis of available data.

METHOD OF ANALYSIS

This paper includes a rapid assessment of the potential vulnerability of the city for expected earthquake scenario which is complied based on available data. Fourteen different parameters were considered for 20 sub-divisions in this study namely: distance from the causative fault-Id, amplification-Ia, liquefaction-Il, landslide-IS, down fall-If, structural behavior-IST, medical emergency availability-IH ,fire services-IF, electricity-IE, gas-IG, transportation-IT, water-IW, socio-economic-ISE aspects of divisions and rescue potentials-ITA. Available data were analyzed for each subdivision for that particular parameter and was given a weight between 1 to maximum relative importance of that particular parameter on the overall seismic vulnerability of the city. This maximum

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rate will be defined for each individual case in the table showing the final results. At the end, a total seismic vulnerability was calculated using equation-1 [Nateghi, 1998].

$$TV_i = \sum_{j=1}^{j=n} I_j \qquad (1)$$

in which: TV = total vulnerability, i = sub-division, J = 1, n (parameter), I = effective weight.

Also, a relative vulnerability was calculated by normalizing total vulnerabilities to the least vulnerability. This enables the city officials to plan accordingly.

ANALYZED DATA

Topography

The area is bounded by the Alborz to the north, the Se-paye to the east, karaj river to the west and southern heights. The northern boundary to the Tehran plain is steeply inclined, northerly dipping reverse fault, the vertical displacement of which is not known but deemed at least 1 km. The Tehran plain is composed of an alluvial pediment that slopes southwards with a gradient decreasing with distance from mountains. Immediately south of the Alborz, there are a series of thick alluvial bahada fans that are incised by the river valleys running from north to south. North of the city, the plain is broken by a number of low alluvial trending E-W. The watercourses cu through these ridges and spread out as wide as gravely fans in the northern and western parts of Tehran [Feghhi, 1999]. Study area is shown in Figure-1.

Geology

The greater Tehran region underlined by the alluvium is classified into four distinct types as follow:

- class D which is recent Alluvium with a thickness of up to 20m.
- class C Tehran formation with a thickness of up to 100m.
- class B Heterogeneous formation with a thickness of up to 300m.
- class A Hezardarreh formation with a thickness of up to 500m.

More on the geology of the region can be find in [Rieben, 1955, 1966]. Figure-2 shows the geological map of Tehran area.

SEISMOTECTONIC AND SEISMICITY

Tehran is built over many faults, Quantenary faulting is the basic tectonic activity in the region with most faults being longitudinal faults following the Alborz Folded-Thrust mountain belt as shown in Figure-3. In terms of seismicity, Table-1 indicates the historical earthquakes in the region which is a good indicator of the seismicity of this region. Based on a research done by [Ashtiany,1992], probability of the occurrence of a strong earthquake with Ms > 7 is around 70%. The distance from causative faults to the north and south of the city then was classified as potential energy release as given in Table-4.

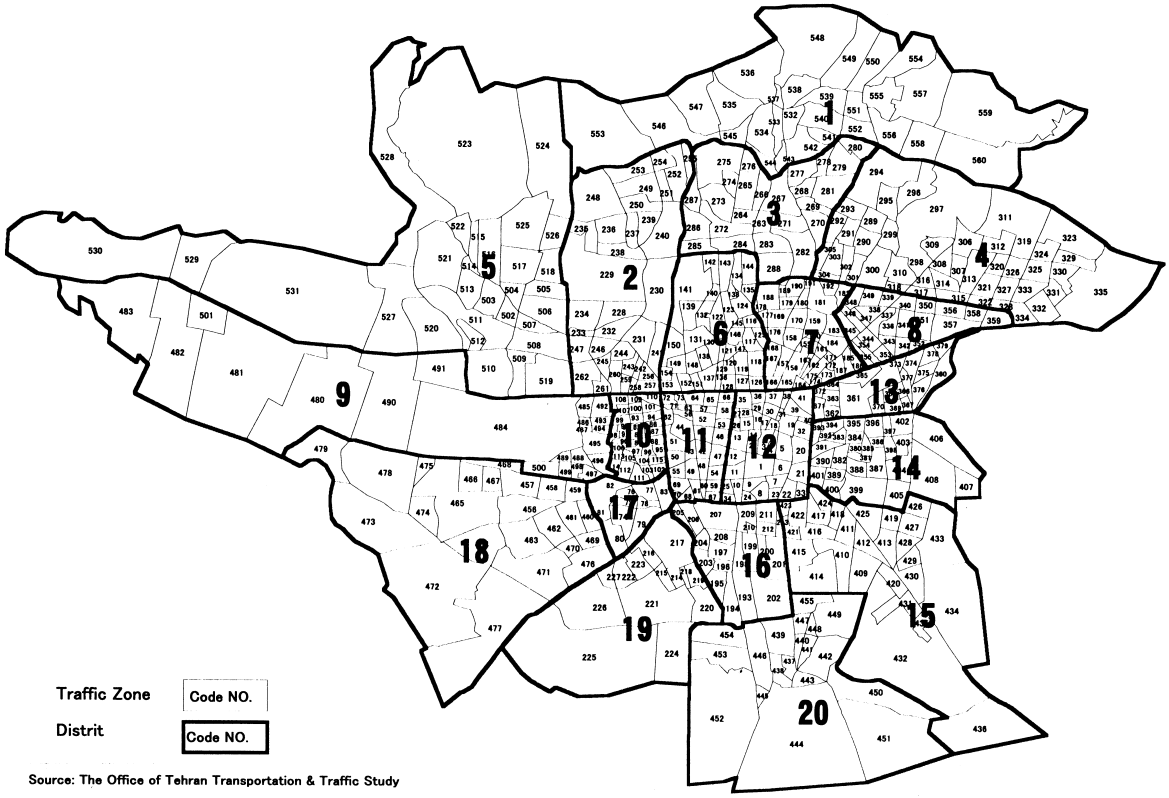

Figure 1: Study area and Location of 20 Sub-Divisions, now 22

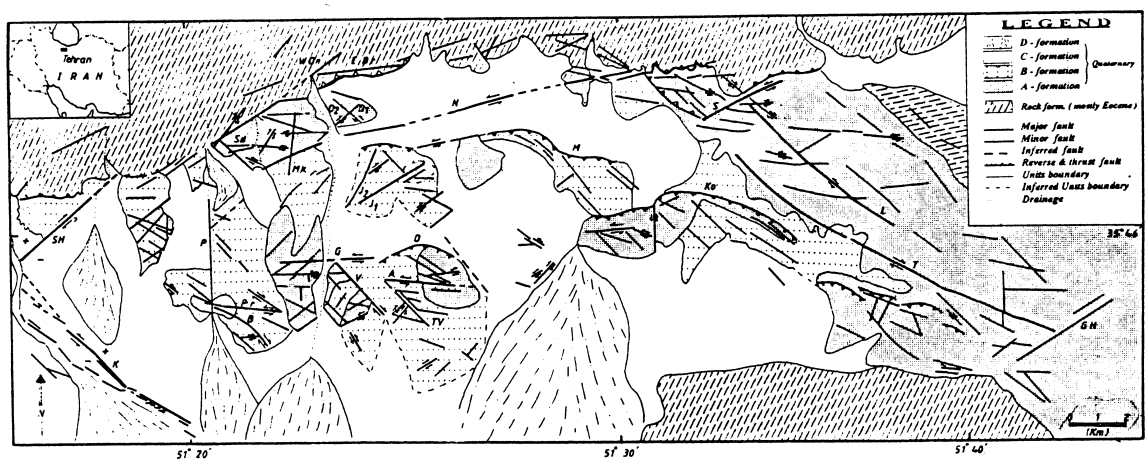

Figure 2: Geological Map of Tehran area and Faults

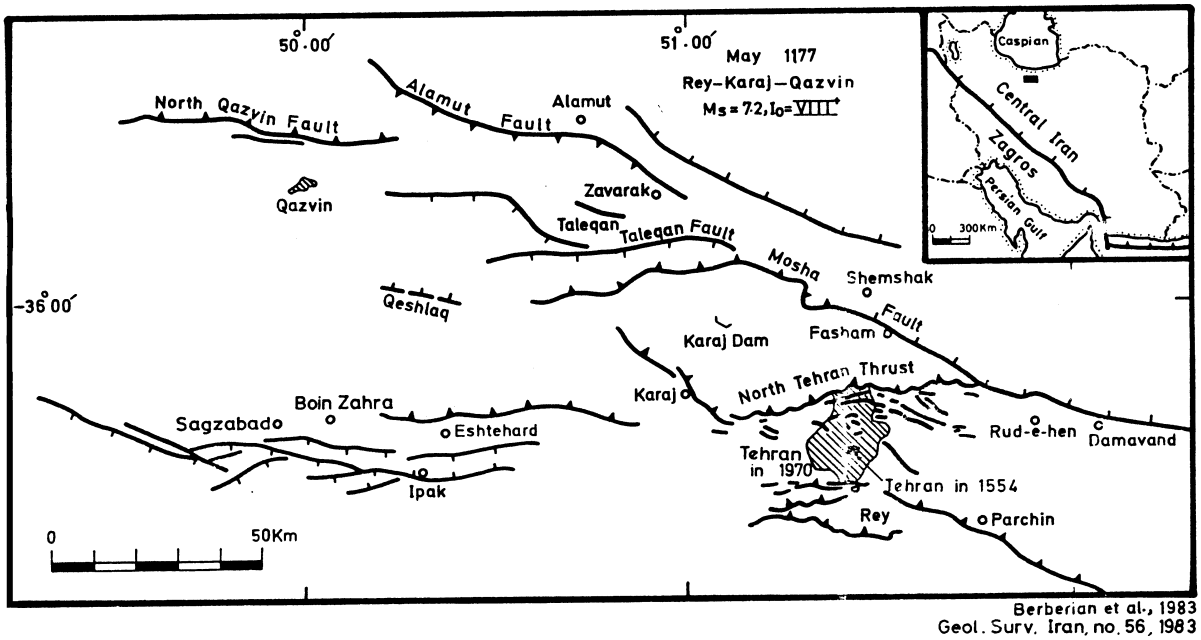

Figure 3: Fault Traces in Tehran Region

Table 1: Historical Earthquakes in the Region

YEAR	County	Fault	Ms	MMI
300 BC	Ray	Parchin, Ray	7.6	X
743	Caspian Gate	Garmasar	7.2	VIII+
855	Ray	Kahrizak	7.1	VIII+
958	Taleghan	Mosha	7.7	X
1117	Karaj	Tehran	7.2	VIII+
1665	Damavand	Mosha	6.5	VIII+
1815	Damavand	Mosha	N/A	V+
1830	Damavand	Mosha	7.1	VIII+

Geotechnical Aspects

Four different phenomenon were considered namely; landslide, liquefaction, amplification and down fall. Available data were microzonation data from the south of the city, landslide zonation of the northern section of the city, liquefaction map of the country with detail analysis of the specific Tehran region and finally amplification studies performed in different sections of the city. Most of these studies are in the form of MS thesis available through universities [Nateghi, 1998]. A typical rating for liquefaction potentials is given in Table-2.

Structural Aspects

There exists about 1,100,000 buildings throughout the city. These buildings differ in their design and construction, but 5 typical distinct structural system is identified in the city, namely; adobe, masonry, steel, R/C and timber. Vulnerability functions for each type was chosen from [Nateghi, 1998] After a detail analysis, a division by division collapse and vulnerability statistics were determined as shown in Table-3 [Nateghi, 1998]. Final results are shown in Table-4

Table 2 : Liquefaction Potentials

Division	Vulnerability	
	RATE-2	RATE-1
1		x
2		x
3		x
4		x
5		x
6		x
7		x
8		x
9		x
10		x
11		x
12		x
13		x
14	x	
15	x	
16	x	
17	x	
18	x	
19	x	
20	x	

Table 3 : Expected Injured & Killed People

Division	killed	Injured
1	77,601	232,803
2	89,479	268,437
3	72,044	216,132
4	176,074	528,223
5	73,034	219,102
6	86,067	258,201
7	127,184	381,552
8	139,074	417,222
9	37,319	111,957
10	52,544	157,632
11	42,123	126,369
12	53,032	159,096
13	32,869	98,607
14	67,528	202,584
15	80,800	242,400
16	51,307	153,921
17	54,095	162,285
18	54,656	163,968
19	30,495	91,485
20	49,300	147,900
SUM	1,446,625	4,339,876

Lifelines

In this case, available data on power and electricity, gas and pump stations, road network and bridges, communication, water and sewage network of the city was analyzed and detail investigation by the experts from each field was performed in each sub-division [Nateghi, 1998]. Final results are shown in Table-4. Water and electricity networks are shown in Figures-4 and 5.

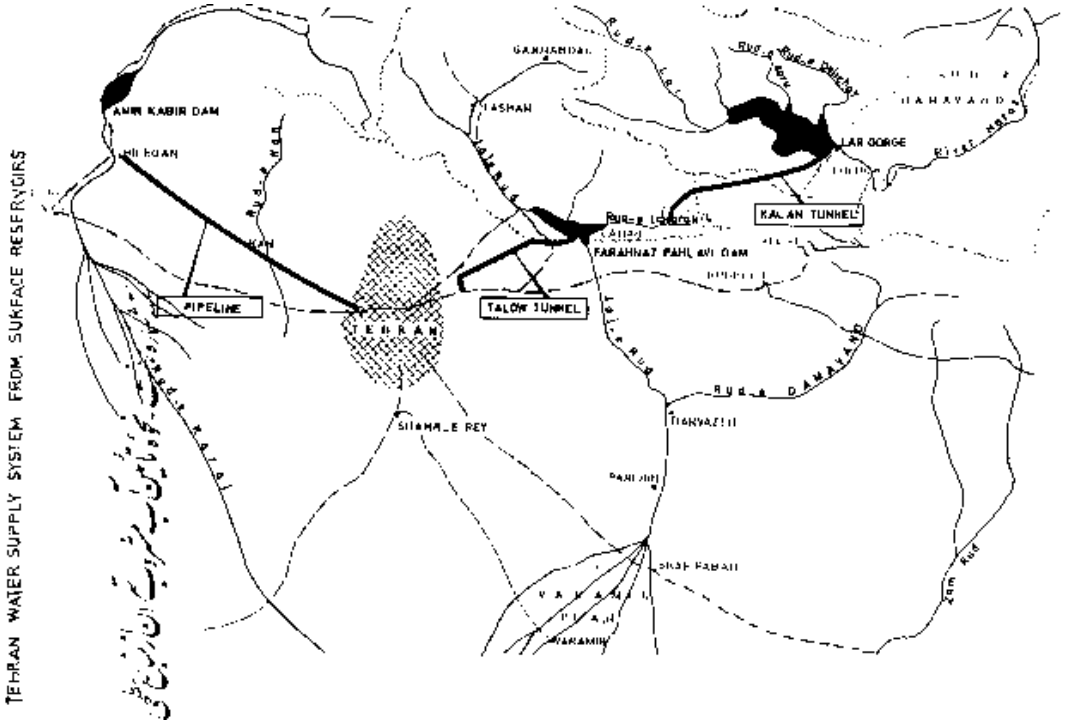

Figure 4: Water Distribution Network of Tehran

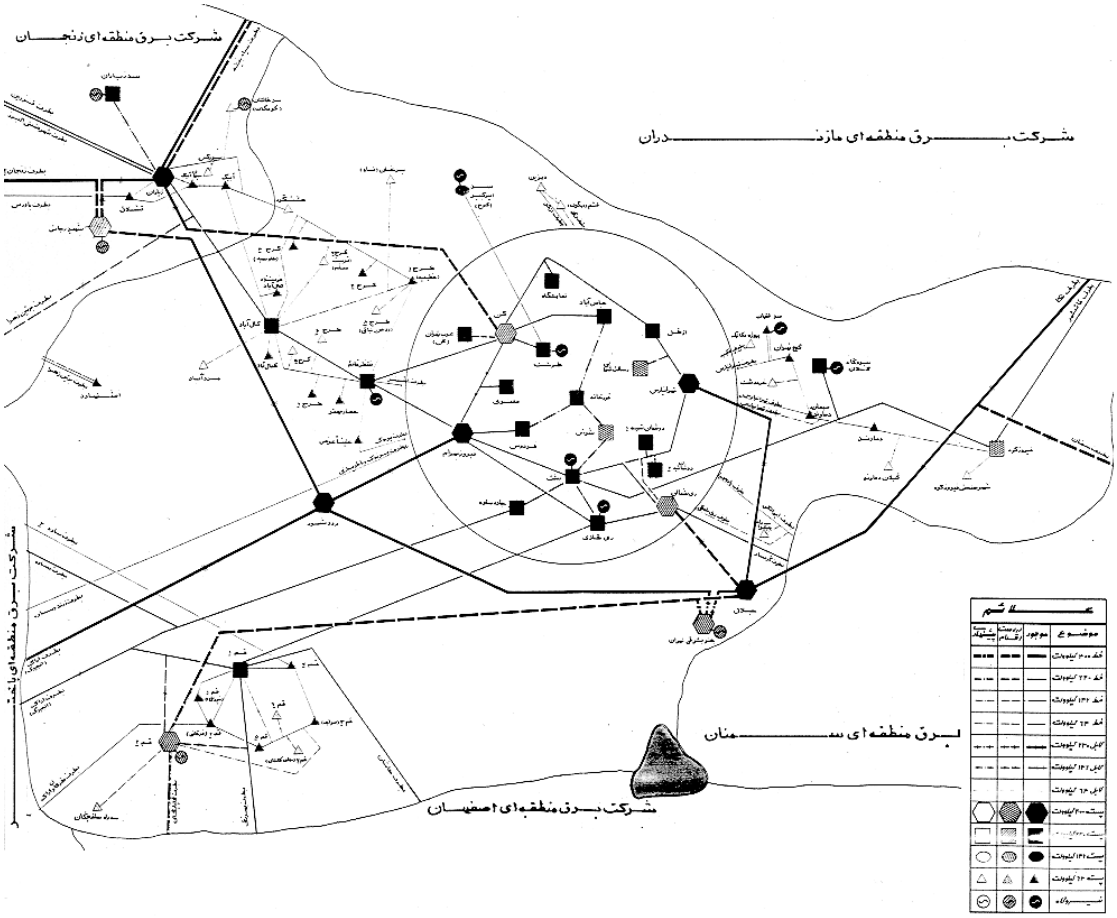

Figure 5: Electricity Distribution Network of Tehran

Table 4 : Seismic Vulnerability Matrix of the Mega City of Tehran

Parameter	Id	Ia	Il	IS	If	IST	IH	IF	IE	IG	IT	IW	ISE	ITA	TV	TV relative
Maximum	4	4	2	2	2	4	3	4	2	2	2	2	2	3	-	-
1	4	4	1	2	1	2	1	3	2	2	2	1	2	1	3072	1
2	3	4	1	2	1	3	2	3	2	1	2	1	2	2	6912	2.25
3	3	4	1	2	1	2	2	3	2	2	2	1	2	2	9216	3
4	3	4	1	2	1	4	3	2	2	1	2	1	2	1	4608	1.5
5	3	4	1	2	1	2	3	4	2	1	2	1	2	1	4608	1.5
6	3	3	1	2	1	1	2	4	2	2	2	2	2	3	13924	4.5
7	3	3	1	2	1	3	2	4	2	2	2	2	2	3	41472	13.5
8	3	3	1	1	1	4	2	3	2	2	2	2	2	3	20736	6.75
9	3	1	1	1	1	3	3	3	2	2	2	2	1	3	3888	1.26
10	3	2	1	1	1	4	2	4	2	2	2	2	2	3	18432	6
11	3	3	1	1	1	3	2	3	2	2	2	2	2	3	10368	3.37
12	3	2	1	1	1	3	2	3	2	2	2	2	2	3	10368	3.37
13	3	2	1	1	1	3	2	4	2	2	2	1	1	3	3456	1.14
14	3	2	2	1	1	4	2	4	2	2	2	1	2	2	12288	4
15	4	4	2	2	1	4	2	3	2	2	2	2	2	2	98306	32
16	4	4	2	1	1	4	2	4	2	2	2	2	2	3	9836	32
17	3	4	2	1	1	4	2	4	2	2	2	2	2	3	3728	24
18	3	4	2	1	1	3	3	4	2	2	2	1	2	1	13826	4.5
19	4	4	2	2	2	2	3	3	2	2	2	2	1	3	110592	36
20	4	4	2	2	2	4	2	3	2	2	2	2	1	3	294962	96

Emergency Services

Hospitals and fire stations were screened using ATC and more detailed inspection method developed for the city in order to investigate the seismic potentials of these buildings. They were mapped onto the city map based on their vulnerability [Nateghi, 1998]. Ranking of these emergency service in each division is given in Table-4.

Socio-Economic

Population for each division was analyzed based on their income class and type of construction they live in. There is a general pattern of socio-economical conditions in each sub-division [Nateghi, 1998]. Certain income class of people live in a certain areas. The results of this analysis is given in Table-4. Also, based on available data, analysis was performed on the number of dead, injured people for the given scenario as shown in Table-3 [Nateghi, 1998].

Search and Rescue

Another parameter considered was the way these sub-divisions were located. Tehran consists of very old sections next to new neighborhoods with very narrow streets some located on hills and slopes. In order to account for the possibility of search and rescue operations, a unique index was also defined for this purposes. Different parts of the city was analyzed considering this local conditions [Nateghi, 1998]. The rating is shown in Table-4.

CONCLUSIONS

A detail study based on available data only, was done to determine the seismic vulnerability of the mega city of Tehran with a population of about 10 million people. Study shows a very dramatic picture for a 0.35g scenario. About 640,000 residence out of 1,100,000 seems to suffer collapse or serious damage while 1,450,000 killed with about 4,330,000 people suffering injuries. Fourteen parameters were considered for each sub division which relative rating for each of the parameters considered was investigated and summarized in a table. This matrix of vulnerability indexes identified in more detail the severity of the problems for given sub divisions. Total and then relative vulnerability for management priority attention was also considered. This indicates that relatively speaking from the worst to the least vulnerable divisions in city of Tehran are as follow: 20 , 19 , 16 , 15 , 17 , 7 , 8 , 10 , 6 , 18 , 14 , 11 , 12 , 3 , 2 , 4 , 5 , 9 , 13 , 1 . Of course this is the overall vulnerability. For detail potentials and problems, a vulnerability matrix was established which provides specific information.

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