No. 57

Japan International Cooperation Agency (JICA)
Centre for Earthquake and Environmental Studies of Tehran (CEST)
Tehran Municipality

The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran

Final Report
Main Report

November 2000

Pacific Consultants International
OYO Corporation

S S F
J R
00-186

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ABBREVIATIONS

General

GTA	Greater Tehran Area
NTF	North Tehran Fault
PSA	Pilot Study Area
SHR	Shahran Station of Seismograph Observatory

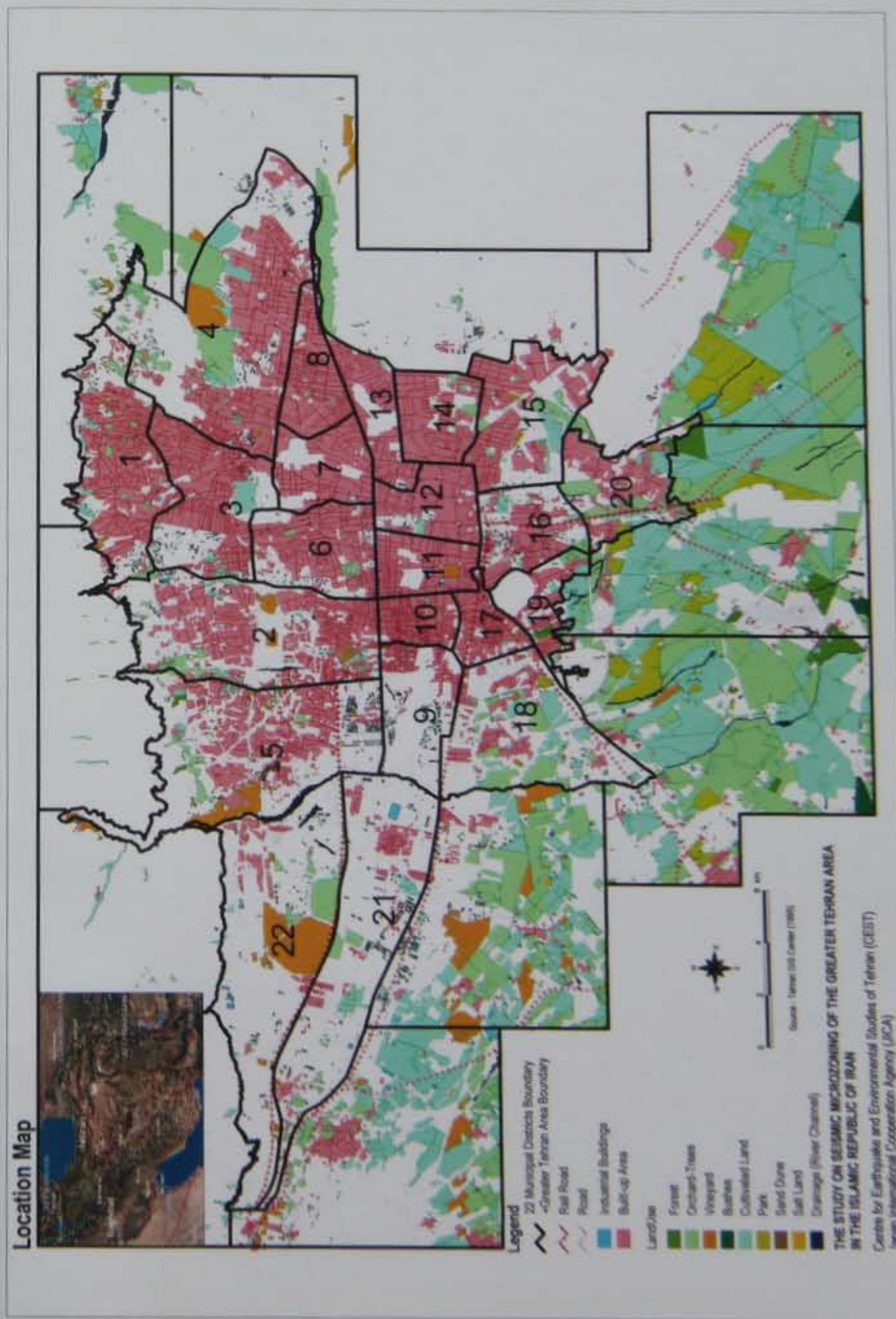
Organisation

AEO	Iran Atomic Energy Organization
BHRC	Building and Housing Research Center, Ministry of Housing and Urban Development
CEST	Centre for Earthquake and Environment Studies of Tehran, Tehran Municipality
CUDPMP	Comprehensive Urban Disaster Prevention and Management Plan
DDTF	District Disaster Task Force
DTF	Disaster Task Force
EPD	Environmental Protection Department
FRO	Forestry and Rangeland Organization
GSI	Geological Survey of Iran
GSMSC	Geotechnical and Strength of Materials Study Center, Tehran Municipality
IESTU	Institute of Environmental Study Tehran University
IGTU	Institute of Geophysics, Tehran University
IIEES	International Institute of Earthquake Engineering and Seismology, Ministry of Culture and Higher Education
IMI	Institute of Meteorology Iran
IRHF	Islamic Revolution Housing Foundation
IRICB	Islamic Republic Iran Central Bank
JICA	Japan International Cooperation Agency
MCHE	Ministry of Culture/Higher Education
MDAF	Ministry of Defence and Armed Forces
MHUD	Ministry of Housing and Urban Development
MOA	Ministry of Agriculture
MOC	Ministry of Commerce
MOC	Ministry of Cooperative
MOE	Ministry of Energy
MOEF	Ministry of Economics and Finance
MOH	Ministry of Health
MOI	Ministry of Interior
MOJC	Ministry of Jihad of Construction

MORT	Ministry of Road and Transportation
MPTT	Ministry of Post, Telegraph and Telephone
NCNDR	National Committee for Natural Disaster Reduction
NDTF	National Disaster Task Force
PBO	Plan and Budget Organization
PDTF	Provincial Disaster Task Force
PMC	Police and Military Commanders
RCSI	Red Crescent Society of Iran
SDDTF	Sub-District Disaster Task Force
SSO	Social Security Organization
TETCO	Tehran Engineering and Technical Consulting Organization, Tehran Municipality
TGIS	Tehran GIS Center, Tehran Municipality
TV/R	Islamic Republic of Iran TV/Radio

Technical Terms

gal	Unit of acceleration, 1 gal equals 1 cm/s^2, 980 gals equal 1 gravitational acceleration
GIS	Geographic information system
JMAI	Japan Meteorological Agency Intensity (seismic intensity scale)
mb	Body wave magnitude
MMI	Modified Mercalli Intensity (seismic intensity scale)
Ms	Surface wave magnitude
Mw	Moment magnitude
N	Blow counts of standard penetration test
Neq	Equivalent SPT N value for 30cm penetration
PGA	Peak Ground Acceleration
RC	Reinforced Concrete
SPT	Standard Penetration Test
Vs	Shear wave velocity

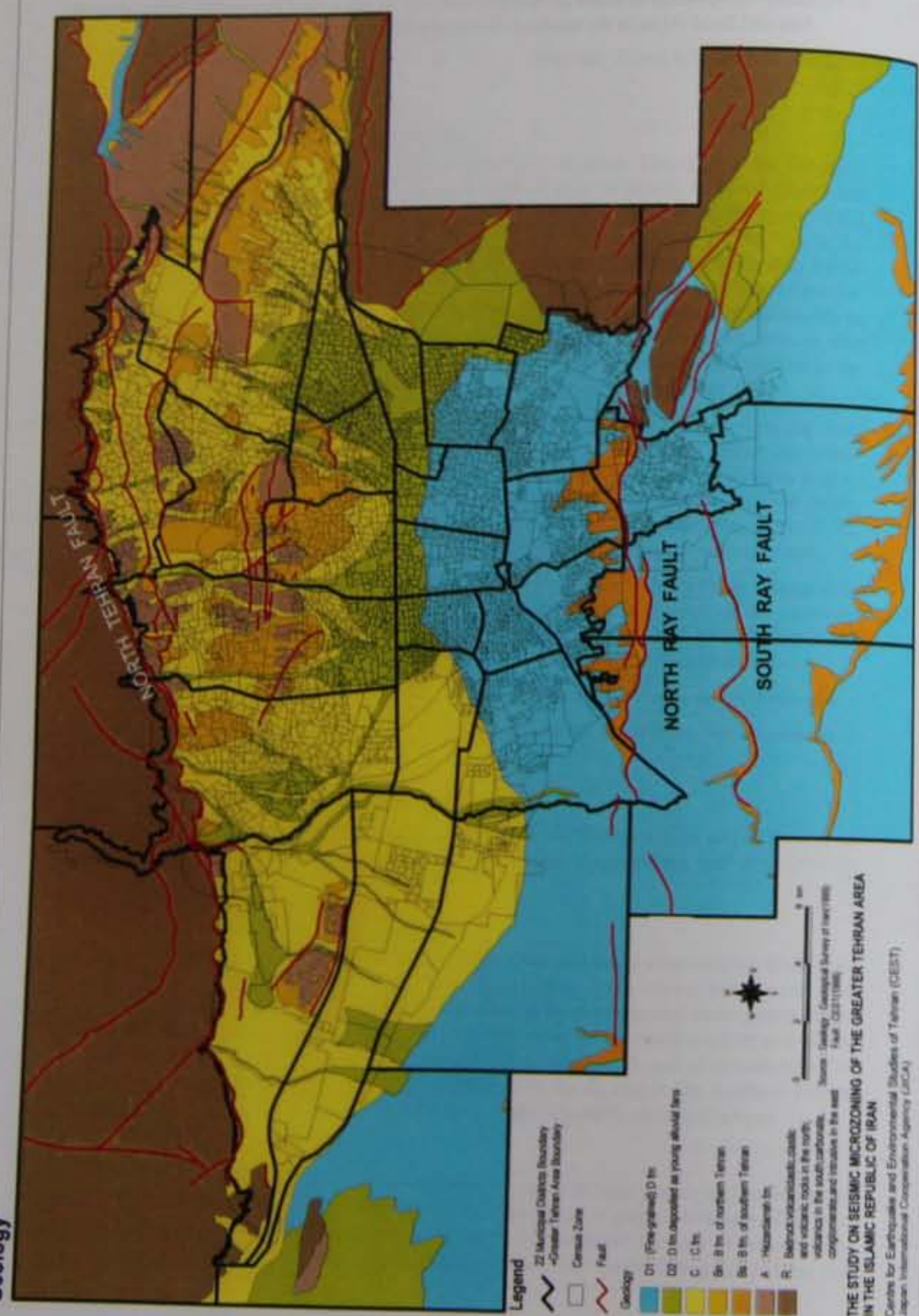


Chapter 2:

Geographic Database Development

Figure 2.2.3

Geology



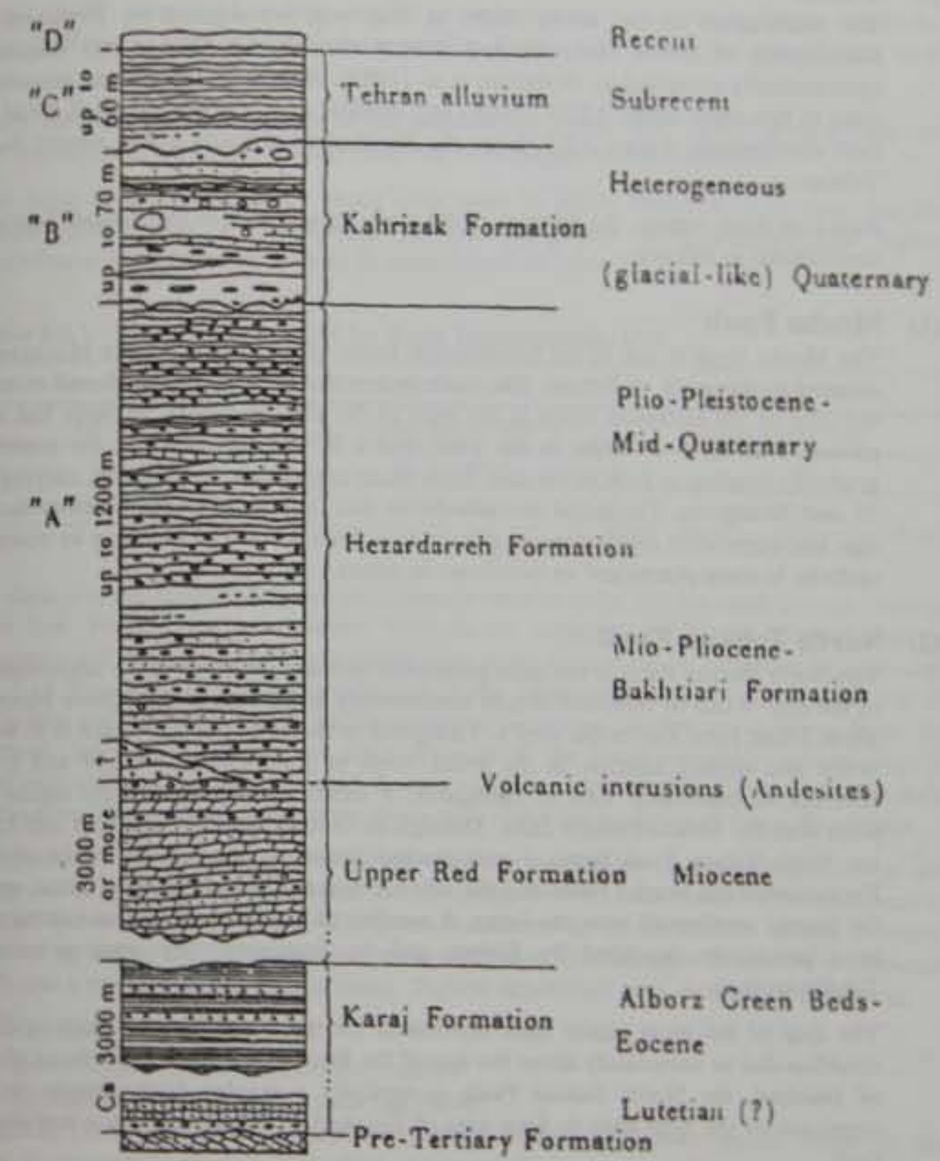


Figure 2.2.4 General section of alluvial deposits in the Tehran region

Source: Geological Observations on Alluvial Deposits in Northern Iran, H. Rieben, Geological Survey of Iran, Report No.9, 1966.

Table 2.2.3 Example of Earthquake Catalogue

No	Date			Time			Epicenter		Depth (km)	Magnitude		Epicentral Intensity	Reference	Area or Quality
	Year	Month	Day	Hour	Minute	Second	Latitude	Longitude		Ms	mb			
151	1485	8	15											
	1485	8	15	18	0		36.7	50.5		7.2		2	AMB	Ia
152	1493	1	10											
	1493	1	10	6	0		33	59.8		7.0		2	AMB	Ib
153	1495													
	1495						34.5	50		5.9			AMB	Ic
154	1497													
	1497						27.2	56.3		6.5		2	AMB	Ic
155	1498													
	1498						37.2	55.2		6.5		2	AMB	Ic
331	1990	11	6											
	1990	11	6	18	45	53	28.23	55.47	16	6.6	6.1		ISC	
	1990	11	6	18	45	52	28.25	55.46	11	6.7	6.2		NEIC	DARAB
	1990	11	6	18	45	54	28.3	55.48	25	6.8	6.3		BJI	
	1990	11	6	18	45	54	28.24	55.54	25	6.7	6.6		MOS	
	1990	11	6	18	45	58	28.29	55.47	32				CSEM	
	1990	11	6	18	45	59	28.06	55.25	15				HRVD	
332	1990	11	6											
	1990	11	6	19	30	20	28.2	55.37	18	5.7	5.3		ISC	
	1990	11	6	19	30	18	28.03	55.47	22	5.5	5.6		MOS	
	1990	11	6	19	30	20	28.4	55.29	19	5.3	5.7		BJI	
	1990	11	6	19	30	20	28.24	55.37	18	5.7	5.4		NEIC	DARAB
	1990	11	6	19	30	26	28.3	55.37	48				CSEM	

Source: Moinfar et.al. (1994)

Table 2.2.4 List of Earthquakes near Tehran

year	month	day	Mw	Latitude (degree)	Longitude (degree)	Epicentral distance (km)	Assumed PGA (gal)
743			7.1	35.30	52.20	81	49
855			7.0	35.60	51.50	12	412
856	12	22	7.9	36.20	54.30	263	17
864	1		5.4	35.70	51.00	41	34
958	2	23	7.7	36.00	51.10	46	161
1119	12	10	6.4	35.70	49.90	140	13
1177	5		7.1	35.70	50.70	68	63
1301			6.6	36.10	53.20	164	12
1485	8	15	7.1	36.70	50.50	140	23
1608	4	20	7.6	36.40	50.50	116	44
1665			6.4	35.70	52.10	59	44
1687			6.4	36.30	52.60	123	15
1809			6.4	36.30	52.50	116	17
1825			6.6	36.10	52.60	113	21
1830	3	27	7.0	35.80	51.70	25	208
1868	8	1	6.3	34.90	52.50	130	13
1930	10	2	5.4	35.78	52.02	52	24
1957	7	2	6.7	36.20	52.60	118	21
1962	9	1	7.1	35.54	49.39	187	15
1983	3	26	5.3	36.12	52.21	83	10
1990	6	20	7.4	36.96	49.39	232	14
1994	11	21	4.5	35.90	51.88	45	14

Source: List from Moinfar et al. (1994)
Location of 1830 earthquake is quoted from Berberian et al.(1999)
Magnitudes and PGA were calculated by Study Team

Table 2.2.5 Number of Earthquakes (100 km from Tehran, from 1996 to 1999)

Magnitude mb	Number of earthquake
0<mb≤1	29
1<mb≤2	670
2<mb≤3	350
3<mb≤4	44
4<mb≤5	5

Source: IGTU (1999)

Table 2.2.6 List of Earthquakes (mb>4, 100 km from Tehran, from 1996 to 1999)

Date	Time	Latitude	Longitude	Depth (km)	mb
1997/6/7	29:47.3	36.17	50.48	7.9	4.2
1997/11/5	42:55.2	35.01	51.55	23.3	4.6
1998/1/9	06:08.5	36.47	52.24	6.5	4.7
1998/12/3	13:27.5	36.17	50.97	17.9	4.5
1999/3/26	06:48.5	36.37	50.26	9.1	4.5

Source: IGTU (1999)

(2) Earthquake Damage in Tehran

Fortunately, Tehran has not suffered severe damage due to an earthquake in over 150 years. Based on the historical earthquake catalogue, earthquakes that could likely affect Tehran can be speculated as follows:

Due to the spatial extent of the Greater Tehran area, a sample site was selected for PGA computations. This point was the Ferdowsi Square, a highly populated area near the City Centre, with a latitude of 35.70N and a longitude of 51.45E. PGA was calculated using Campbell et al. (1997) for a dip-slip type earthquake and alluvial ground conditions. Details are explained in Chapter 3, section 3.3.1.

The largest Peak Ground Acceleration (PGA) was 412 gal, observed in the earthquake of 855. The second largest PGA observation occurred in 1830, and the third largest in 958. According to Berberian (1999), the events in the years 958, 1830 and 1665 occurred in a segment of the Mosha Fault. It has also been said that the event in 855 may have occurred at the South Ray Fault. As for the North Tehran Fault, it is not clear, but the events in 958 and 1177 are correlated with this fault according to Berberian et al. (1983).

The following excerpts Ambraseys and Melville (1982) describe the damage caused by these historical earthquakes:

Year 855 :

A major earthquake in Ray destroyed many houses and caused a large number of casualties in the district. The shock was strongly felt, perhaps with some damages in Qum and Kashan. Aftershocks continued for more than a month.

Year 958 :

There was a catastrophic earthquake in the northern part of central Persia. It destroyed all villages in the districts of Ray and Taliqan, both in the plains and in the mountains, and much of the city of Ray was totally ruined, heavy casualties being reported in both districts. In Taliqan, there were only 30 survivors and in the district of Ray, 150 villages were destroyed, one village in the mountains being overwhelmed by landslides. A mountain near Ray was fissured and water spouted out of the ground. In the mountains of Ruyan to the north of Ray, large-scale landslides blocked the course of a river whose waters receded to form a lake. Damage extended to the northwest into Dailam and south to Qum and Kashan. The shock was possibly felt in Isfahan and as far west as in Baghdad. Damaging aftershocks continued for forty days and were felt throughout north-central Persia. It is possible that the earthquake was connected with an abnormal drop in the level of the Caspian Sea, which, however, seems to have occurred before the event.

Year 1177 :

An earthquake destroyed many towns of Persian Iraq, along the southern slopes of the Alburz up to the region beyond Ray. The cities particularly devastated were Qazvin and Ray, where many people were killed. Internal evidence indicates that the Ray area, eastern Buyin Zahra and the Karaj settlements were worst affected.

Year 1665 :

There was a destructive earthquake in Damavand and its dependencies. The earthquake destroyed many houses and buildings in Damavand. An inscription in the Masjid-i jami refers to the earthquake damage and records the restoration work done in 1670.

Year 1830 :

On the morning of 2 Shawwal 1245, a major earthquake in the southern Mazandaran almost totally destroyed the districts of Shamiranat and Damavand, east of Tehran. About 70 villages, lying eastwards of the Jai-rud, along the routes via Damavand to Simnan and Damghan, were ruined and more than 500 people were killed in Damavand alone. Damage extended to Jaj-rud, where the Caravanserai was shattered and in Tehran, many old houses collapsed killing about 30 people. Not a single house in the capital escaped from the damage and part of the palace, together with many adjoining houses and part of the bazaar were thrown down. The Arg, the Great Audience Hall, a number of mansions, as well as the old British Embassy building were badly damaged and garden walls were levelled off on the ground. The loss of property in Tehran was estimated at half a million tomans. The shock caused some damage to a number of public buildings in Amul, Sari and Damghan and triggered rock-falls that blocked the passes on the Harhaz and Talar-rud roads to the north. The earthquake was felt as far as Baku and was followed by violent aftershocks that caused additional damage in the Shamiranat region and great panic in Tehran, where a large proportion of the population camped in tents. The royal court also encamped in the open courts of the Arg. The aftershock of 6 April destroyed the old caravanserai totally at Jajrud.

As have been mentioned, Tehran has not suffered severe damage in over 150 years, but there occurred many devastating earthquakes in recent years in other regions of Iran. In 1997, three disastrous earthquakes occurred. On 4 February, a magnitude 6.1 earthquake rocked Northern Khorasan and East Mazandaran in northeast Iran. In total, 91 people died and 5,500 houses collapsed. On 28 February, an earthquake of magnitude 5.5 hit Ardebil and Meshkin-shahr in northwest Iran. A total of 800 people died and 8,500 houses, 100 % of houses in the area, collapsed. On 10 May, a large earthquake of magnitude 7.3 hit Birijand and Qaen in the southern part of the Khorasan Province in eastern Iran. The overall damage was 1,568 dead and 13,605 houses completely destroyed.

On 21 June 1990, a magnitude 7.3, large earthquake hit the Manjil region. The damage was devastating, 37,000 people died and 100,000 houses collapsed. After the disastrous earthquake, many academic investigations were carried out and many reports were written. However, there are only a few quantitative studies on vulnerability functions of different types of structures. It is necessary to continue research of this type with relevant organisations in Iran.

Figure 2.2.6

Epicentral Distribution (Historical Earthquake [734-1994])

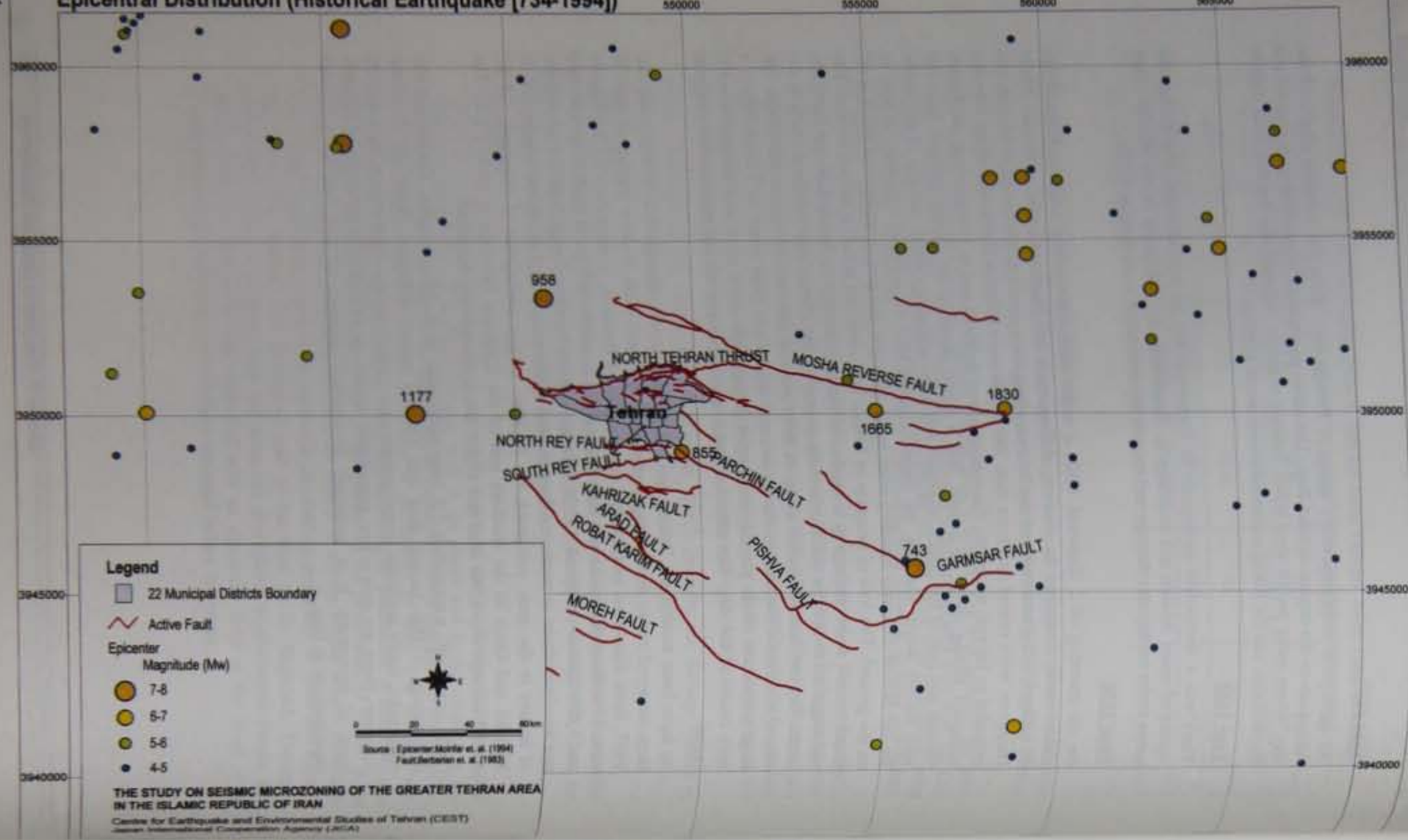
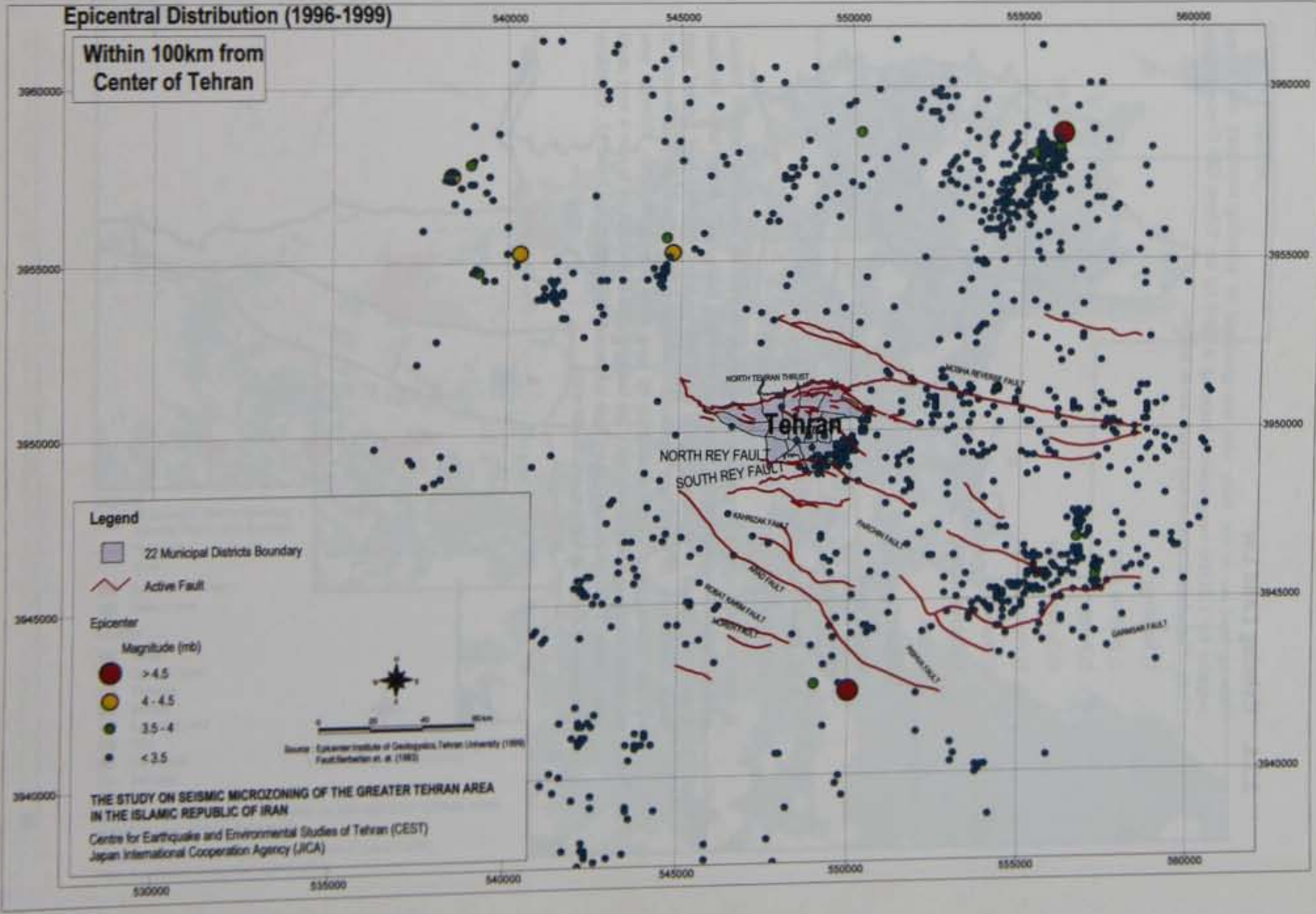


Figure 2.2.7

Epicentral Distribution (1996-1999)



2.2.6. Existing Land Use

Existing land use of the study area was generated by selecting necessary map layers prepared for 1:25,000 topographical mapping in 1995 by the Tehran GIS Center (Figure 2.2.8). The selected thirteen map layers are as follow:

1) Buildings
2) Built-up Area
3) Forest
4) Orchard -Trees
5) Vineyard
6) Bushes
7) Cultivated Land
8) Park
9) Sand Dune
10) Salt Land
11) Drainage
12) Road
13) Railway

In these map layers, built-up areas, which represent the existing urbanised areas of Tehran, were calculated for each district. Results are shown in Table 2.2.7. In this table, Districts 7, 8, 10, 11, 12 and 14 are densely made up of built-up areas, and they have limited open space. Districts 6, 13 and 17 are also densely urbanised. Districts 21 and 22, located in western Tehran, have a very small built-up area ratio (less than 10%), although new residential areas are being developed. The built-up ratio of District 18 is also a very small value (13%). The airport and military base are located in Districts 9, 13 and 19. Extensive open space is shown as white zones on the map.

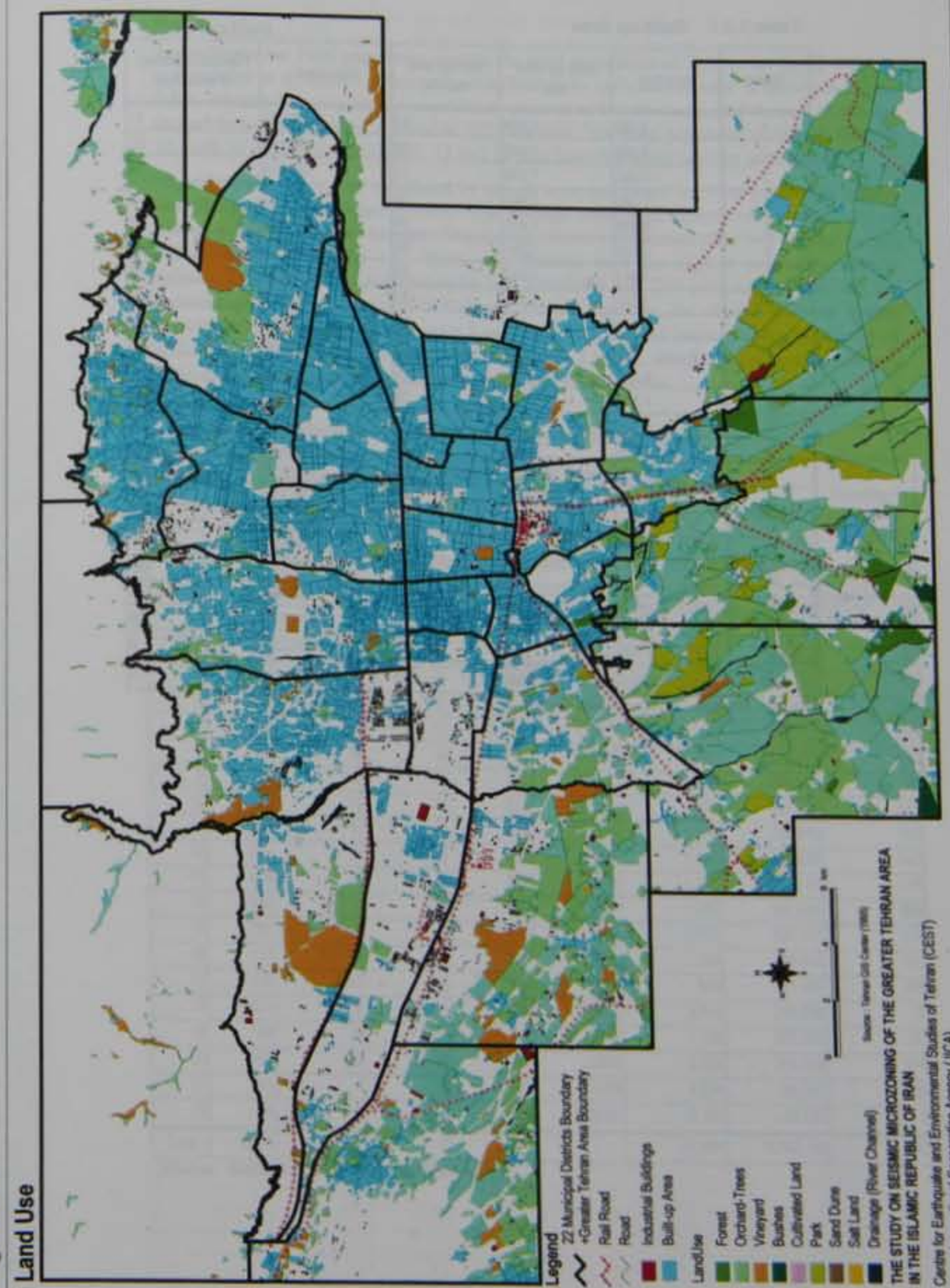


Figure 2.2.8

Table 2.2.7 Built-up Area

District	Area (ha)	Built-up Area (ha)	Built-up area ratio (%)	Population	Population Density (Person/ha)
1	3,462	1,826	53	245,502	71
2	4,968	1,910	38	456,414	92
3	2,945	1,639	56	259,019	88
4	7,260	2,645	36	663,166	91
5	5,915	1,431	24	427,955	72
6	2,149	1,291	60	220,331	103
7	1,541	1,082	70	300,212	195
8	1,327	1,074	81	332,005	250
9	1,960	290	15	173,482	89
10	808	604	75	282,308	349
11	1,189	881	74	225,840	190
12	1,359	1,074	79	189,625	140
13	1,391	850	61	245,142	176
14	1,459	1,067	73	392,524	269
15	2,852	1,371	48	622,517	218
16	1,649	678	41	298,410	181
17	829	536	65	287,367	347
18	3,794	508	13	293,598	77
19	1,152	407	35	227,389	197
20	2,033	796	39	354,449	174
21	5,208	394	8	188,890	36
22	6,154	234	4	56,020	9
Total	61,404	22,588	37	6,742,165	110

Source: Statistics Center of Iran (1996)

2.2.7. Population

According to the 1996 population census, the total population of Tehran for its 22 districts is calculated at 6,742,165. Population distribution by each census zone is shown in Figure 2.2.9. District 4 has the largest population, counted at 663 thousand, and district 15 has the second-largest population, counted at 622 thousand. The least populated district is District 22, with 56 thousand. Districts 9, 12 and 21 also have relatively smaller populations.

Population density is also calculated by census zone and based on 1996 population census data (Table 2.2.8 and Figure 2.2.10). The average population density of the entire city of Tehran is 110 persons per hectare. The average density of District 10 is 349 person/ ha and 347 person/ha in District 17. These two districts have the highest population density values. District 14 has 269 person/ha and District 8 has 250 person/ha. These are the second-highest density districts in Tehran. On the contrary, the district with the lowest population density is District 22, with 9 person/ha. The second lowest district is District 21, with 36 person/ha. The density of Districts 1, 2, 3 and 4, which are located in northern Tehran, is shown to be between 71 person/ha and 92 person/ha.

Table 2.2.8 Population / Density Distribution by Districts

District	No of Census Zones	Number of Census Zones		Highest Population Density (person/ha)		Area (ha)	Population	Population Density (Person/ha)
		Density exceeds 600 p/ha	Density exceeds 800 p/ha	Density (p/ha)	Zone No.			
1	163	0	0	391	01075	3,462	245,502	71
2	238	0	0	313	02149	4,968	456,414	92
3	155	0	0	449	03108	2,945	259,019	88
4	297	5	0	710	04133	7,260	663,166	91
5	215	1	0	673	05033	5,915	427,955	72
6	123	0	0	324	06088	2,149	220,331	103
7	151	0	0	554	07081	1,541	300,212	195
8	150	5	0	712	08014	1,327	332,005	250
9	80	10	0	761	09047	1,960	173,482	89
10	125	2	0	632	10083	808	282,308	349
11	110	0	0	446	11089	1,189	225,840	190
12	108	0	0	422	12060	1,359	189,625	140
13	113	0	0	508	13034	1,391	245,142	176
14	168	1	0	621	14119	1,459	392,524	269
15	252	33	4	878	15060	2,852	622,517	219
16	129	6	0	744	16077	1,649	298,410	181
17	109	30	0	783	17082	829	287,367	347
18	121	14	1	826	18097	3,794	293,598	77
19	88	8	0	680	19041	1,152	227,389	197
20	167	0	0	588	20093	2,033	354,449	174
21	85	4	0	778	21048	5,208	188,890	36
22	26	0	0	164	22010	6,154	56,020	9
Total	3,173	119	5			61,404	6,742,165	110

Source: Statistics Center of Iran (1996)

As shown in Table 2.2.8, it is remarkable that Districts 9,15,17 and 18 have more than 10 census zones with densities of more than 600 persons/ha. A detailed list of these census zones is shown in Table 2.2.9.

Table 2.2.9 List of Census Zones (more than 600persons/ha)

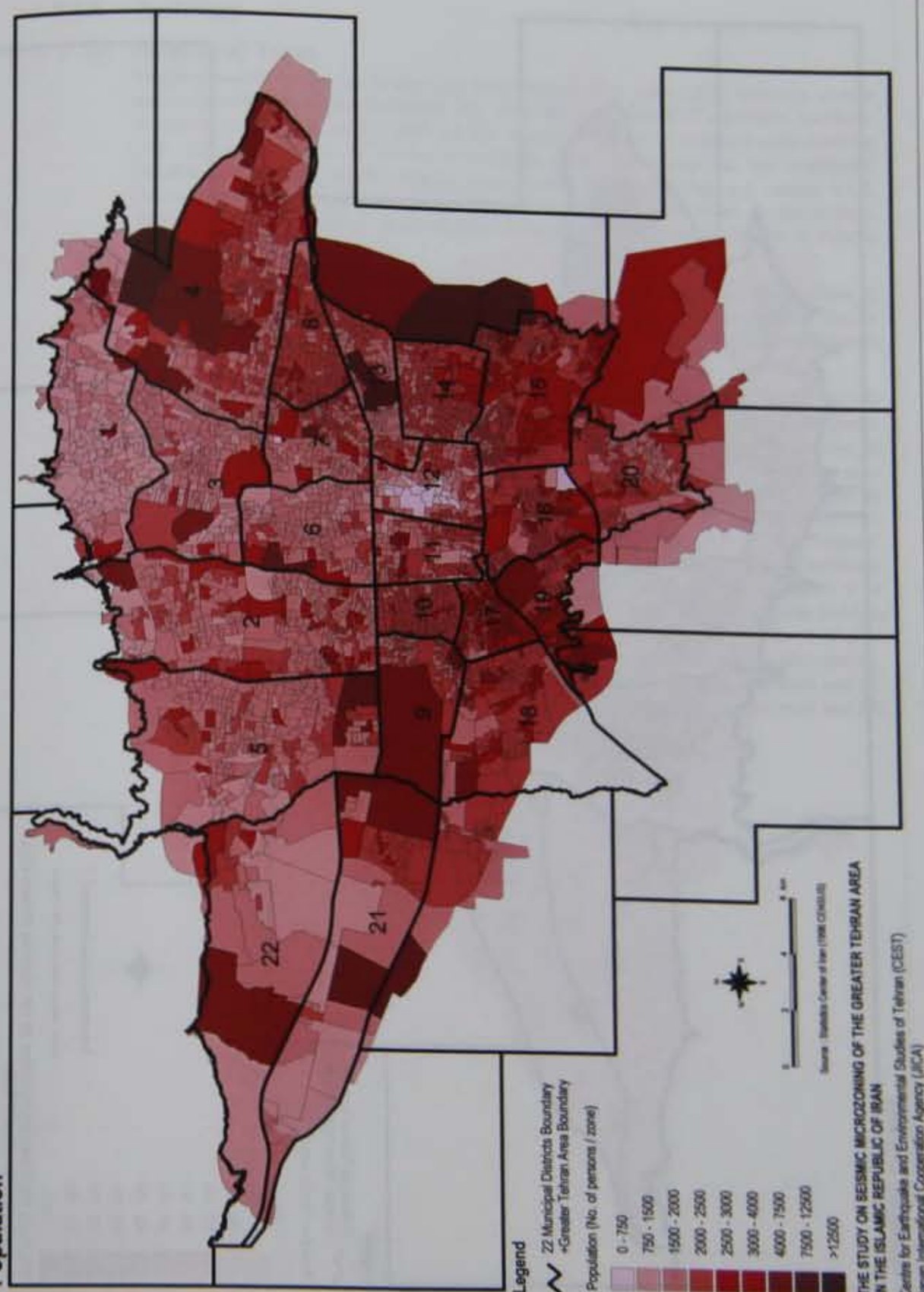
District	Census Zone No.	Population	Area (ha)	Population Density (P/ha)
4	04121	2,054	3.11	661
	04126	2,132	3.43	621
	04130	1,832	2.99	612
	04132	2,323	3.68	632
	04133	2,395	3.37	710
5	05033	2,393	3.55	673
8	08014	2,378	3.34	712
	08015	2,170	3.05	711
	08025	2,454	3.89	632
	08028	2,224	3.55	627
	08030	2,363	3.60	657
9	09028	2,007	2.82	711
	09029	2,066	2.94	703
	09030	1,905	2.90	656
	09035	2,210	3.48	636
	09043	1,965	3.24	606
	09045	2,038	2.93	696
	09047	2,021	2.66	761
	09049	1,831	2.94	624
	09053	2,026	3.29	615
	09063	1,984	3.26	609
10	10052	2,515	4.05	621
	10083	2,435	3.85	632
14	14119	2,302	3.70	621
15	15013	2,206	2.68	822
	15014	2,070	3.31	626
	15015	2,216	2.97	747
	15016	2,241	3.59	624
	15017	2,430	3.96	614
	15023	2,117	3.38	627
	15049	2,389	3.85	621
	15050	2,438	3.95	617
	15052	2,373	3.47	684
	15053	2,303	3.38	682
	15055	2,334	2.91	803
	15056	2,143	3.46	619
	15058	2,212	2.92	758
	15059	2,129	2.74	777
	15060	2,302	2.62	878
	15062	2,222	3.18	698
	15064	2,242	2.99	750
	15065	2,280	3.80	600
	15067	2,301	3.37	682
	15074	2,171	3.45	629
	15081	2,111	3.04	694
	15086	2,060	2.71	759
	15087	2,429	3.33	730
	15089	2,273	3.57	636
	15093	2,357	2.76	854
	15103	2,535	3.92	646

15	15106	2,348	3.49	673
	15108	2,018	3.18	635
	15113	2,309	3.00	770
	15133	2,595	4.15	626
	15135	2,349	3.53	665
	15210	2,618	4.29	611
	15228	2,719	4.35	626
16	16075	2,458	3.81	645
	16076	2,467	3.78	653
	16077	2,531	3.40	744
	16085	2,276	3.55	642
	16087	2,285	3.61	633
	16088	2,183	3.27	668
17	17013	2,343	3.64	644
	17032	2,804	4.25	660
	17034	2,554	4.13	618
	17040	2,516	3.67	685
	17042	2,668	3.69	722
	17043	2,484	3.34	744
	17044	2,582	4.21	613
	17046	2,623	3.53	744
	17047	2,518	3.49	722
	17048	2,486	3.55	701
	17049	2,426	3.15	771
	17050	2,323	3.28	709
	17051	2,440	3.70	659
	17055	2,894	4.52	640
	17057	2,466	3.67	672
	17059	2,692	3.68	731
	17061	2,712	4.12	659
	17067	2,499	3.79	660
	17074	2,836	3.87	733
	17079	3,497	5.41	646
	17081	2,786	4.34	643
	17082	2,915	3.72	783
	17083	3,157	5.20	608
	17084	2,723	4.48	608
	17085	3,338	4.88	685
	17094	2,398	3.41	703
	17096	2,529	4.02	629
	17097	2,676	4.08	656
	17098	2,502	4.09	612
	17100	2,524	3.58	705
18	18006	2,589	3.58	723
	18007	2,798	4.40	636
	18013	2,540	4.03	630
	18063	2,399	3.80	632
	18064	2,526	4.18	605
	18067	2,337	3.86	605
	18080	2,520	3.62	697
	18082	2,274	3.53	645
	18088	2,349	3.81	617
	18097	2,351	2.84	826
	18098	2,444	3.37	725
	18099	2,430	3.51	692
	18119	2,810	4.07	691
	18124	2,319	3.58	647
19	19012	2,511	3.91	642
	19014	2,502	3.73	672

19	19016	2,653	4.28	619
	19018	2,655	4.28	620
	19019	2,543	3.83	664
	19025	2,624	4.34	605
	19041	2,499	3.67	680
	19042	2,394	3.58	668
21	21048	2,232	2.87	778
	21053	2,117	3.48	608
	21054	2,380	3.43	695
	21055	2,240	2.93	765

Figure 2.2.9

Population



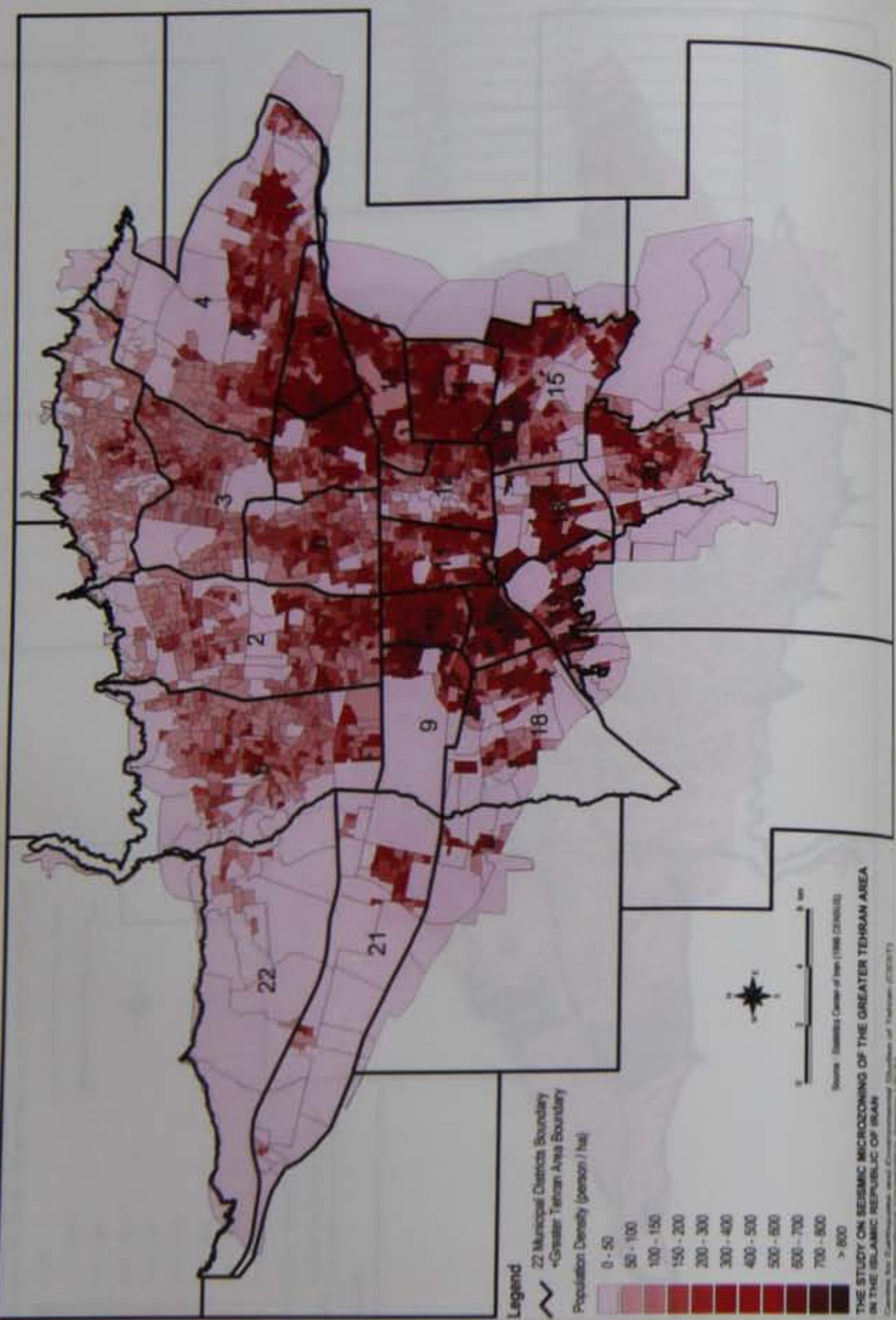


Figure 2.2.10

2.2.8. Buildings

(1) Structural Types

Building statistics were also prepared by SCI based on 1996 census data; however, census data only covers residential buildings. For 1996, the total number of residential buildings in Tehran is 1,484,138 units (Figure 2.2.11). This figure seems to represent each dwelling unit. Apartment houses or connected buildings should be counted as one residential building unit, from the seismic damage analysis point of view. In Chapter 4, section 4.1.2, the methodology and figures used for building units are explained in detail. In this section, based on available statistics, characteristics of the existing building distribution in Tehran are described.

Districts 2, 4, 5 and 15 have more than 100 thousand building units. The total number of buildings in District 22 is only 11,982 units, the smallest number of buildings per district within the entire city. The district with the second smallest number of buildings is District 21 and the third is District 9.

Buildings are classified into four categories according to structural type 1) Steel, 2) RC, 3) Others and 4) Unknown. Table 2.2.10 shows the distribution of these four categories aggregated into each district. Detailed structural type distribution is shown in a series of maps (Figure 2.2.12 to Figure 2.2.14). The category "Others" is further classified into nine (9) structural types. The total number of steel buildings is 604,363 units (41 %), RC is 169,960 (11 %), Others is 678,273 (46 %) and Unknown is 31,542 (2 %). Steel and RC buildings are considered to be relatively new and large sized buildings in Tehran. "Others" are older, more traditional types of buildings. The distribution pattern of these buildings shows the characteristics of Tehran's urban growth. Districts having more than 60 % of Steel structures plus RC structures are Districts 1, 2, 3, 4, 5, 6 and 22. All of these districts, except for District 22, are located in northern Tehran. District 5 consists of 83 % of steel and RC buildings and District 2 consists of 81 % of these structural types. On the contrary, Districts 10, 16 and 17, which are located in southern Tehran consist of less Steel and RC structures. District 9, 11, 12, 13, 18 and 19 also have a lower percentage of steel and RC structures.

Table 2.2.10 Building Distribution by Structure (Dwelling Unit)

District	Structural Type (No. of buildings)				Total by district	Percentage of Steel and RC Structures
	Steel	RC	Other	Unknown		
1	28,961	13,886	18,319	1,392	62,558	68
2	59,945	34,875	20,453	2,325	117,598	81
3	41,122	13,652	14,111	1,308	70,193	78
4	72,009	19,877	52,246	3,397	147,529	62
5	47,974	37,014	15,703	1,850	102,541	83
6	31,756	6,380	20,039	937	59,112	65
7	35,575	4,131	36,591	1,762	78,059	51
8	33,972	2,431	45,383	1,735	83,521	44
9	9,346	2,930	25,032	518	37,826	32
10	14,049	415	46,501	1,230	62,195	23
11	19,640	1,033	32,498	1,125	54,296	38
12	12,570	799	24,876	1,000	39,245	34
13	19,764	1,650	36,483	1,188	59,105	36
14	32,549	4,543	48,515	1,837	87,444	42
15	44,767	9,162	65,853	2,830	122,612	44
16	12,104	1,966	34,592	1,426	50,088	28
17	9,452	242	31,333	1,251	42,278	23
18	15,180	436	30,420	1,304	47,340	33
19	13,828	759	27,152	794	42,533	34
20	27,098	5,821	36,227	1,453	70,599	47
21	16,046	3,752	14,942	744	35,484	56
22	6,636	4,206	1,004	136	11,982	90
Total	604,363	169,960	678,273	31,542	1,484,138	52

Source: Statistics Center of Iran (1996)

Figure 2.2.11

Building Distribution [Dwelling Unit]

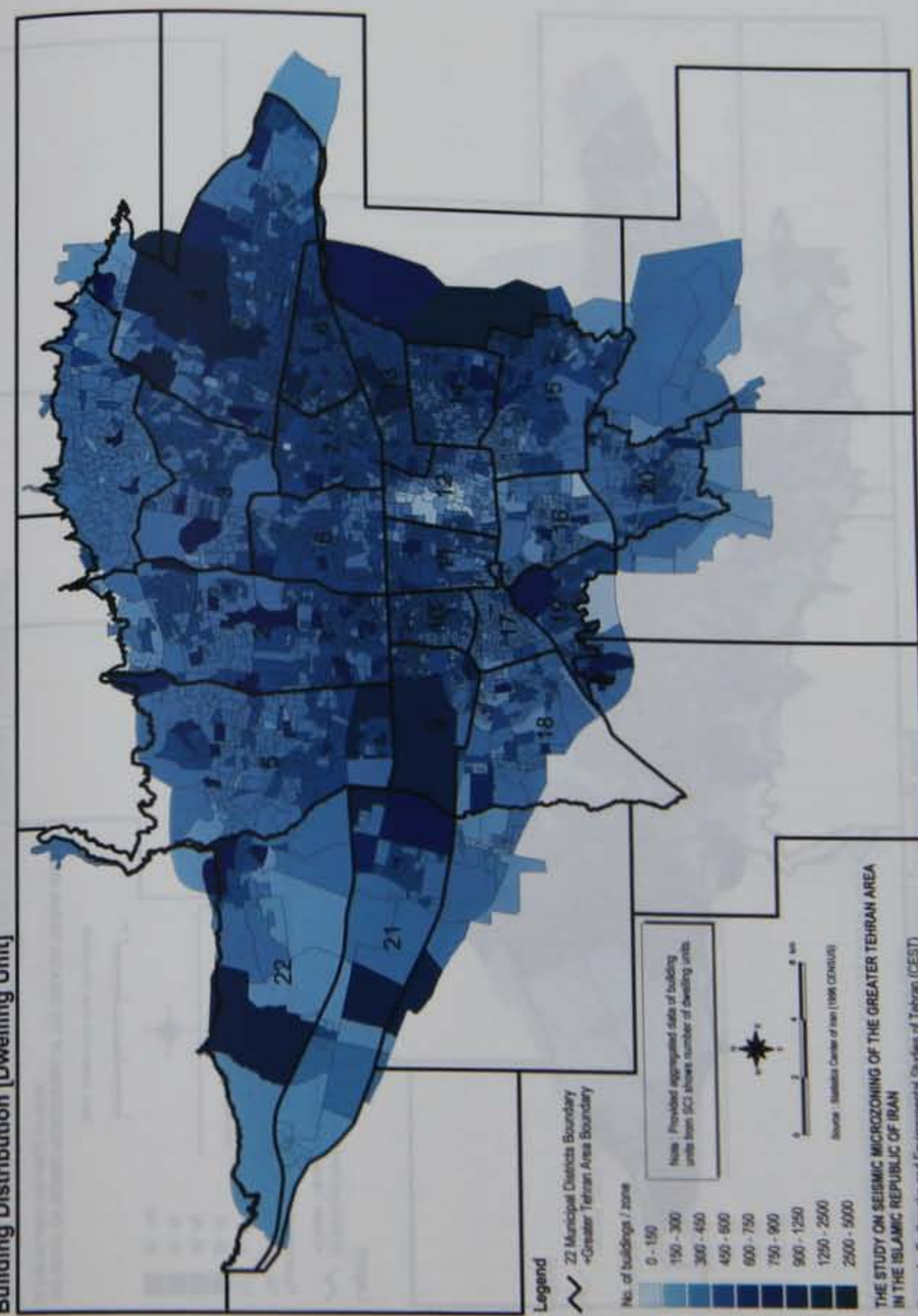


Figure 2.2.12

Building Distribution by Structure (Steel) [Dwelling Unit]

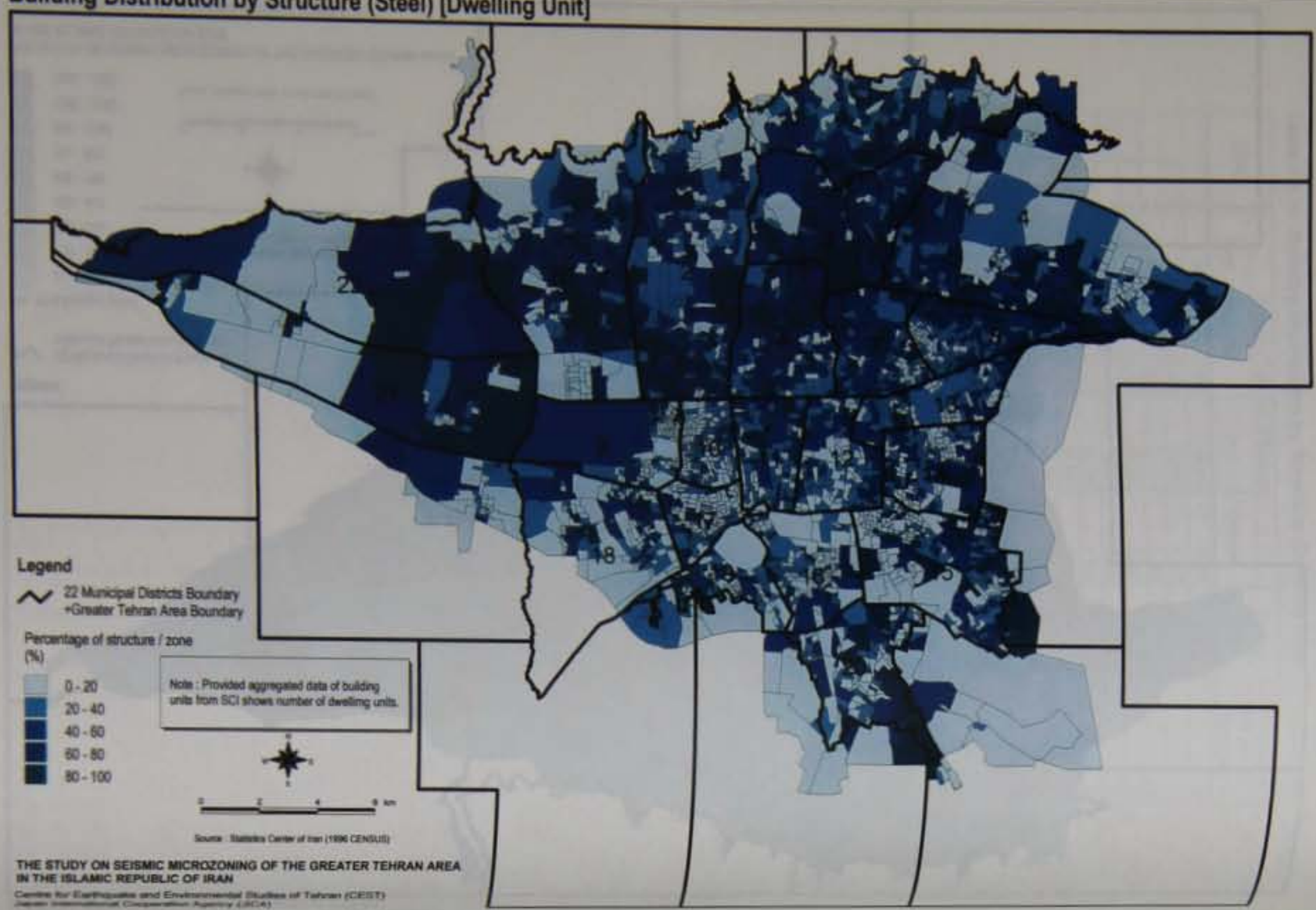


Figure 2.2.13

Building Distribution by Structure (Reinforced Concrete) [Dwelling Unit]

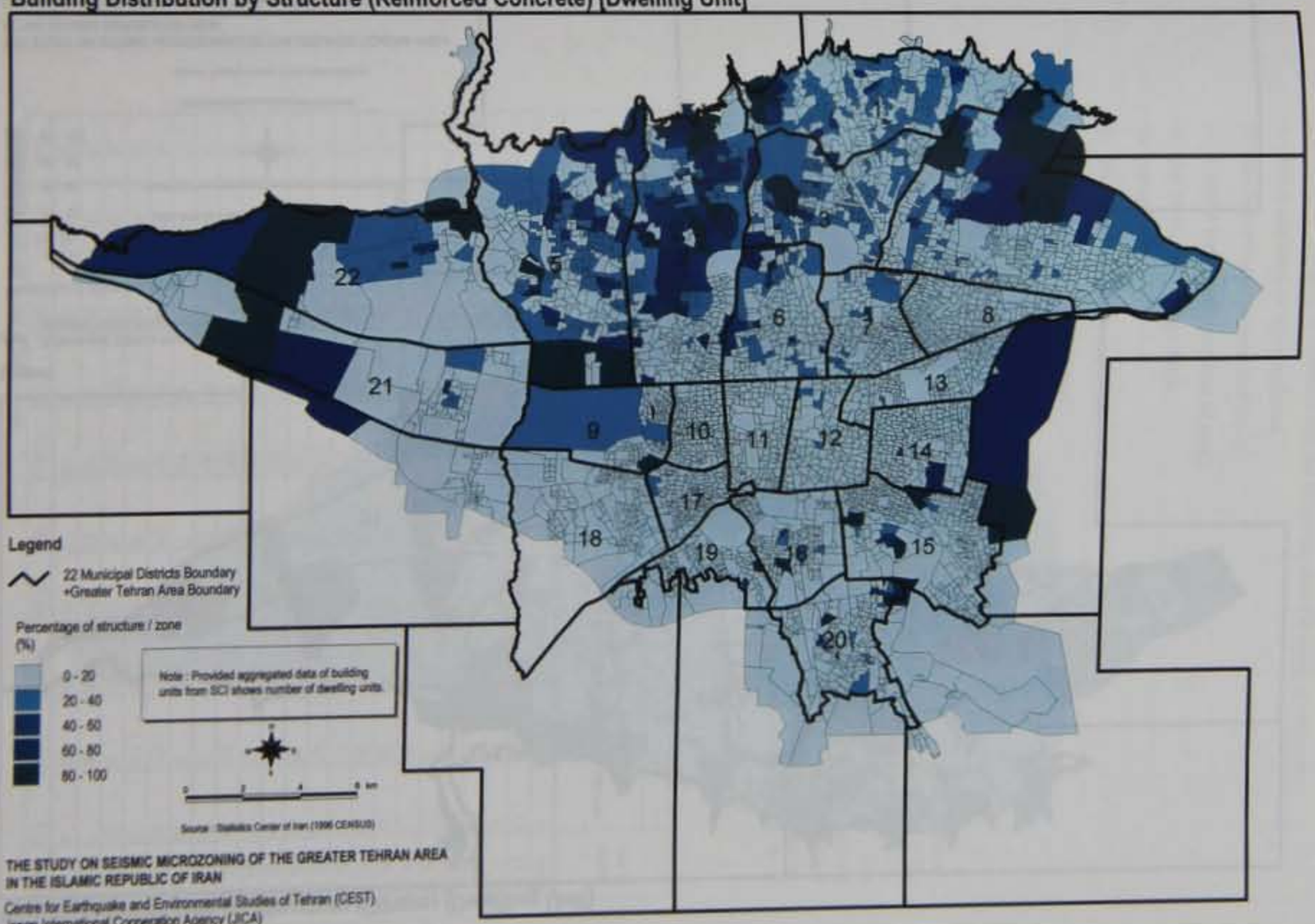
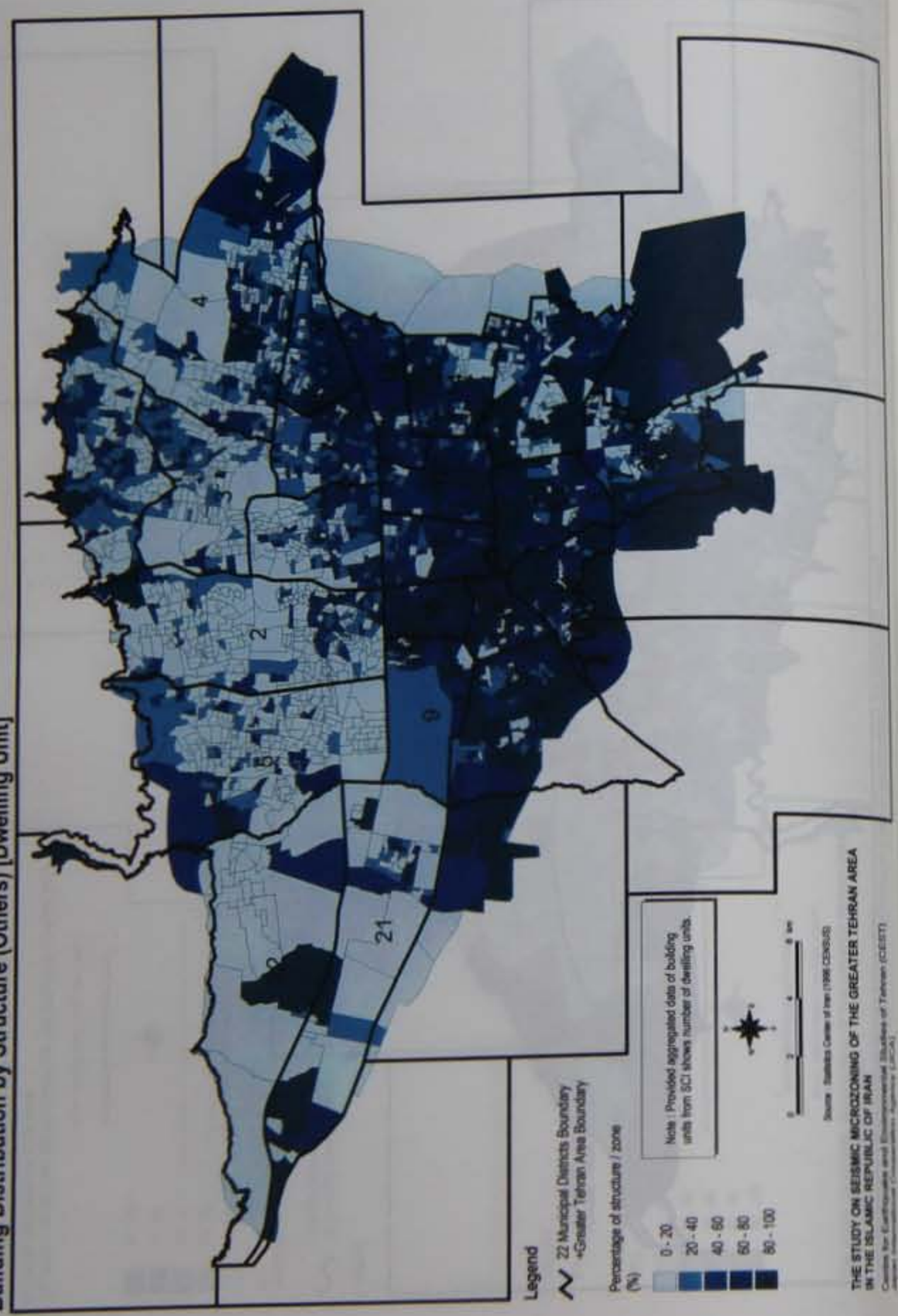


Figure 2.2.14

Building Distribution by Structure (Others) [Dwelling Unit]



The "Others" category is classified into the following nine (9) types of structures:

1) Brick and steel, or stone and steel
2) Brick and wood, or stone and wood
3) Cement block (with any kind of roof)
4) All brick, or stone and brick
5) All wood
6) Sun-dried mud brick and wood
7) Sun-dried mud brick and mud
8) Others
9) Unknown

The first structural type, brick and steel, or stone and steel, makes up 91 % of the "Others" category. The second structural type, brick and wood, or Stone and Wood, makes up 4 %. In total, 95 % of the "Others" category consists of these two structures. Table 2.2.11 shows in detail the number of each structural type in the "Others" category. The distribution pattern, by census zone, of each structural type in these categories is presented by a series of maps. Districts 10, 16 and 17 have more than 70 % of traditional-type buildings, and Districts 9, 11, 12, 13, 18 and 19 have more than 60 % of these structures. District 22, where much new residential development is taking place, has only 10 % of traditional-type structures.

Table 2.2.11 Detail Structure of Others (Dwelling Unit)

District	"Other" Structural Types (No. of buildings)									Total by district
	Brick and Steel, or Stone and Steel	Brick and Wood, or Stone and Wood	Cement Block (with any kind of roof)	All Brick, or Stone and Brick	All Wood	Sun-dried Mud Brick and Wood	Sun-dried Mud Brick and Mud	Others	Unknown	
1	14,761	1,360	323	960	24	276	252	96	9	18,061
2	19,539	543	424	1,005	63	204	128	292	13	22,211
3	16,136	282	584	169	8	41	8	24	30	17,282
4	39,000	460	356	683	14	45	37	56	62	40,713
5	26,104	147	110	365	5	17	65	51	22	26,886
6	26,240	100	54	411	2	7	16	6	11	26,847
7	32,704	380	97	768	12	14	46	35	3	34,059
8	34,009	591	138	481	115	103	30	16	22	35,505
9	14,857	802	32	259	4	60	24	26	25	16,089
10	31,899	1,468	283	371	14	170	97	11	12	34,325
11	30,348	1,393	490	725	10	156	132	47	8	33,309
12	32,119	1,596	57	56	75	316	72	36	3	34,330
13	29,896	3,227	62	952	80	1,078	419	61	9	35,784
14	39,274	3,377	29	715	112	1,343	443	51	27	45,371
15	57,160	6,258	65	661	189	3,975	1,391	213	29	69,941
16	34,545	1,214	167	567	52	887	83	2	24	37,541
17	27,387	576	42	163	7	124	139	8	16	28,462
18	25,430	1,685	181	197	121	94	127	1,401	25	29,261
19	21,408	809	73	28	18	162	36	1,110	3	23,647
20	40,246	433	553	932	14	139	137	18	21	42,493
21	20,123	303	65	148	21	245	180	30	1	21,116
22	4,512	253	4	38	2	133	64	30	4	5,040
Total	617,697	27,257	4,189	10,654	962	9,589	3,926	3,620	379	678,273

Source: Statistics Center of Iran (1996)

(2) Building Storey

For the study, SCI cooperated to complement 1996 census data with building storey data supplied by the Post Office. A summarized table building storey distribution is shown in Table 2.2.12. The data is obscure for 14% of Tehran's total buildings, and accuracy of the data is not high. Therefore, further data collection/revision/correction is necessary.

By observing existing data prepared by SCI, 68% of the buildings within Tehran's 22 districts have up to 3 stories. In Districts 2, 3, 5, 6, 21 and 22, the percentage of buildings with less than 3 stories is 41% - 56%. Therefore, it can be said that the ratio of low-rise residential building in these districts is relatively low. On the other hand, in Districts 10, 13, 14, 16, 17, 18, 19 and 20, the percentage of buildings have less than 3 stories is more than 75%, a percentage which can be considered comparatively high. Particularly, in District 17, 90% of buildings have less than 3 stories, while in both Districts 10 and 18, 79% of buildings have less than 3 stories.

Figure 2.2.15 to Figure 2.2.17 show building distribution by storey for Tehran's 22 Municipal Districts.

Table 2.2.12 Building Distribution by Storey (Dwelling Unit)

District	ST1-3	ST4-15	OVER ST15	Unknown	Total by District
1	43,117	12,102	513	6,826	62,558
2	63,700	35,335	3,082	15,481	117,598
3	36,402	24,851	1,169	7,771	70,193
4	103,365	24,057	314	19,793	147,529
5	56,811	23,271	3	22,456	102,541
6	24,420	28,545	117	6,030	59,112
7	46,845	24,664	94	6,456	78,059
8	60,955	13,242	5	9,319	83,521
9	28,250	3,961	2	5,613	37,826
10	48,970	8,231	2	4,992	62,195
11	35,600	14,502	71	4,123	54,296
12	29,200	4,585	7	5,453	39,245
13	44,989	6,653	5	7,458	59,105
14	65,640	9,338	2	12,464	87,444
15	90,622	8,493	22	23,475	122,612
16	41,490	4,329	2	4,267	50,088
17	38,239	1,208	0	2,831	42,278
18	37,168	1,014	2	9,156	47,340
19	33,148	1,327	0	8,058	42,533
20	55,679	5,692	8	9,220	70,599
21	19,940	4,479	10	11,055	35,484
22	6,549	2,103	0	3,330	11,982
Total	1,011,099	261,982	5,430	205,627	1,484,138
Percentage	68.1	17.7	0.4	13.9	100

Source: Statistics Center of Iran (1999)

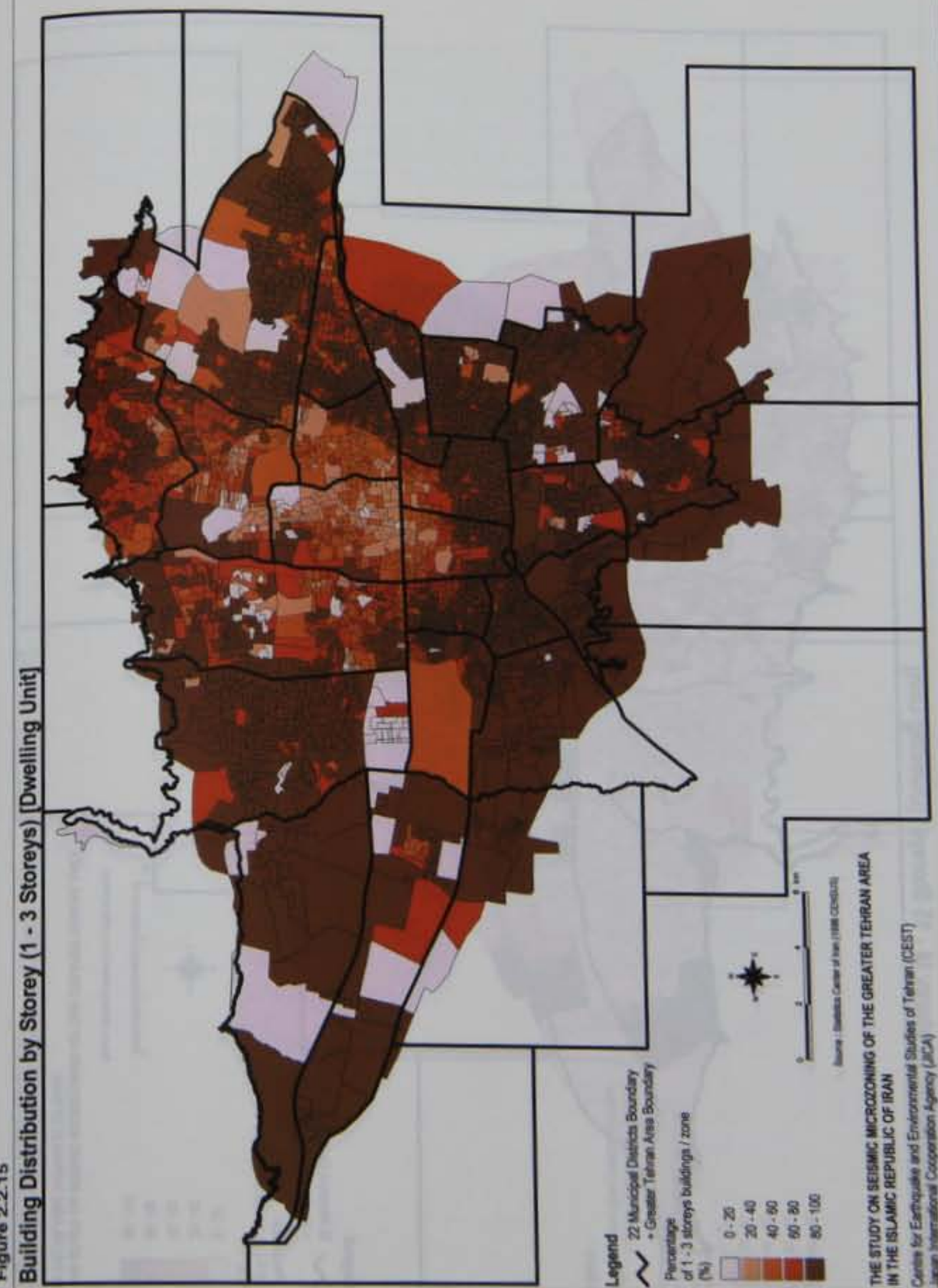


Figure 2.2.15 Building Distribution by Storey (1 - 3 Storeys) [Dwelling Unit]

Figure 2.2.16

Building Distribution by storey (4 - 15 Storeys) [Dwelling Unit]

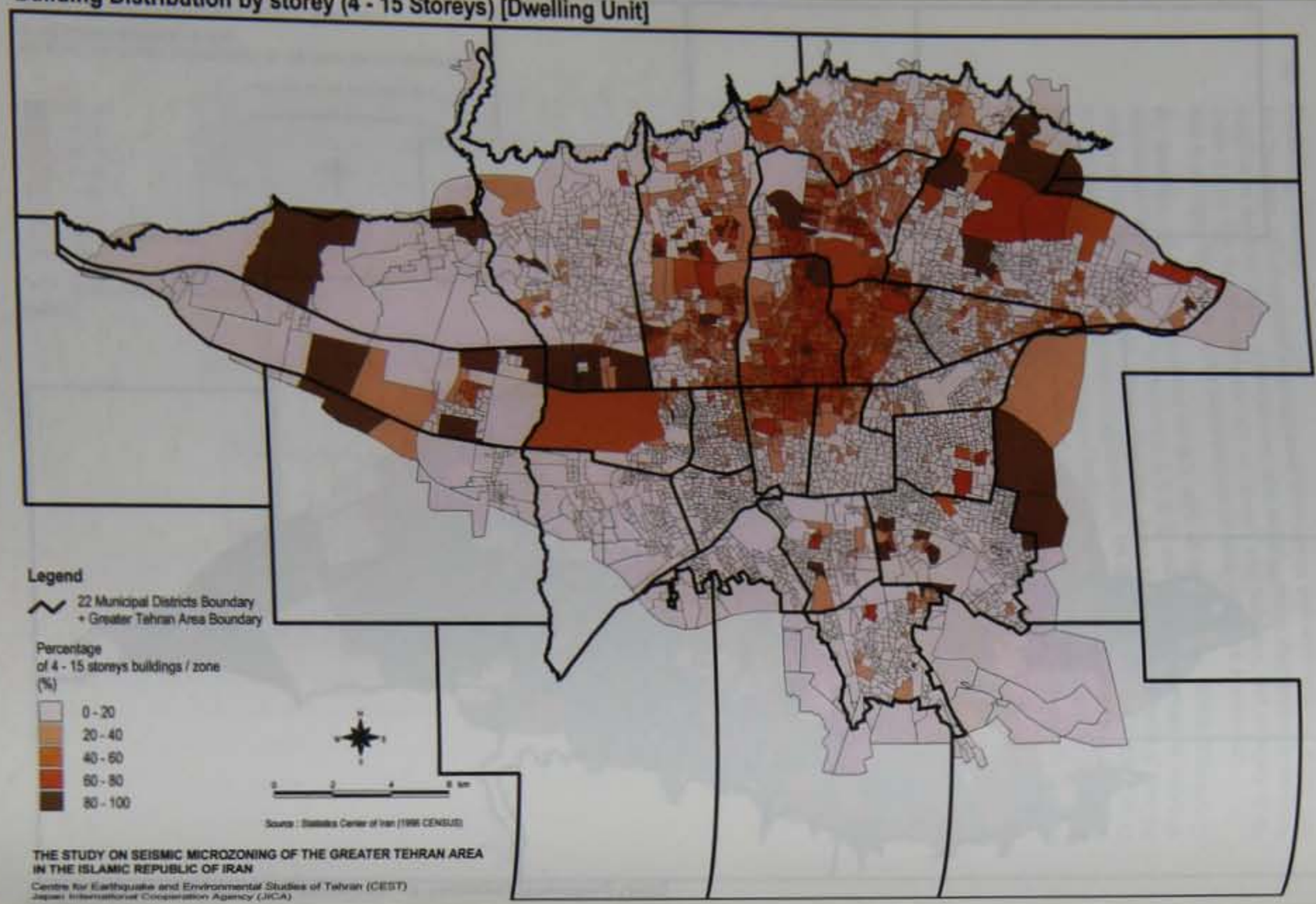
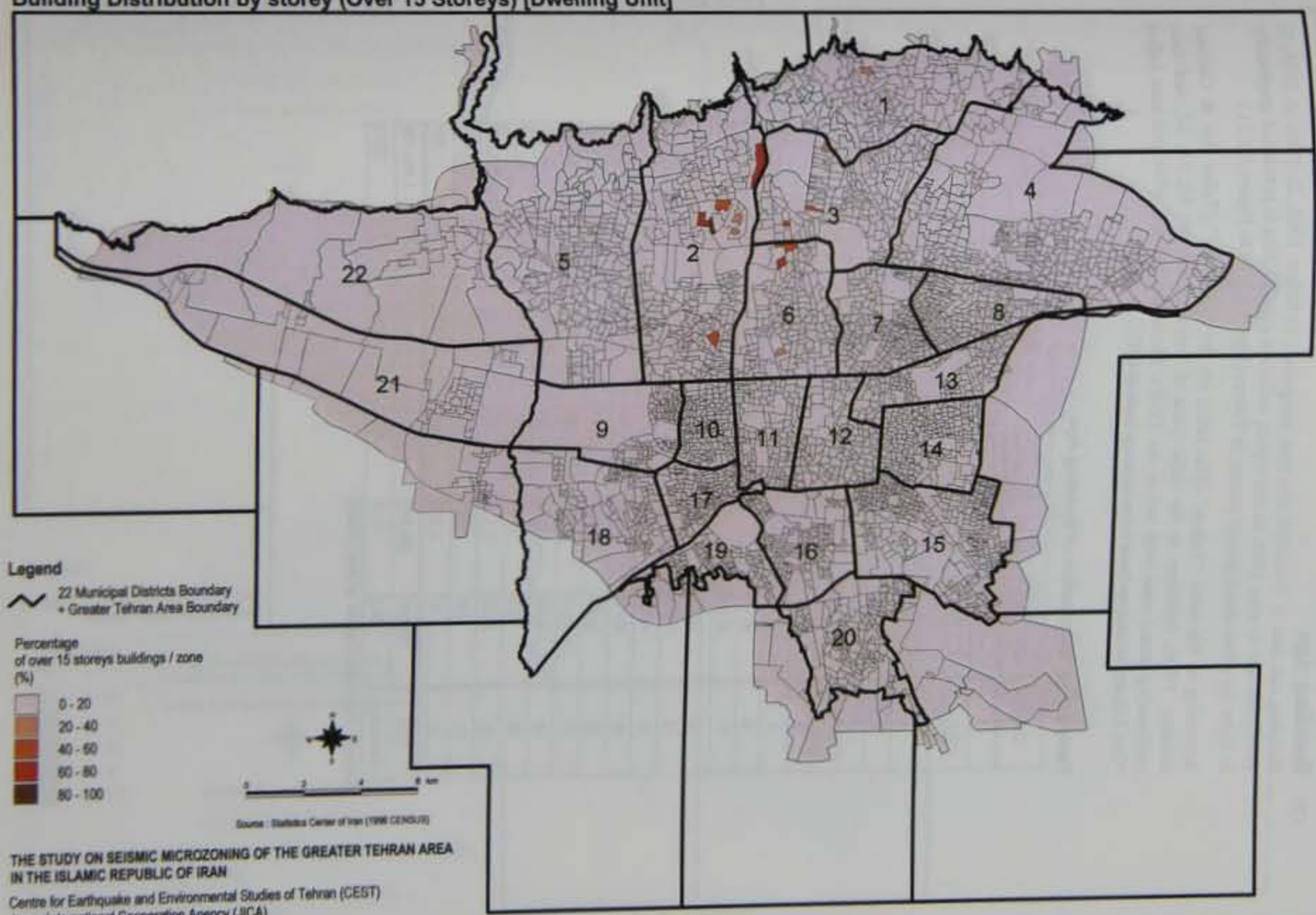


Figure 2.2.17

Building Distribution by storey (Over 15 Storeys) [Dwelling Unit]



(3) Building Age

Building age data is classified into four categories: 1) before 1966, 2) 1966 to 1975, 3) 1976-1988 and 4) after 1988. In this report, collected existing data is presented graphically to show the urban development pattern in Tehran (Figure 2.2.18 to Figure 2.2.21).

According to the book "Tehran –The Jewel on the Silk Road" (Taher Art & Cultural Institute, 1999), buildings in the older parts of Tehran (Districts 10, 11, 12, and their surrounding areas) were built before the 1950's. Moreover, the old urbanised area called "Old Tehran" is said to have been built up before 1891.

Table 2.2.13 Distribution of Building Age

District	Before 1966	Age 1966-75	Age 1976-88	After 1988	Unknown	Total by District
1	7,681	8,850	29,404	16,051	572	62,558
2	5,612	18,652	47,562	44,634	1,138	117,598
3	6,168	15,239	31,046	17,168	572	70,193
4	5,497	15,976	88,139	36,492	1,425	147,529
5	1,557	2,547	56,177	41,219	1,041	102,541
6	15,588	14,794	18,545	9,827	358	59,112
7	24,271	17,911	18,878	16,435	564	78,059
8	20,270	24,825	26,379	11,381	666	83,521
9	7,621	18,493	9,400	2,069	243	37,826
10	28,433	15,111	9,505	8,549	597	62,195
11	22,932	10,012	12,195	8,572	585	54,296
12	19,096	5,850	9,348	4,367	584	39,245
13	17,726	16,991	16,293	7,659	436	59,105
14	19,526	24,874	27,371	14,273	1,400	87,444
15	10,774	16,904	74,894	17,973	2,067	122,612
16	13,085	16,591	15,924	3,658	830	50,088
17	8,979	16,670	13,534	2,385	710	42,278
18	1,120	5,973	31,530	7,926	791	47,340
19	263	2,241	33,353	6,285	391	42,533
20	8,383	12,978	38,094	10,331	813	70,599
21	326	1,482	20,209	13,095	372	35,484
22	37	2,324	4,409	5,118	94	11,982
Total	244,945	285,288	632,189	305,467	16,249	1,484,138
Percentage	16.5	19.2	42.6	20.6	1.1	100.0

Source: Statistics Center of Iran (1999)

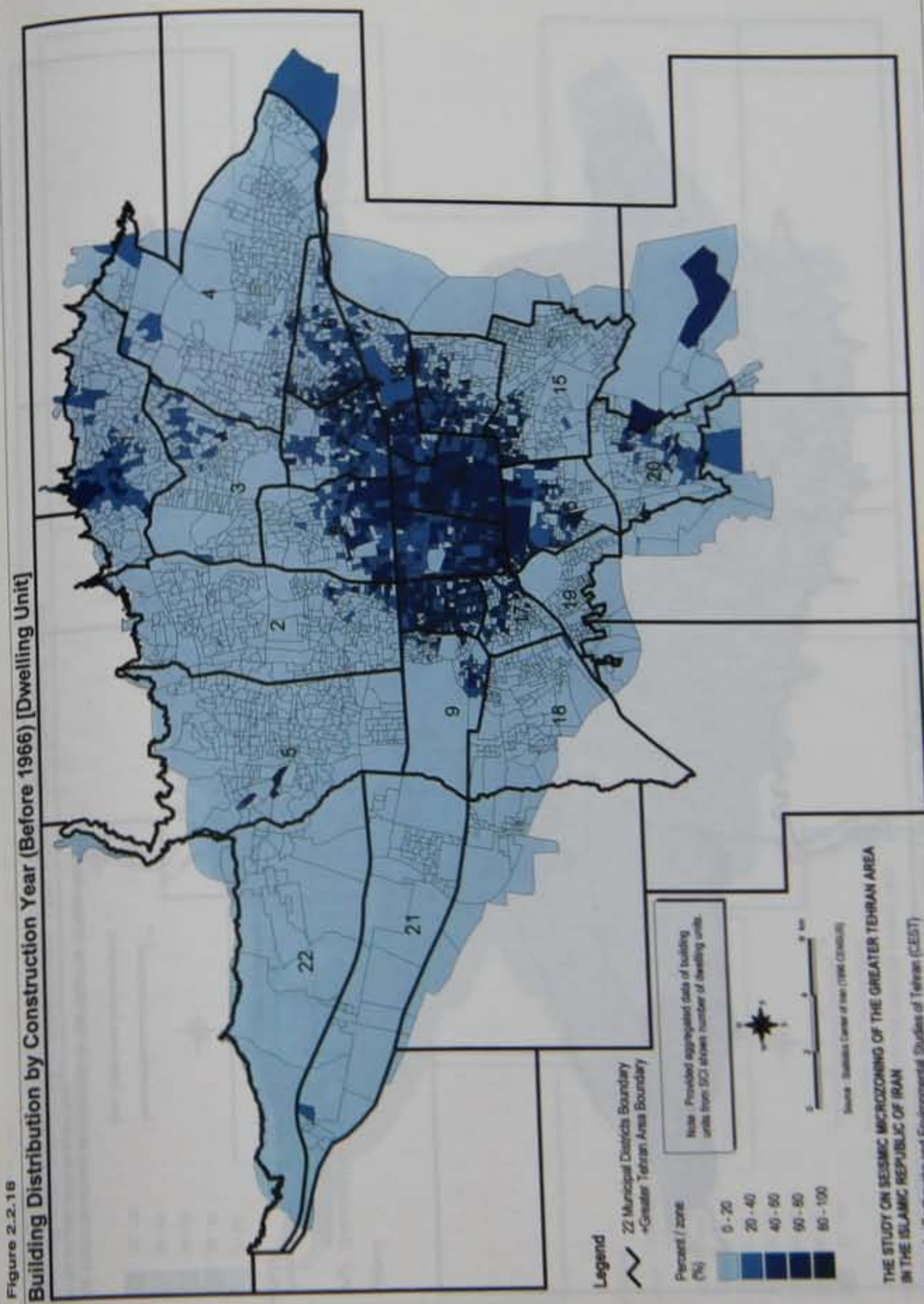


Figure 2.2.18
Building Distribution by Construction Year (Before 1966) [Dwelling Unit]

Figure 2.2.19

Building Distribution by Construction Year (1966-1975) [Dwelling Unit]

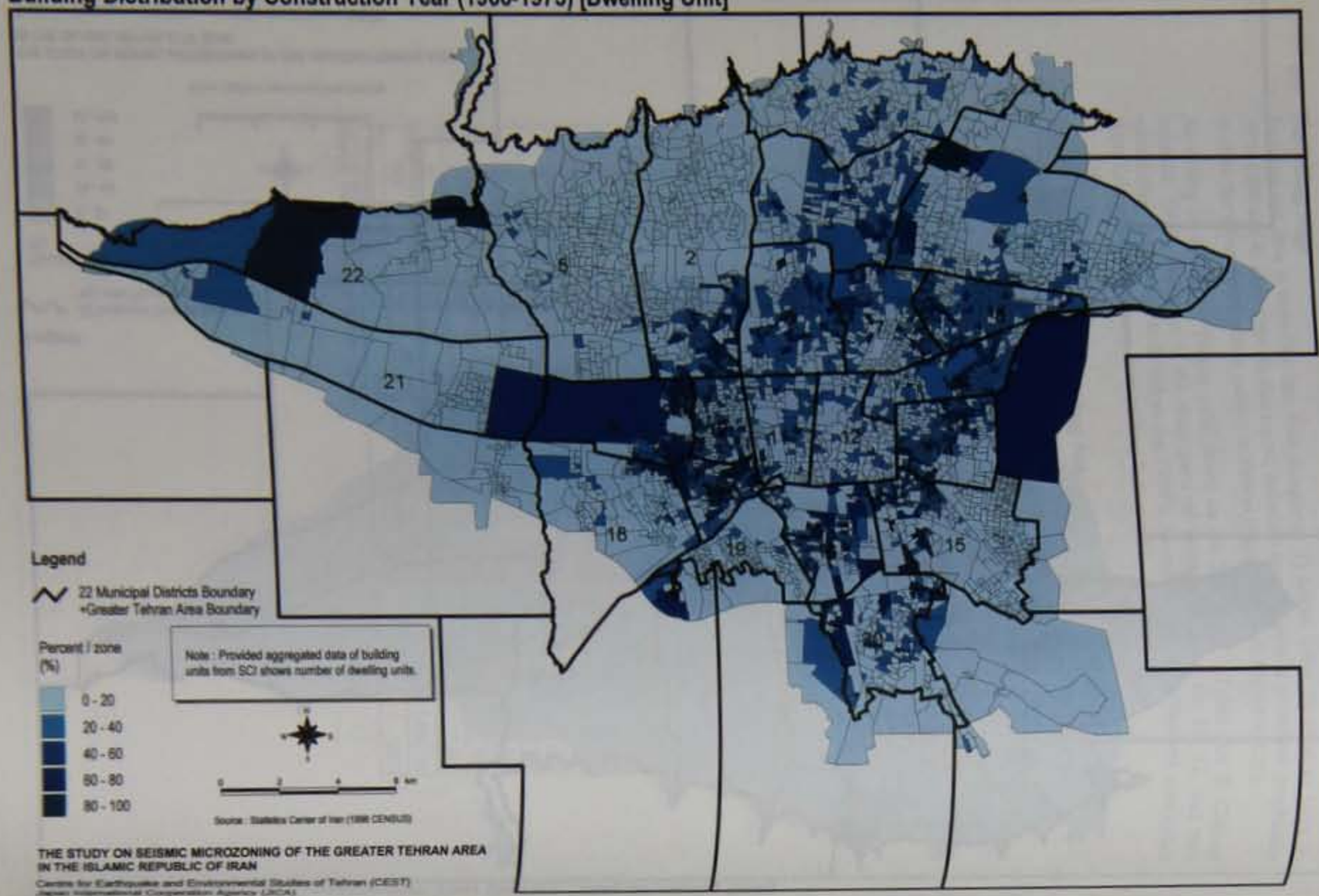


Figure 2.2.20

Building Distribution by Construction Year (1976-1988) [Dwelling Unit]

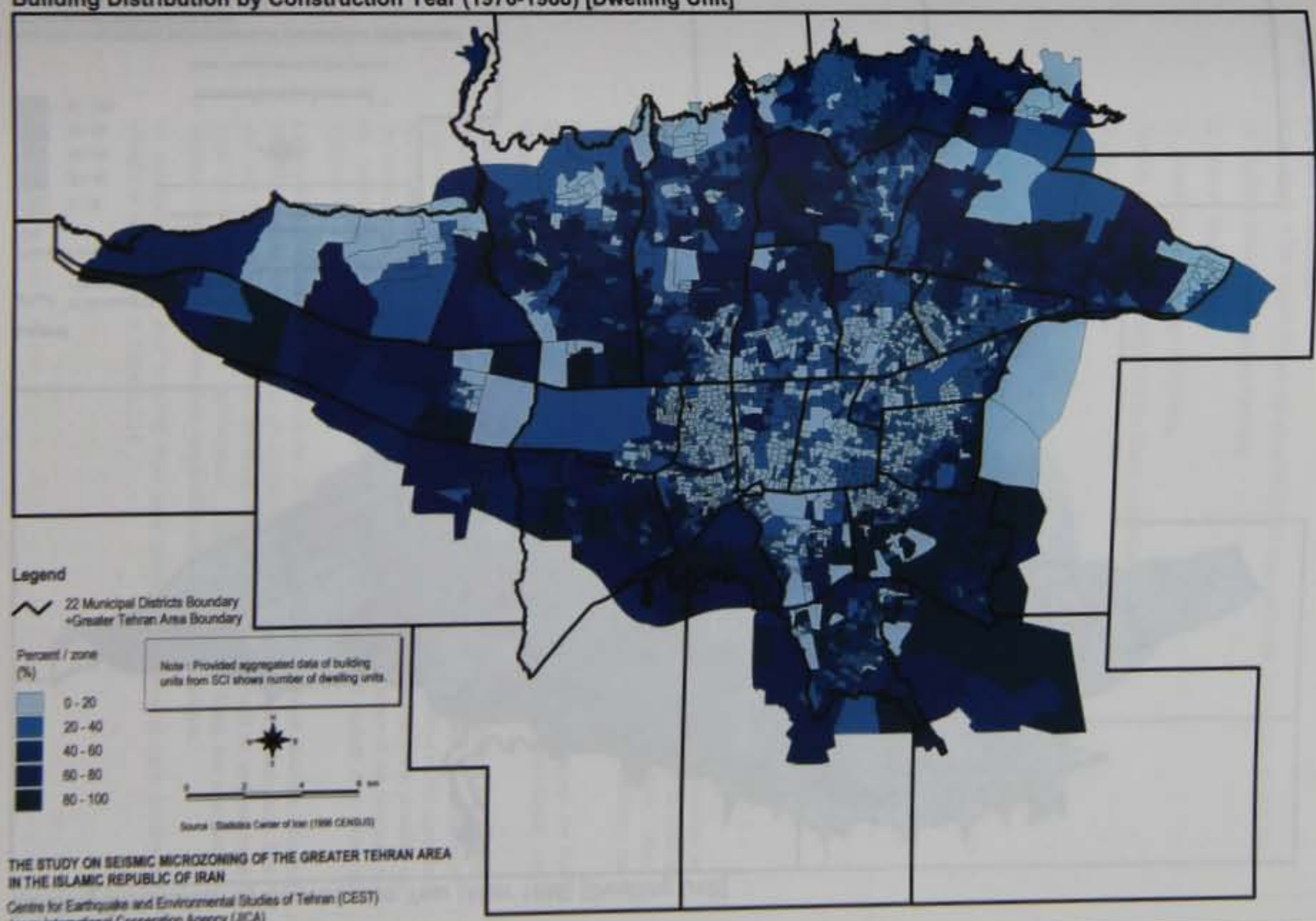
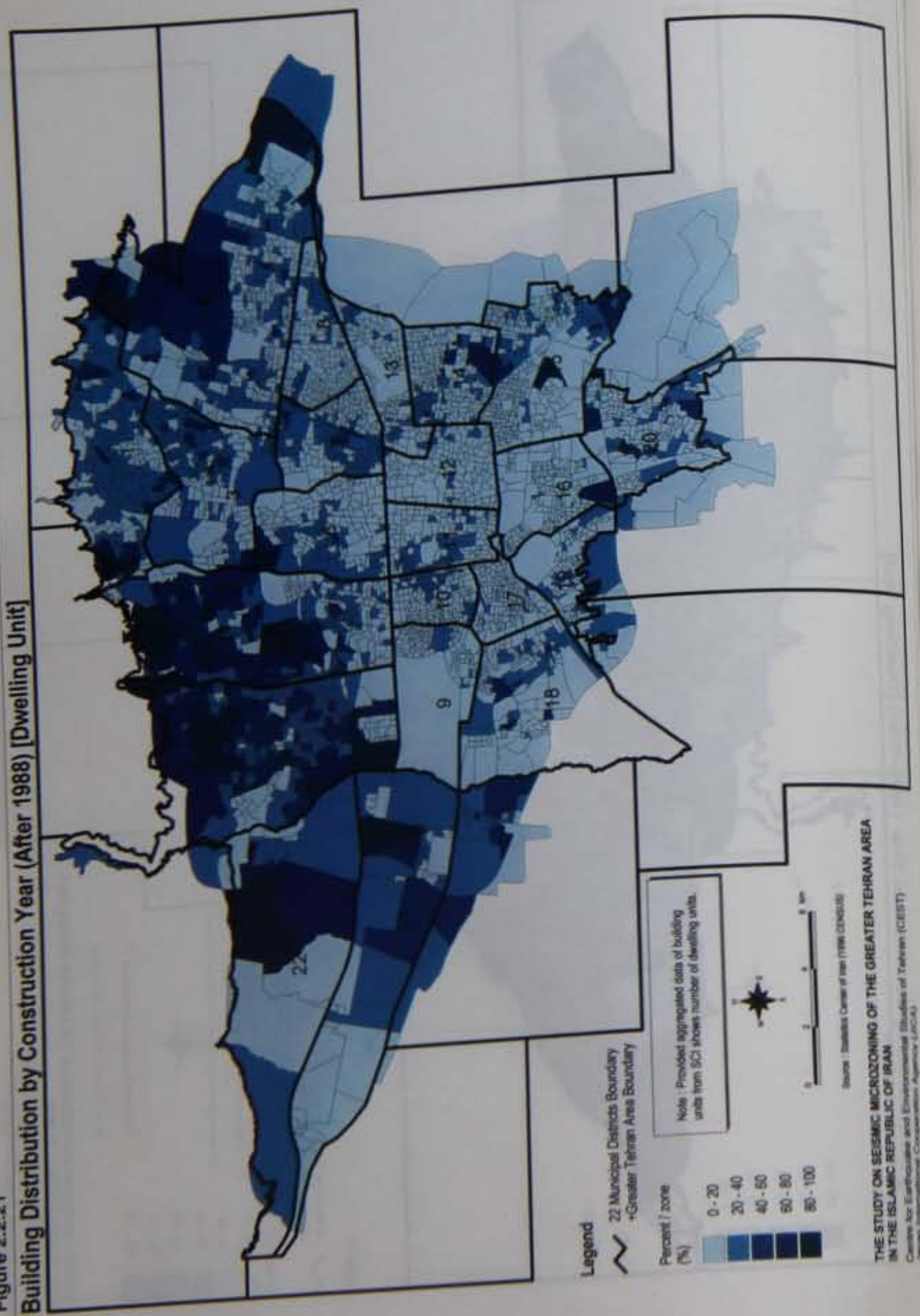


Figure 2.2.21

Building Distribution by Construction Year (After 1988) [Dwelling Unit]



2.2.9. Urban Facilities

In the study, wide ranges of data for urban facilities were collected. Those data consist of:

1) Facility Name, Address and Function
2) Size of land, building
3) Structural type and age of building

The list of the urban facilities for the Study is as follows:

1) Fire Fighting Stations
2) Police Stations
3) Traffic Police Stations
4) Hospitals
5) Governmental Facilities
6) Educational Facilities
   - Elementary Schools
   - Intermediate Schools
   - High Schools
   - Higher Education Centers (Universities)
7) Parks and Public Open Spaces

In order to strengthen the disaster response capacities of Tehran, the above information can be used in future urban planning. Such information can be extremely useful in making decisions related to locations of new facilities in order to improve their function. Also, when an earthquake occurs, having lists and knowing the locations of these facilities can minimise or prevent damage from a serious disaster.

This information was collected in cooperation with 20 Municipal Districts except for Fire Fighting Station data, which were compiled by Tehran's Fire Fighting Department, and Hospital data, which were compiled by Ministry of Health.

Since the volume of data is relatively large, one of the most critical problems in the process of compiling the data is the difficulty of unifying the data. Also, related agencies were requested to prepare maps of the locations of these facilities, however, most of the agencies are not able to do so, therefore, the Study Team prepared these maps whenever possible in the limited time available. However, to maintain the quality and accuracy of the database in the future, the municipality itself will have to check the data and update it in order to improve it.

Concerning the data requested from the 20 Municipal Districts, several districts have not yet prepared the data, and almost all districts have many discrepancies in their data. Since the time for this study is limited, the Study Team expects the data will be updated by the local Iranian team for future improvement. Therefore, the Study Team has analysed the damage based on the available data supplied by each district and agencies.

In accordance to the data received from each district, the number of each facility per district is summarised in Table 2.2.14.

Table 2.2.14 Facility Distribution by District

District	Fire Fighting Station	Police	Traffic Police	Hospital	Governmental Facility	Elementary School	Intermediate School	High School	Higher Education Center	Park and Public Open Space
1	1	13	0	19	12	69	34	45	17	18
2	4	3	2	3	1	102	97	92	19	37
3	4	13	0	11	4	39	43	48	40	44
4	5	9	0	6	1	83	67	66	19	131
5	4	2	2	4	2	50	52	56	6	46
6	4	3	1	28	15	59	54	33	48	27
7	1	13	2	22	11	51	36	38	16	28
8	2	1	2	5	2	70	37	36	0	26
9	0	2	0	2	3	45	29	33	5	10
10	3	0	2	9	4	54	34	33	2	19
11	6	6	1	13	1	92	62	54	21	10
12	3	5	1	13	1	16	14	14	5	11
13	3	1	0	5	0	66	46	27	10	13
14	2	4	1	14	6	58	25	53	0	36
15	3	3	2	2	10	249	4	2	1	26
16	1	4	0	6	5	62	38	39	0	32
17	1	2	0	2	1	26	26	20	0	27
18	1	2	0	8	0	86	52	43	5	62
19	2	1	0	2	7	27	30	20	1	18
20	2	5	0	4	2	102	56	80	10	37
21	3	1	0	1	0	13	5	10	0	0
22	2	0	0	1	0	1	5	2	0	0
Outside	2	-	-	-	-	-	-	-	-	-
Total	59	93	16	180	88	1,420	846	844	225	658

(1) Fire Fighting Stations

The fire fighting department of the Tehran Municipality prepared facility data for fire fighting stations. In Tehran, there are 55 fire fighting stations, excluding 4 administrative centers. Table 2.2.14 shows the distribution of stations, with the Operations Headquarters located in District 3, the Central Office and Public and International Relations Office located in District 10, and the Educational Facility located in District 5. Figure 2.2.22 shows the location of each facility.

Since the number of fire fighting stations and offices are limited, the accuracy of the data is acceptable. However, coordinate data of the facilities' location was not acceptable. To develop the facilities location map, the Study Team visited the fire fighting department headquarters and transferred the locations from a map kept in the operations room to improve the quality of the database.

(2) Police Stations

Police station data were prepared by 20 municipal districts of Tehran. Since a representative of each district prepared the data, and even though the Study Team provided the representatives with instructions, several discrepancies exist. To avoid such discrepancies, in general, it is ideal for data to be prepared by one organisation. However, for the Study, since it was not possible to collect data from the Tehran Police Department itself, the Study Team asked the Municipality to prepare the data. To build up a database, it is important that the data itself have to unify the format throughout the city. Figure 2.2.23 shows the location of Police Stations in Tehran.

(3) Traffic Police Stations

Traffic Police Station data were also prepared, separately, by 20 municipal districts. Therefore, the same discrepancies can be found in many places. For instance, the format of construction year data is different from district to district. The data should be prepared by the Traffic Police Department. Figure 2.2.24 shows the location of Traffic Police Stations.

(4) Hospitals

The detail data for hospitals were prepared by the Ministry of Health. Accuracy of the data is high since one organization prepared the data for every district. However, some hospitals are missing in the data. Since the Tehran Municipality also prepared some hospitals data, duplicate data were eliminated and the remaining data was added to the data prepared by the Ministry of Health. The distribution of hospitals can be found in Figure 2.2.25.

(5) Governmental Facilities

The data for governmental facilities were prepared by 20 municipal districts. In the data, many duplications can be found; for instance, fire fighting stations and hospitals were included in the list. In addition, facilities not directly related to disaster management such as, banks, museums, workshops, etc. were also included.. The purpose of collecting governmental facilities data is to learn and have available the location of major facilities that will act as controlling units in response to an earthquake. Therefore, the Study Team screened the data and picked out the facilities that were considered important for disaster management. The location of these facilities is shown in Figure 2.2.26.

(6) Educational Facilities

At the time of earthquake events, educational facilities will be used as evacuation sites. Also, if the earthquake occurs in the daytime, it is extremely important to have earthquake-resistant buildings to minimise human casualties. Educational facilities consist of 1)elementary schools, 2)intermediate schools, 3)high schools and 4)higher education

centers. The data for these facilities were prepared by 20 municipal districts. It is ideal for this data to be prepared by the Ministry of Education and the Ministry of Higher Education, since the Ministry of Education keeps a list of Educational Facilities. However, this list does not include building information, which is now under compilation, and, thus, the list was not ready at the time requested.

As a result, the data contains many errors and there are many missing pieces of information. To maintain the quality of the damage estimation and to ensure the planning of proper evacuation sites in case of a seismic disaster, the data should be controlled by the Ministry of Education.

The location of each facility, including elementary schools, intermediate schools, high schools and higher education centers, are shown in a series of maps (Figure 2.2.27 to Figure 2.2.30).

(7) Parks and Public Open Spaces

Parks and public open spaces have an important role in the event of an earthquake. They can be used as primary evacuation sites and construction sites for temporary housing. The data on parks and public open spaces were prepared by 20 municipal districts, since the Municipality is in charge of many parks and open spaces. The data include land area. For future planning of disaster prevention and management, it is extremely important to know the existing condition of land availability. The accuracy of this data is still doubtful, since small open spaces are not covered in the data. It is strongly recommended to update the data for proper planning. The distribution of parks and public opens space are shown in Figure 2.2.31.

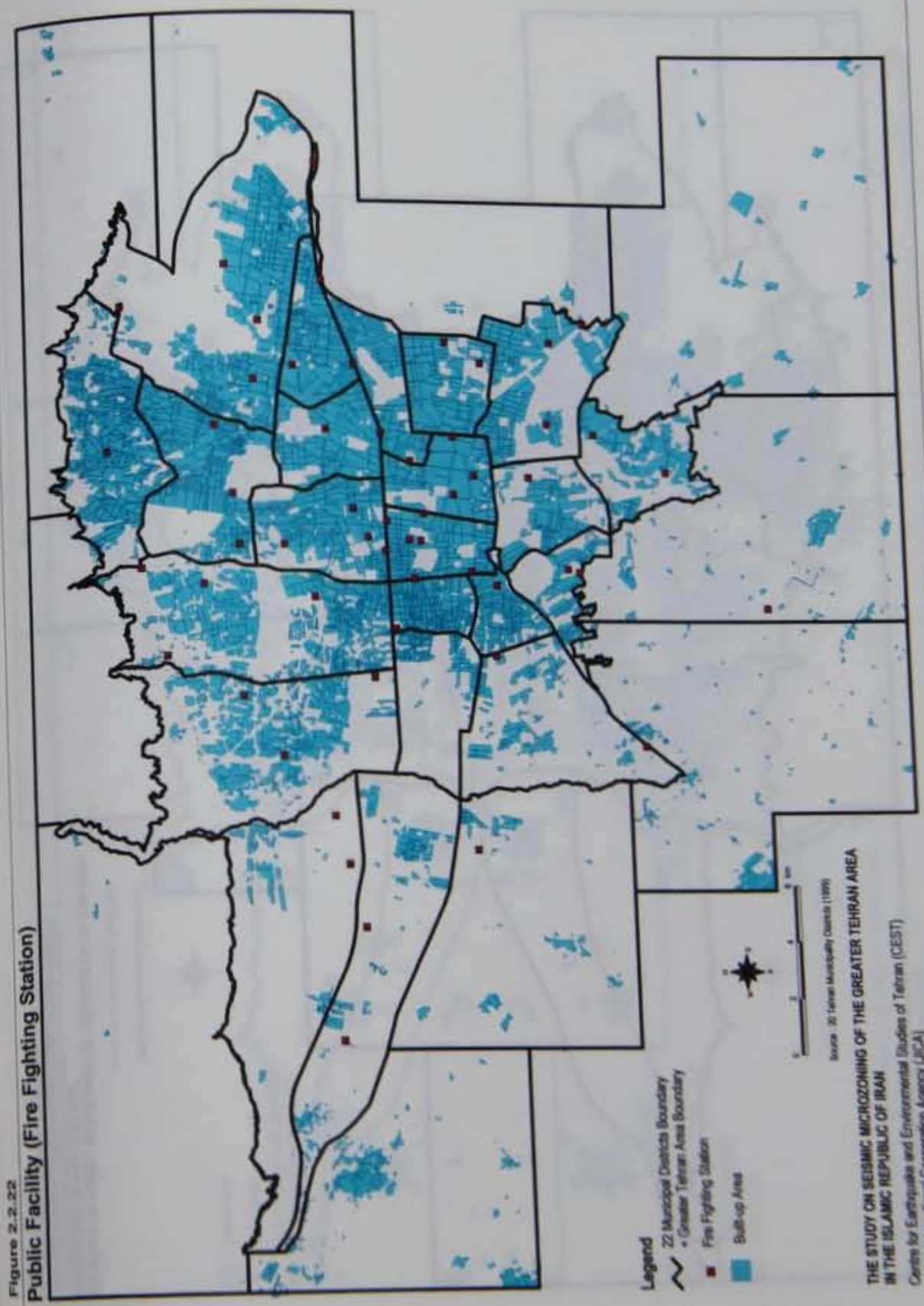


Figure 2.2.22
Public Facility (Fire Fighting Station)

Figure 2.2.23

Public Facility (Police Station)

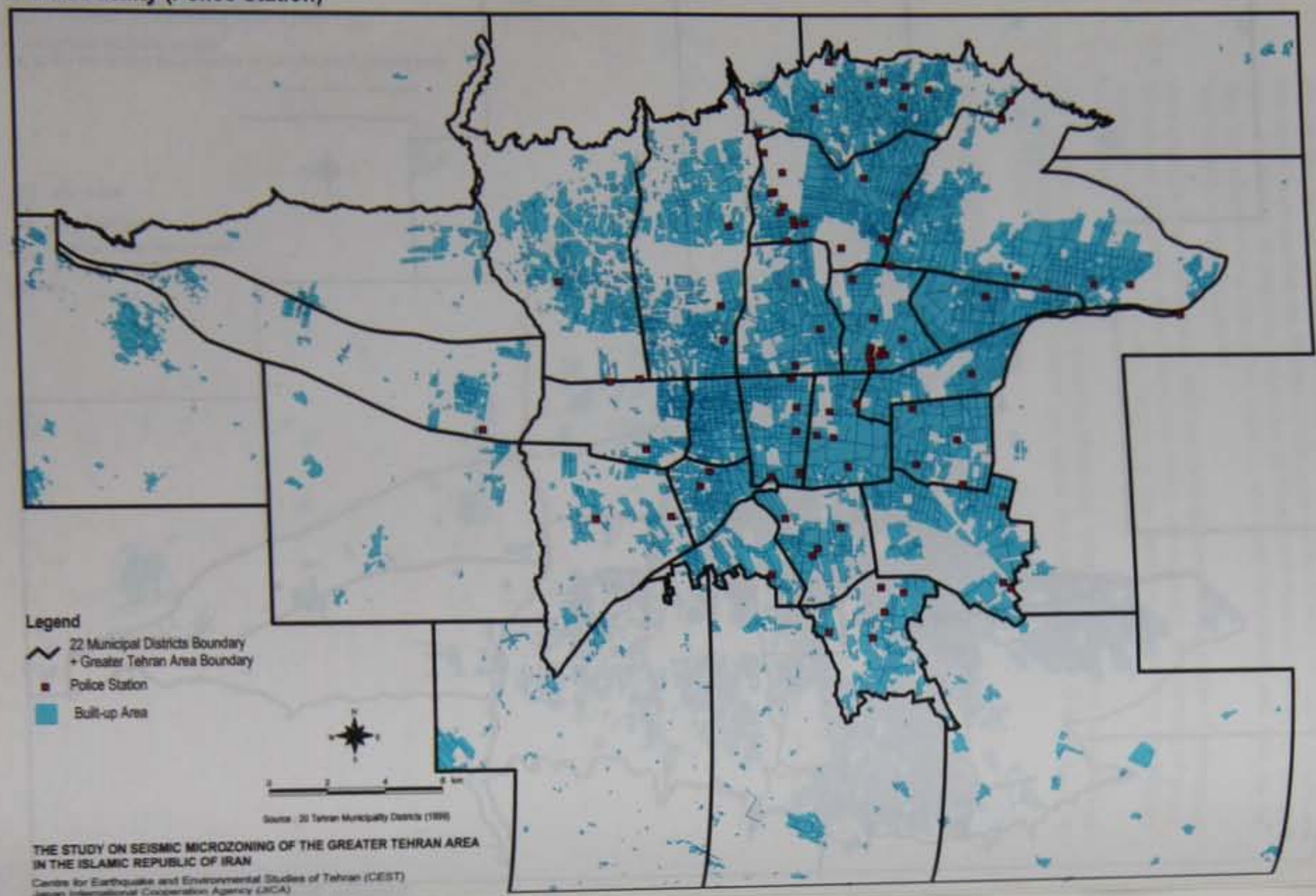


Figure 2.2.24

Public Facility (Traffic Police Station)

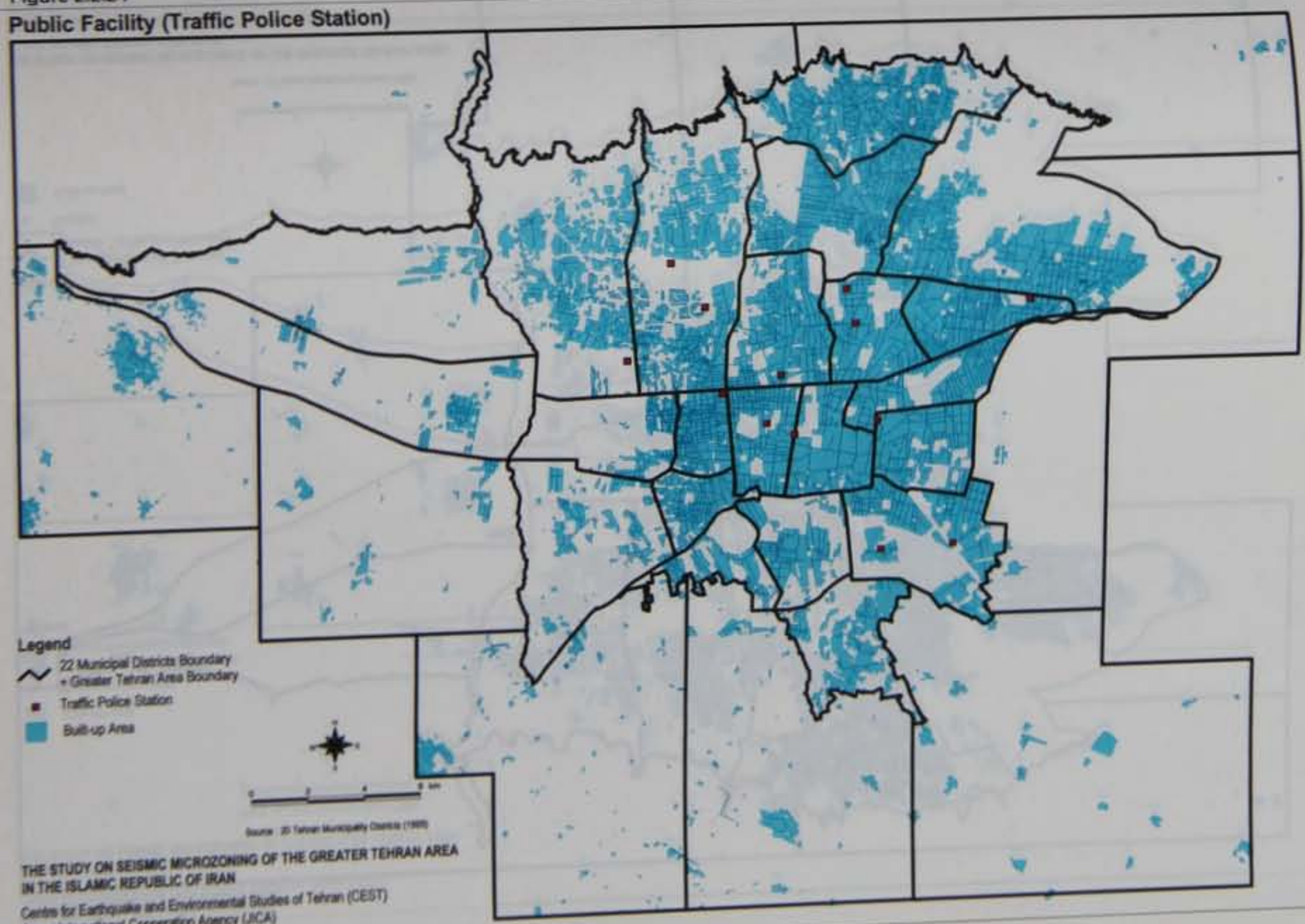


Figure 2.2.25

Public Facility (Hospital)

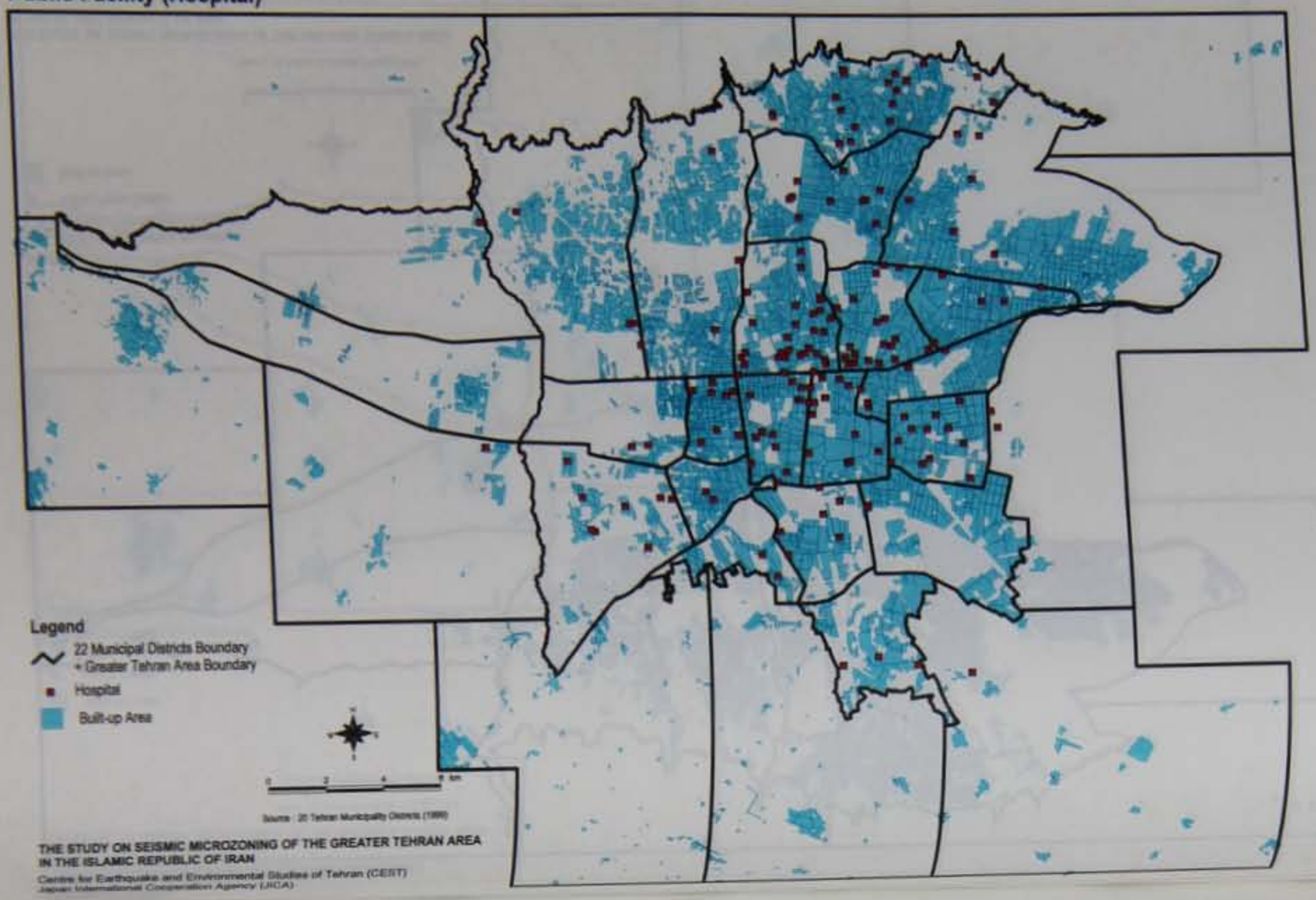


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Figure 2.2.26

Public Facility (Governmental)

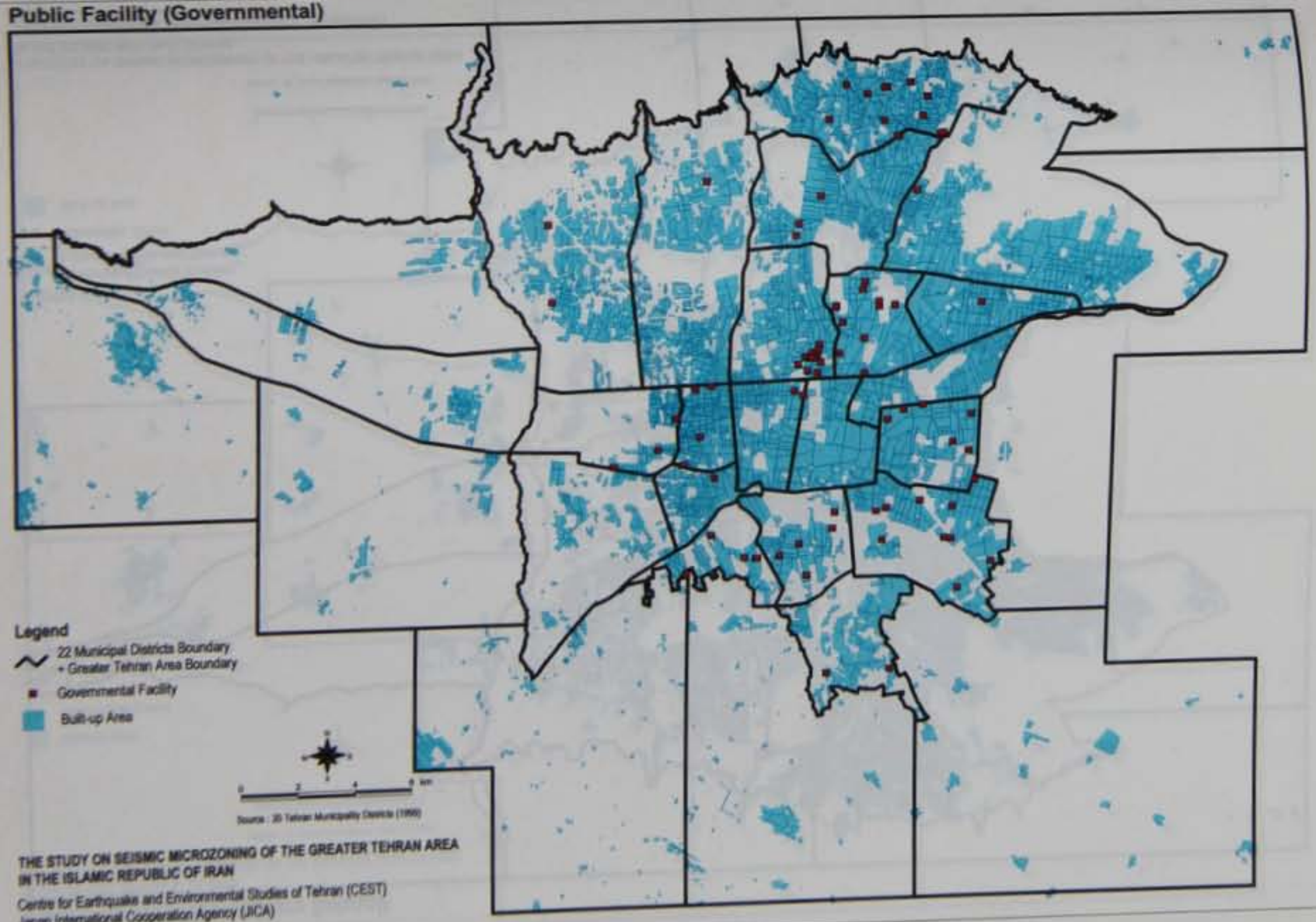

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Figure 2.2.27

Public Facility (Elementary School)

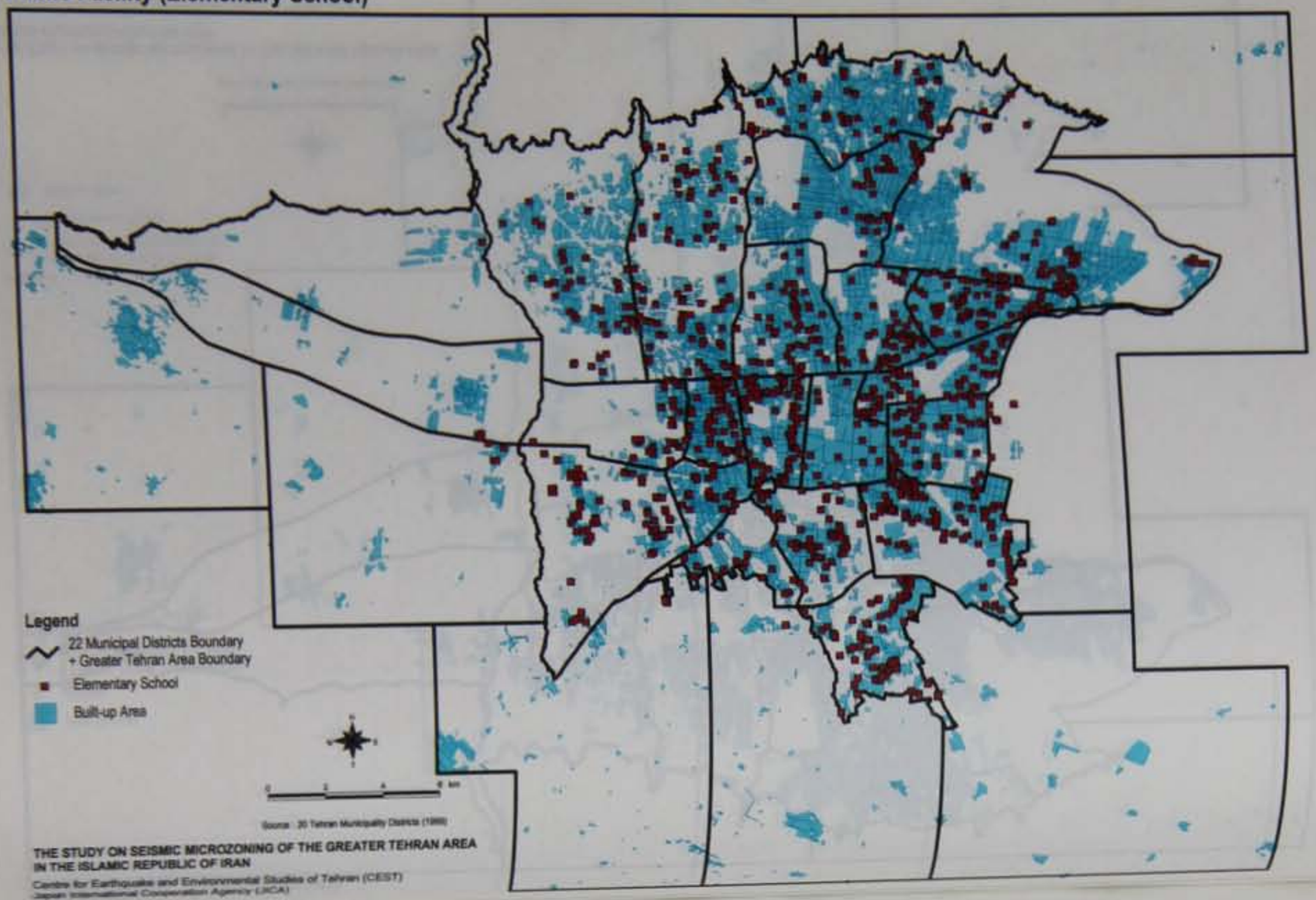

Figure 2.2.28

Public Facility (Intermediate School)

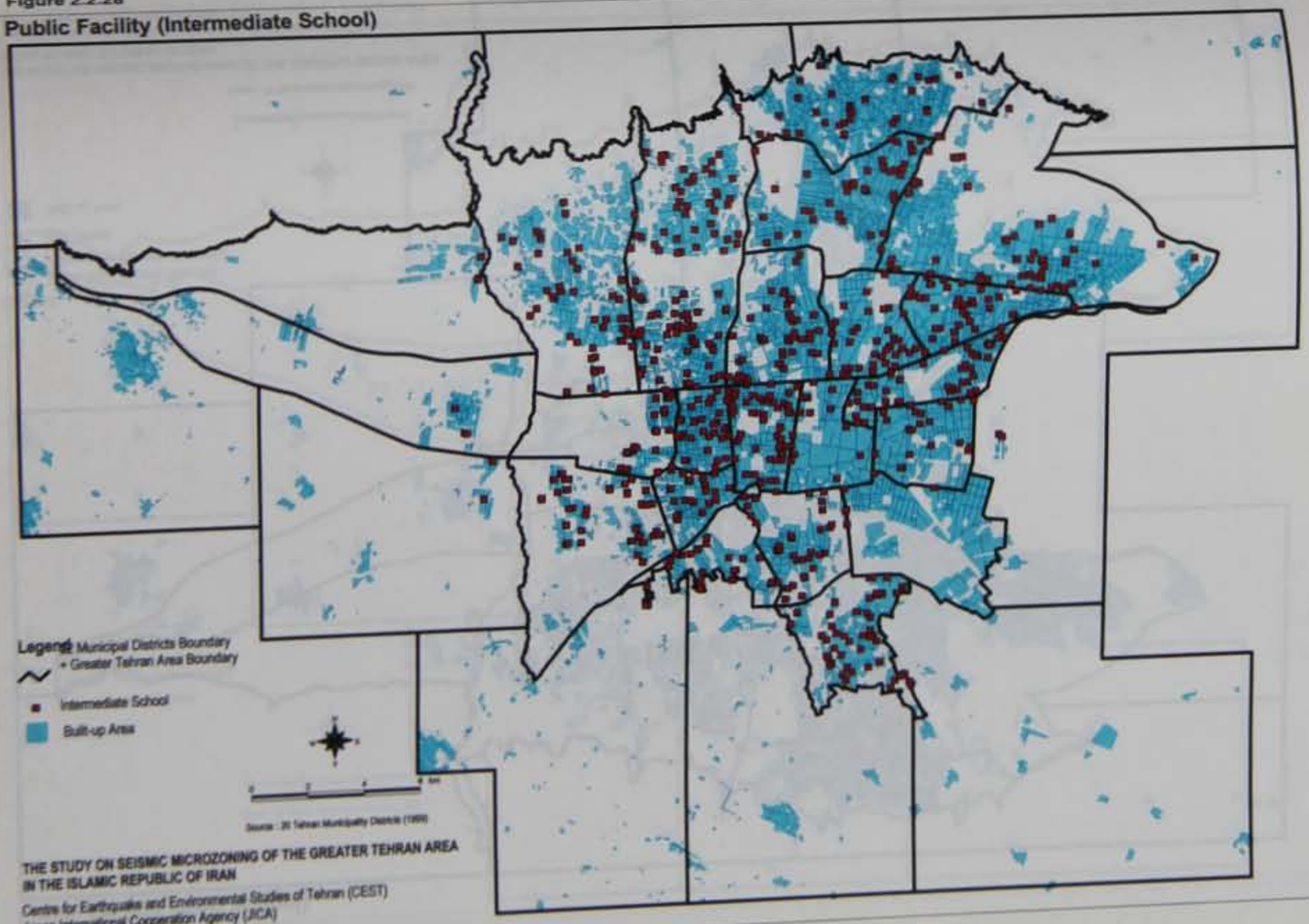

Figure 2.2.29

Public Facility (High School)

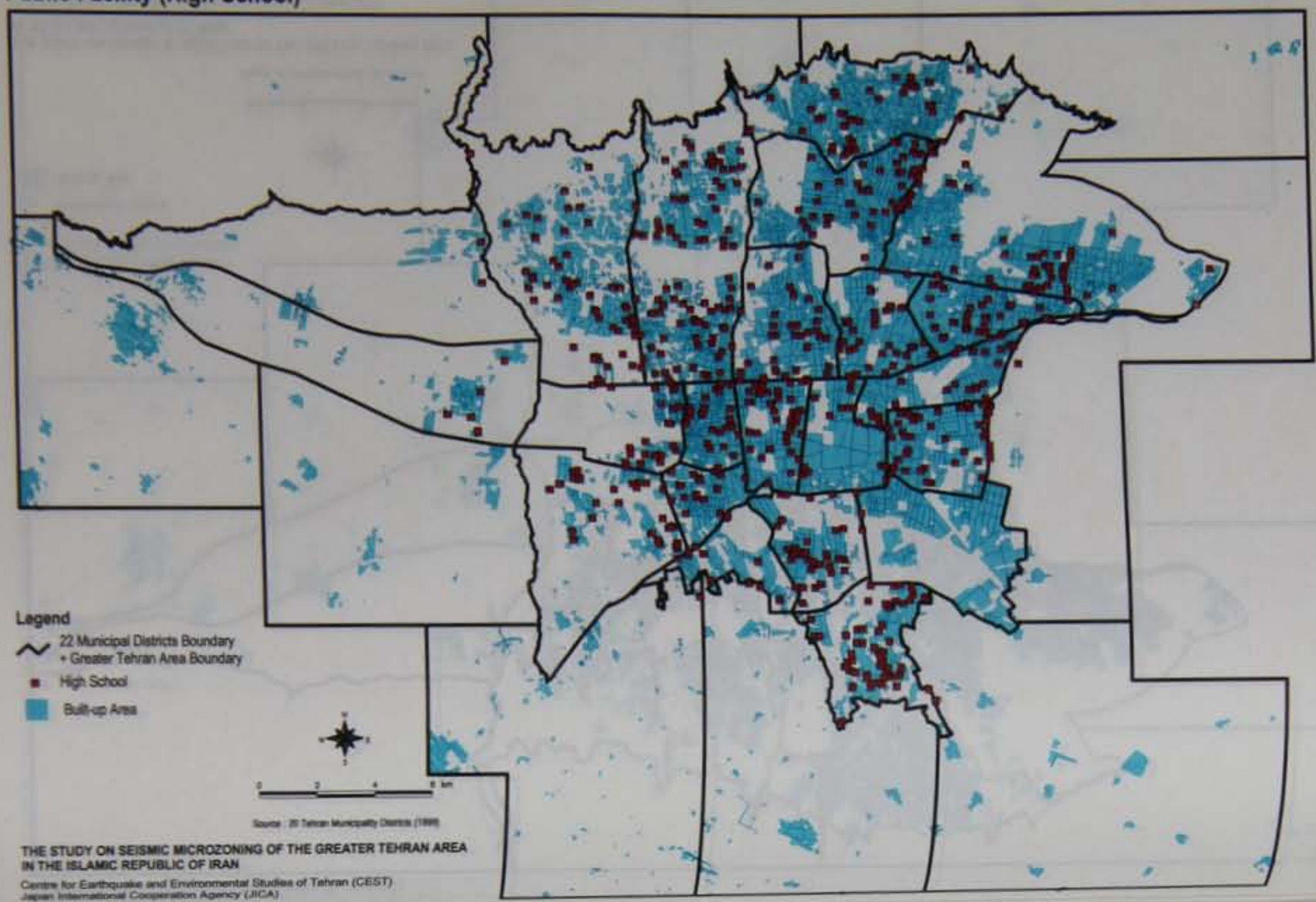

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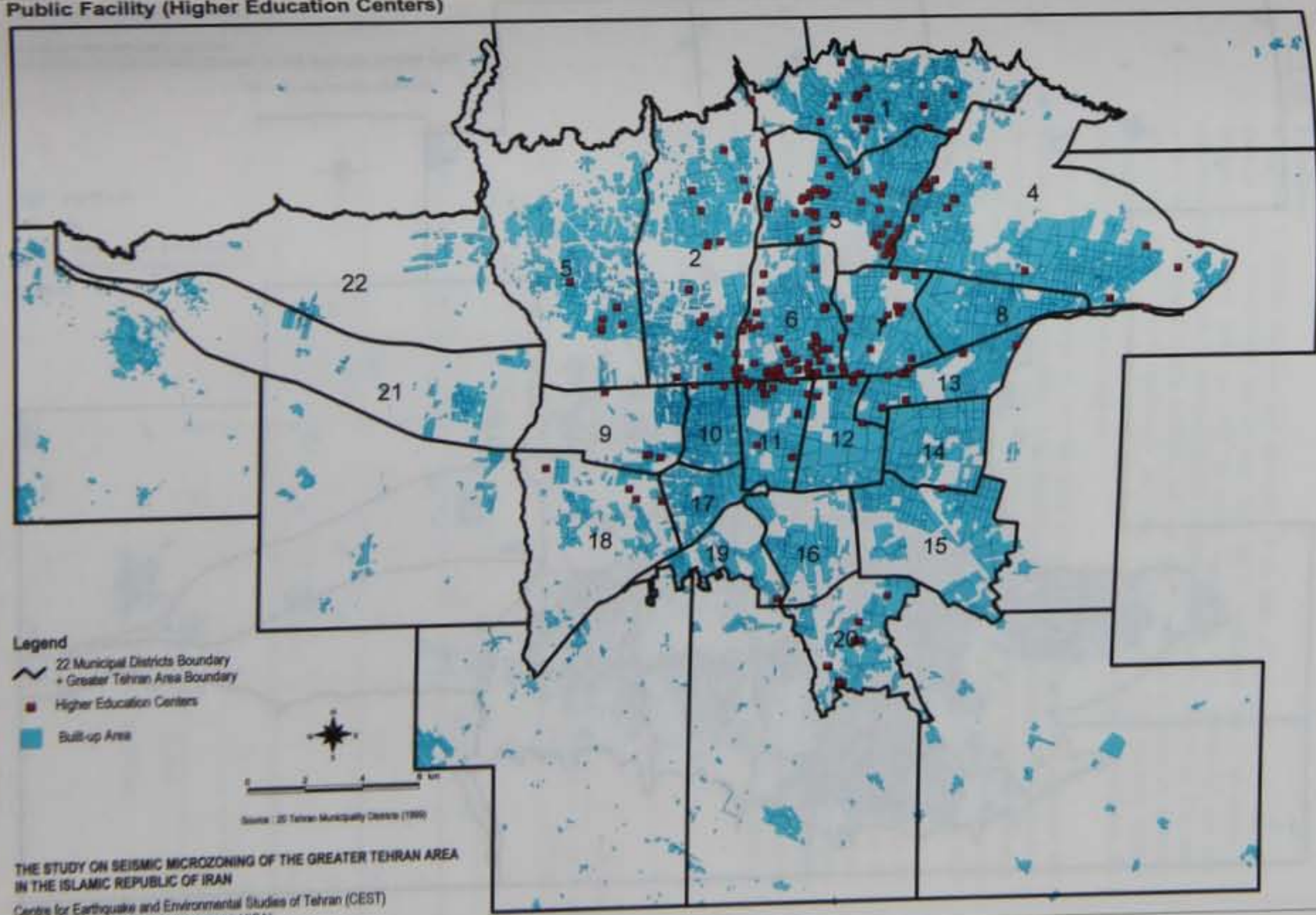
Figure 2.2.30

Public Facility (Higher Education Centers)



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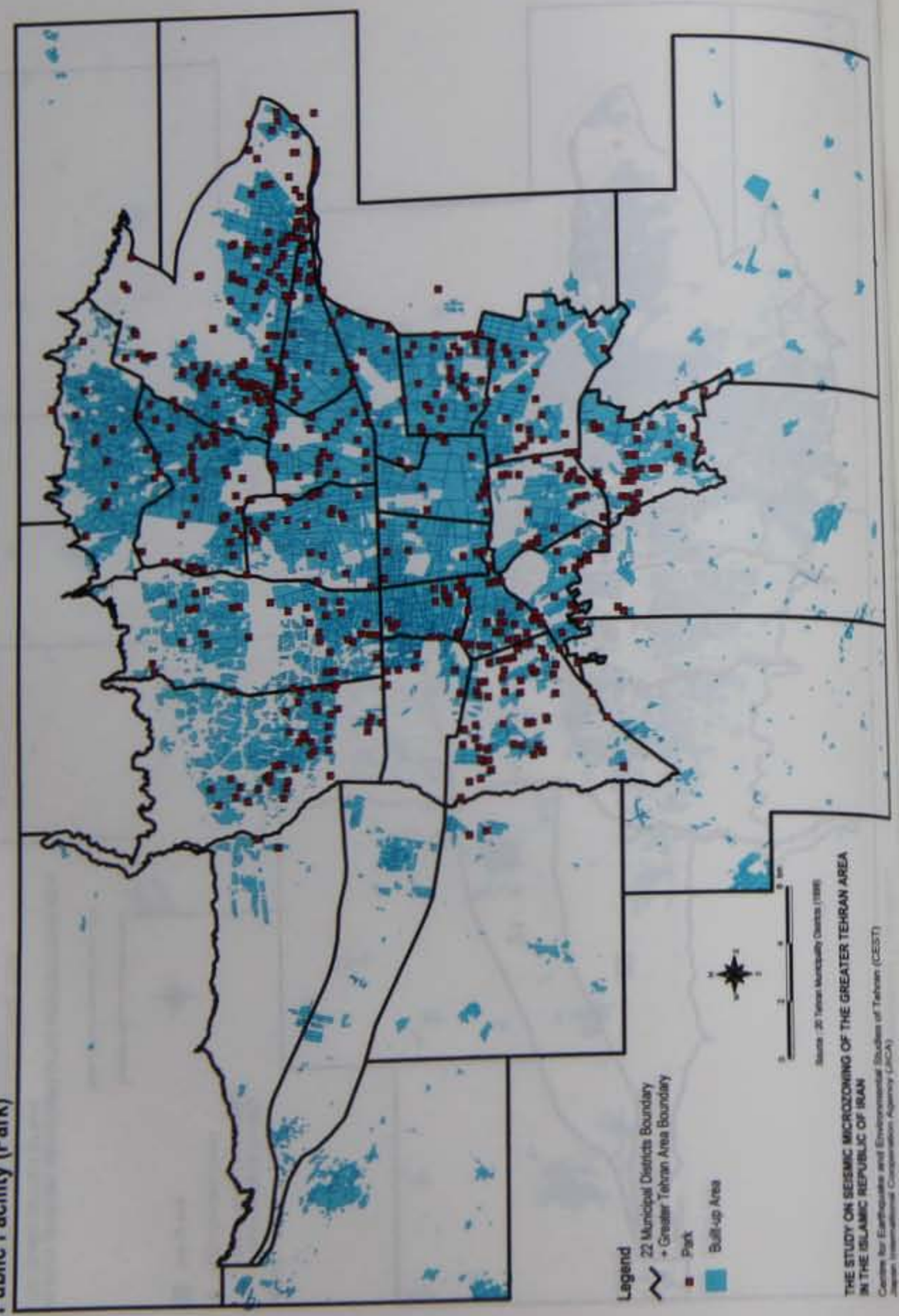

Figure 2.2.31 Public Facility (Park)

2.2.10. Lifelines

In relation to lifeline facilities and networks, at the time of earthquake, two kinds of damage to the citizen's life and the city itself can be considered. One is no access to lifelines for ordinary daily use (e.g., no access to drinking water, electricity, gas and telecommunications) due to damaged lifeline facilities and networks, in general. The other is that, due to damaged lifeline facilities and networks, occurrence of secondary disasters (e.g., fires, electric shock, explosions, etc.) may take place. For these reasons, lifeline management agencies have to establish disaster management systems to minimise the damage in the event of an earthquake.

In the study, a wide-range of data has been gathered from lifeline-related agencies and companies (water, gas, electricity, telecommunication). Since the comprehensive database set-up initiated by this Study is the first of its kind in Tehran, a lack of quality and missing data can be observed. However, basic data, including information on the systems' main networks, were set up. In the report, these preliminary data can be seen on the maps of each lifeline system.

Since May 1999, the Study Team has collected lifeline data. Details of data collection for lifelines are shown in Table 2.2.15. Unfortunately, limited data has been gathered for the Study, and, therefore, future improvement of the database is strongly suggested. In general, all lifeline agencies somehow relate each other. For example, if the telecommunication company does not have a self-generated system, and if the electric company cannot supply electricity, all the telecommunication systems will be non-operational. This problem can be applied to the water and gas companies as well. Therefore, the exchange of information and cooperation between agencies is important to reduce the problem.

Table 2.2.15 Collected data from lifeline agencies

Lifeline Data	Related Agency	Necessary Data			
		Map			Data Table
		Own Sub-districts Map	Main Network Map	Main Distribution Map	Length of Local Distribution Line
Water	Tehran Province Water & Sewage Co.	○	○	○	×
	Format	Paper	AutoCAD File	AutoCAD File	-
Gas	National Iranian Gas Co.	○	○	○	○
	Format	Paper	Paper	Paper	Paper
Electricity	Power Generation & Transmission Co.	○	○	×	○
	Format	Paper	AutoCAD File	-	Paper
Telecommunications	Telecommunications Co. of IRAN	○	○	×	○
	Format	Paper	-	-	Paper

○ Received
× Not Received

Figure 2.2.32

Lifeline (Water)

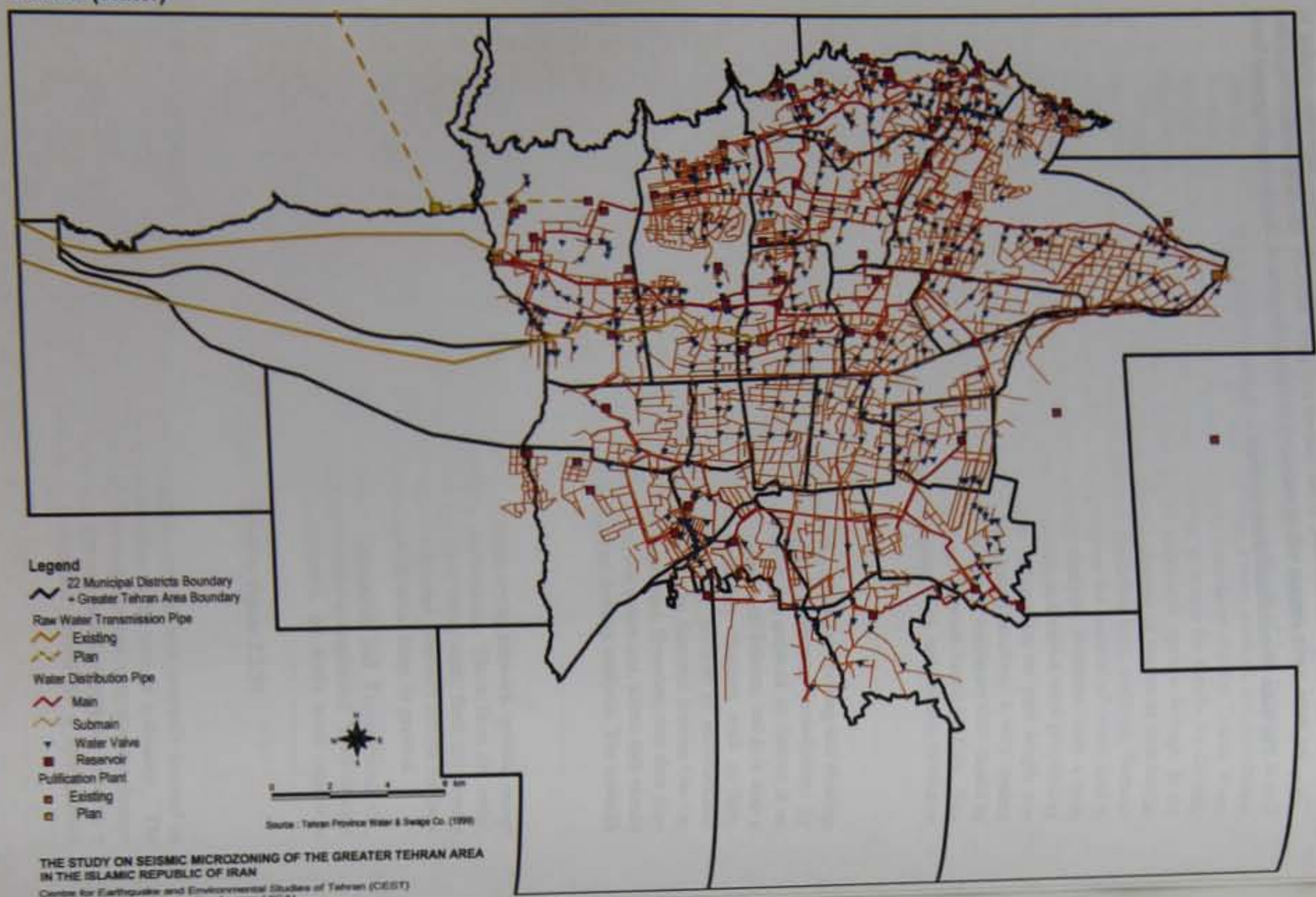

Figure 2.2.33

Lifeline (Gas)

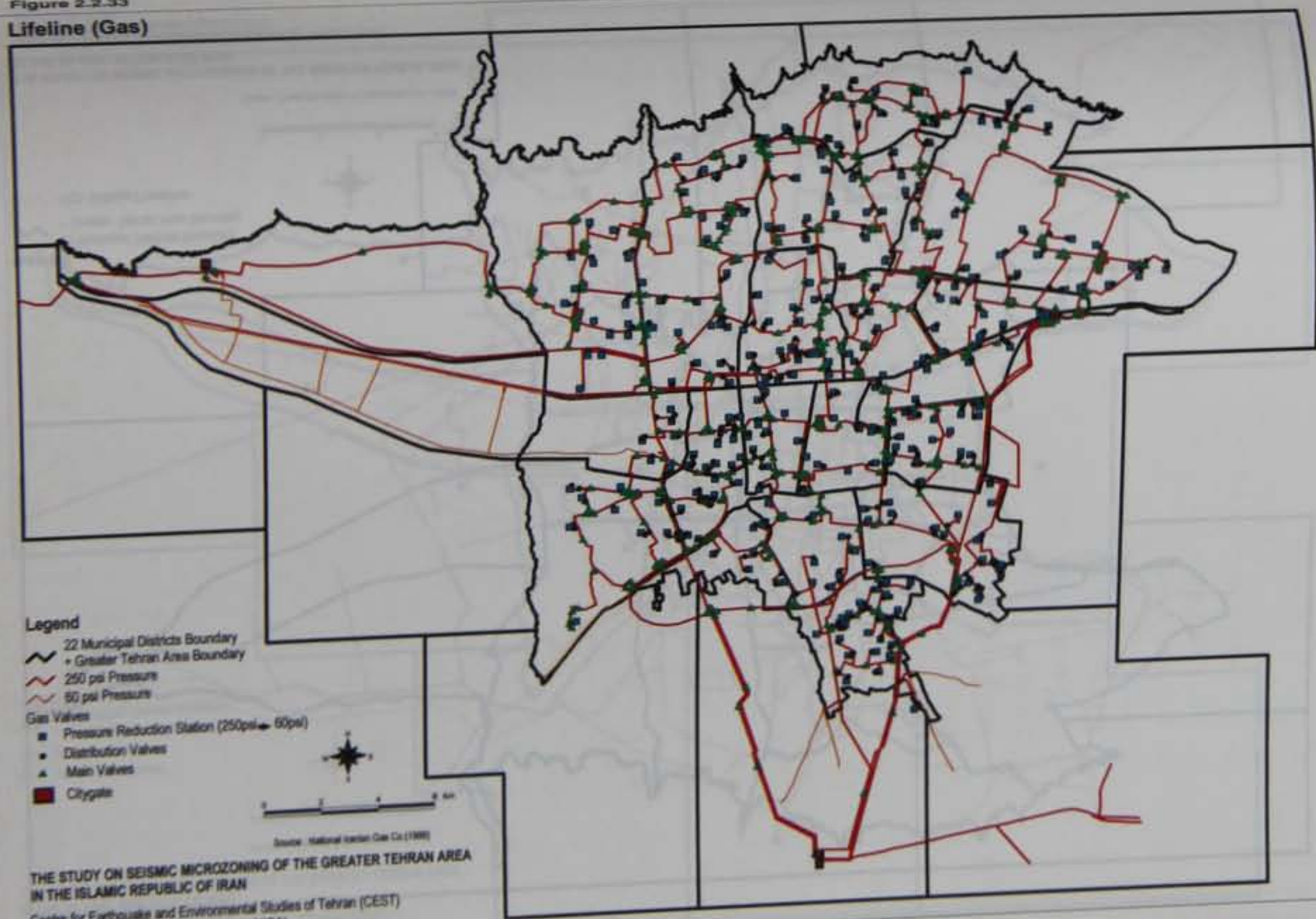

Figure 2.2.34

Lifeline (Electricity)

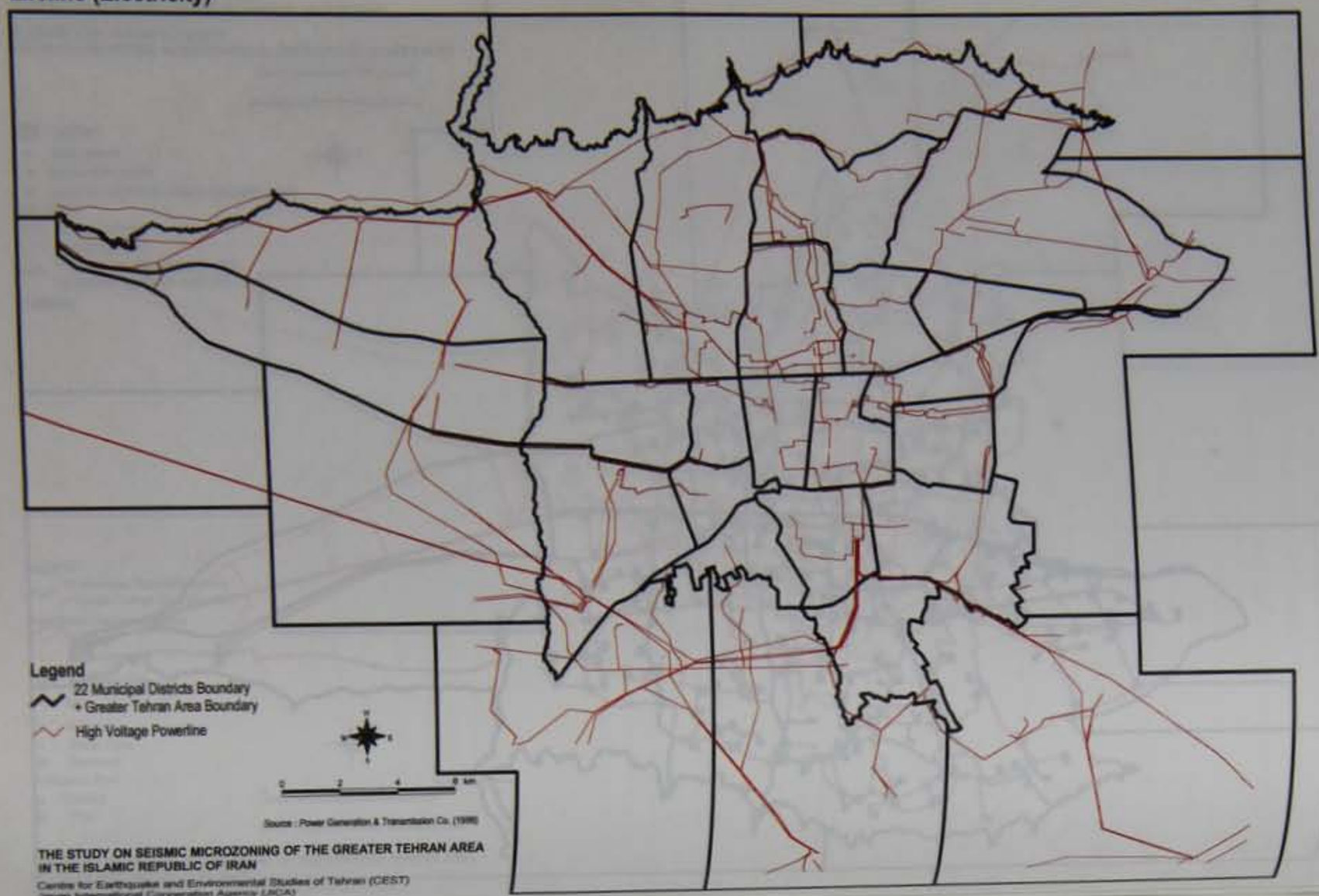

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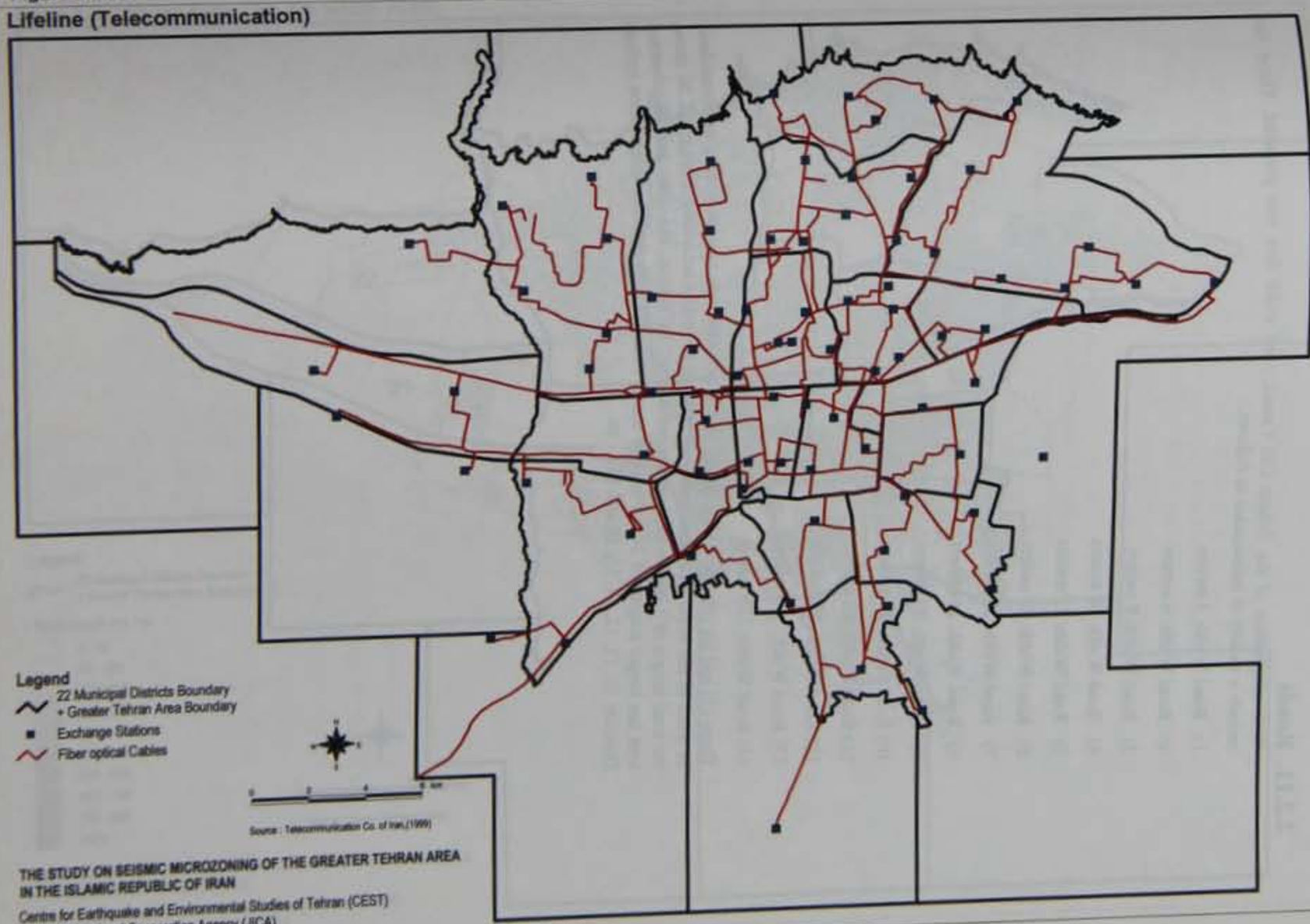
Figure 2.2.35

Lifeline (Telecommunication)



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2.2.11. Roads

With cooperation of the Tehran GIS Center, road width data was prepared. These data include a variety of information as follows.:

1) Road Width: 3 meters
2) Road Width: 6 meters
3) Road Width: 8 meters
4) Road Width: 10 meters
5) Road Width: 12 meters
6) Road Width: 15 meters
7) Road Width: 20 meters
8) Road Width: 24 meters
9) Road Width: 30 meters
10) Road Width: 35 meters
11) Road Width: 40 meters
12) Road Width: 45 meters
13) Road Width: 76 meters
14) Road Width: 120 meters

Three (3) and six (6) meter wide roads, which are relatively narrow streets, are considered as weak in the event of an earthquake in relation to rescue activities. Figure 2.2.36 shows the total length of 3- and 6-meter roads per hector. In Tehran, the older part of urbanised area has longer lengths of 3- and 6-meter roads. Districts with this characterisation include Districts 10, 11, 12, 14, 15, 16 and 17.

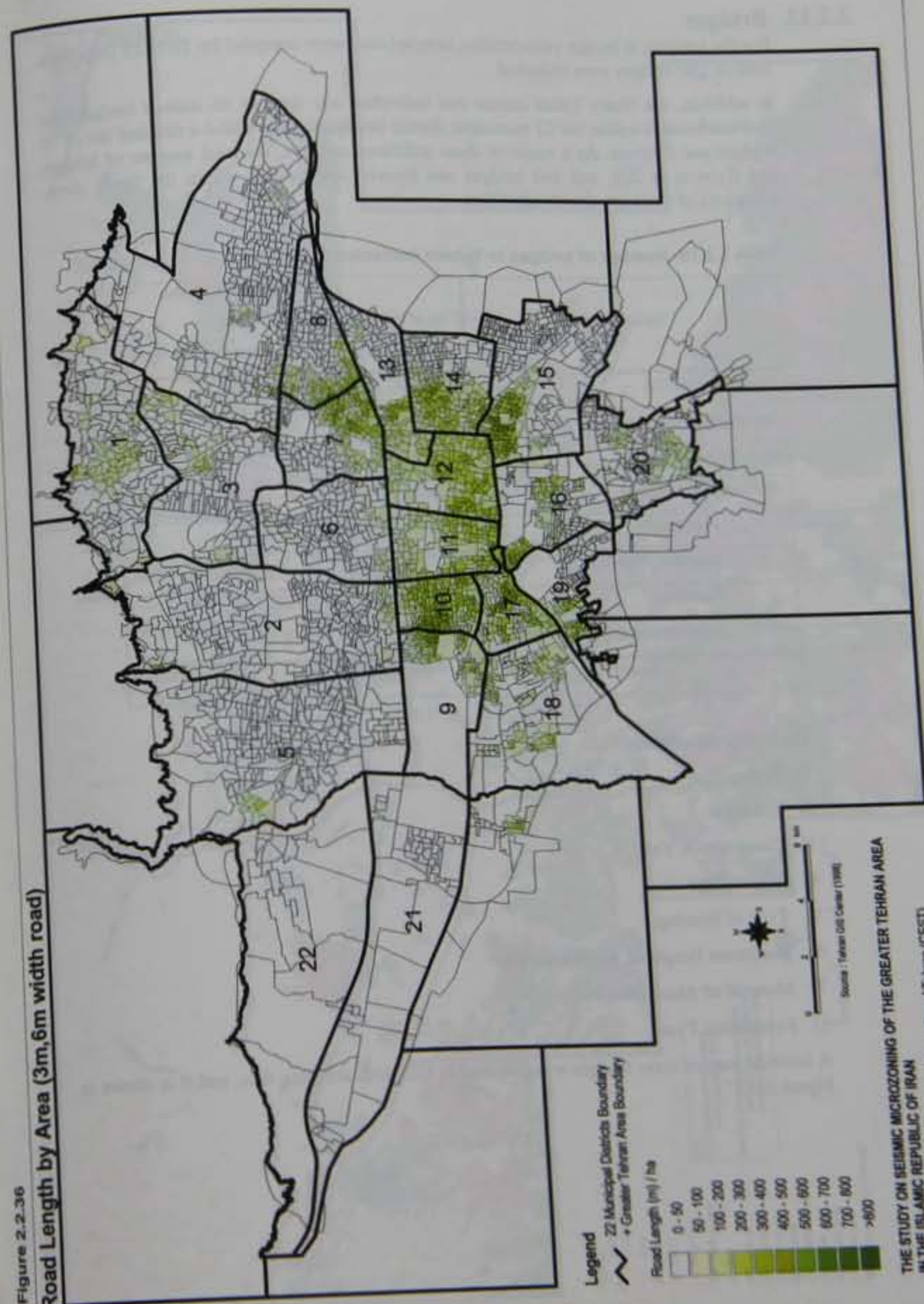

Figure 2.2.36

2.2.12. Bridges

For the analysis of bridge vulnerability, detailed data were compiled by TETCO. Data for a total of 160 bridges were collected.

In addition, the Study Team carried out individual site surveys on missed bridges and flyovers located within the 22 municipal district boundaries and added a detailed list of 79 bridges and flyovers. As a result of these additional surveys, the total number of bridges and flyovers is 239, and 168 bridges and flyovers are located within the Study Area. Locations of these are clearly identified.

Table 2.2.16 Number of bridges in Tehran (collected for the Study)

Type of Bridge	No. of bridges	Within the Study Area and Location Identified
Road Bridge (TETCO)	56	50
Railroad Bridge (TETCO)	51	0
Metro Bridge (TETCO)	53	39
JICA Study Team Identified	79	79
Road-Road		50
Road-Metro, Railways		16
Road-River		11
Metro, Railways-River		2
Total	239	168

The bridge data consist of :

1) Name
2) Location
3) Construction Year
4) Girder Type
5) Type of Bearing
6) Maximum Height of Abutment / Pier
7) Material of Abutment / Pier
8) Foundation Type

A location map of these bridges was prepared in GIS with attribute data, and it is shown in Figure 2.2.37.

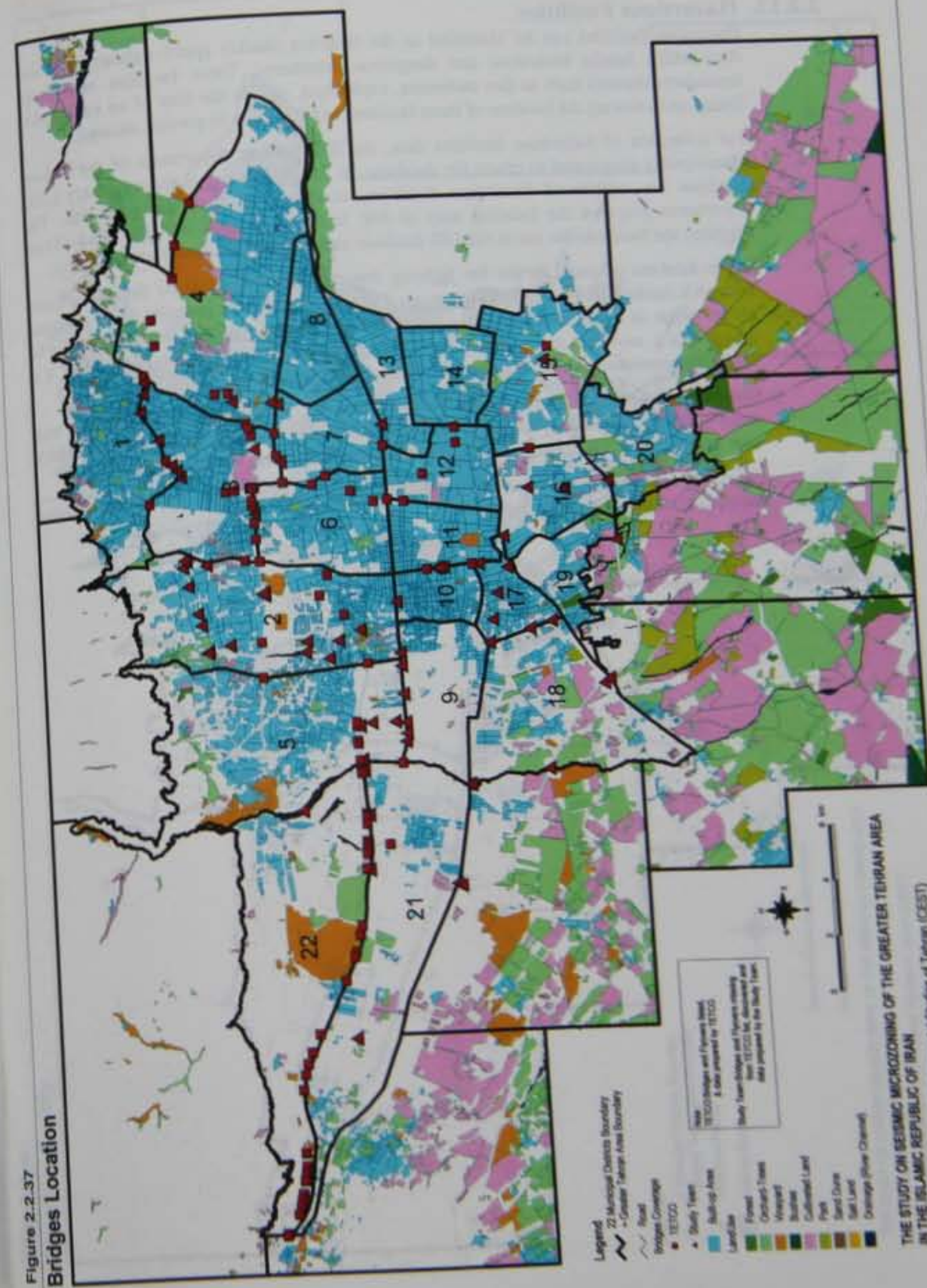

Figure 2.2.37
Bridges Location

2.2.13. Hazardous Facilities

Hazardous facilities can be identified as the facilities (mainly petrol stations, factories, etc.) which handle hazardous and dangerous substances. These facilities may cause secondary disasters such as fire outbreaks, explosions, etc. At the time of an earthquake, listing and knowing the location of these facilities can minimise or prevent damage.

For collection of hazardous facilities data, the fire fighting department of the Tehran Municipality cooperated to create the database. In Tehran, a total of approximately 1,500 facilities are considered hazardous facilities, according to their categorisation. The department prepared the location map of 840 facilities in total, and the Study Team digitised the locations for use in the GIS database and included necessary attribute data.

In the database prepared by the fire fighting department, many outdated data were found through a random check. For instance, many kerosene distributors included in the database are no longer in business or have changed location. The data, which is outdated, cannot be trusted and it may lend to a serious disaster in the event of an earthquake. Therefore, it is urgently recommended to update the data as soon as possible.

Since lack of addresses and inaccuracies were found in the data supplied, a location map could not be completed. Also, there were many facilities included in the database which were not considered as hazardous facilities and were eliminated for the damage analysis.

Figure 2.2.38 shows the location of hazardous facilities, as prepared by the fire fighting department of the Tehran Municipality.

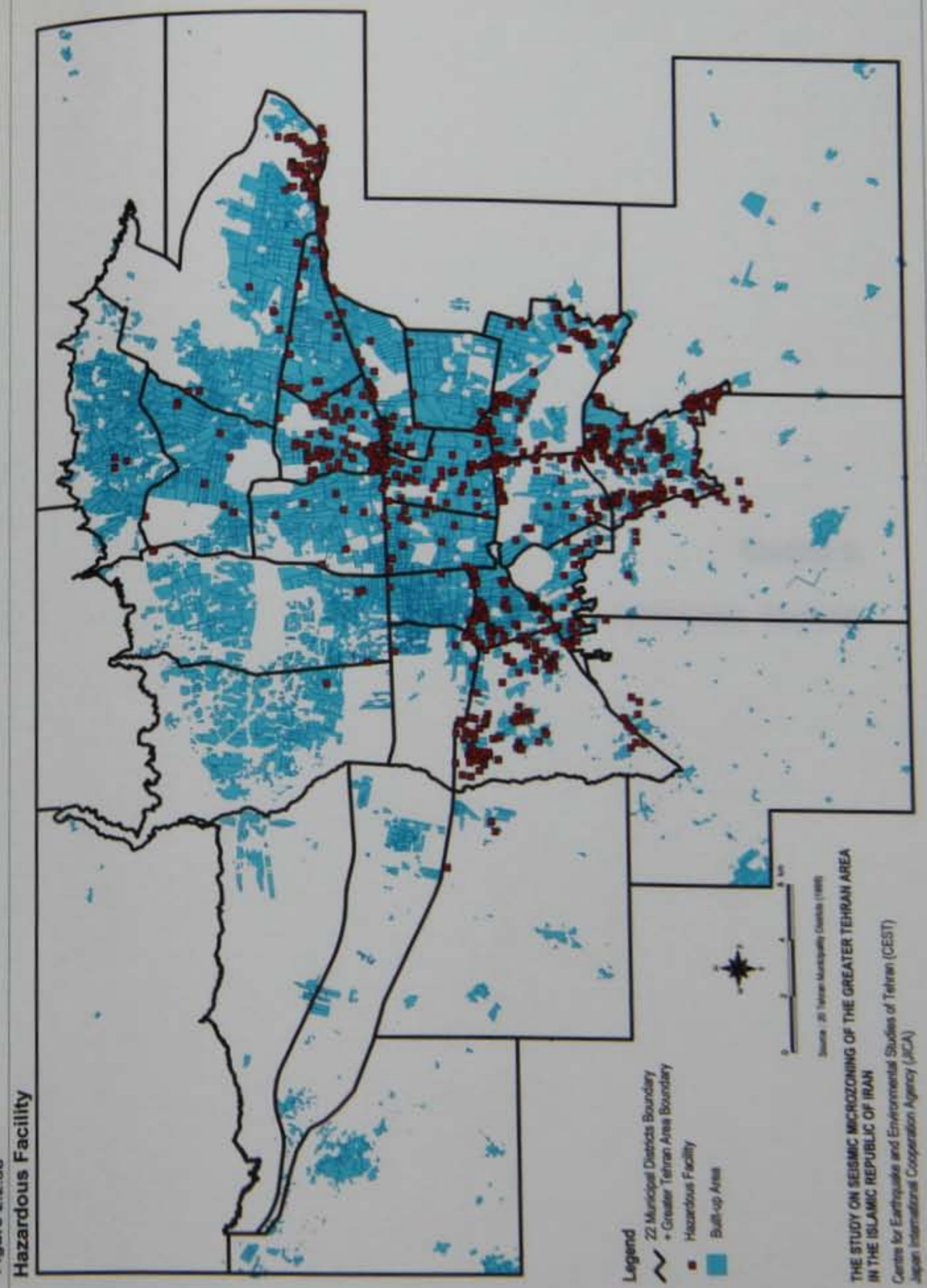

Figure 2.2.38

Chapter 3:

Earthquake Analysis

3.2. Ground Classification

The ground condition of the Study Area was analysed and classified to construct the ground model for seismic analysis. The outline of the ground classification is summarised as follows:

3.2.1. Data Used for the Ground Classification

Fifty boreholes were drilled in the Study Area in order to collect essential ground information. Details of the investigation were summarised in the Field Report. Shear wave velocities of ground were measured in technical cooperation with Exploration Division, Institute of Geophysics, Tehran University (IGTU). Suspension PS logging method and downhole PS logging method were introduced. This borehole data served as the framework for the ground classification. The location of these boreholes is shown in Figure 3.2.1. Typical borehole logs are shown in Figure 3.2.2, Figure 3.2.3, and Figure 3.2.4. Further, about 400 borehole data were used to analyse the ground condition of the Study Area. Most of these borehole data were collected courtesy of Geotechnical and Strength of Material Study Center, Tehran Municipality (GSMSC). The general geological cross section of the Study Area is shown in Figure 3.2.5.

3.2.2. Seismic Bedrock

Normally, it is very difficult to investigate the distribution of the geological seismic bedrock (i.e., hard rock with high shear wave velocity (Vs>3000m/sec)) in plain areas. Therefore, the concept of engineering seismic bedrock is employed for the seismic microzonation analysis. The Technical Committee for Earthquake Foundation Engineering, TC4, ISSMFE (1993) recommends the use of engineering seismic bedrock of shear wave velocity Vs of around 600m/sec.

As described in Chapter 3.2.4, shear wave velocity and the N values obtained from standard penetration tests are mutually related. The N values are recalculated as equivalent to 30cm penetration Neq. Based on this relationship, Vs = 600m/sec corresponds to Neq =100. Therefore, the engineering seismic bedrock for the Study is defined as follows:

> Engineering Seismic Bedrock in this Study
>
> - The layer at which the shear wave velocity Vs exceeds 600m/sec or the Neq value exceeds 100, and
> - The continuity and thickness of the engineering seismic bedrock is adequate for wave propagation

Based on the above definition, the distribution of the engineering seismic bedrock in the Study Area is estimated. In the eastern alluvial plain, the engineering seismic bedrock is situated at a depth of around GL-150m. This is the deepest part in the Study Area. From this area, the depth of the engineering seismic bedrock becomes shallower towards the north and east. The depth becomes approximately GL-35m at the boundary of the fan and the plain. The depth of the engineering seismic bedrock in ***C*** and ***D_2*** formations is estimated at approximately GL-20 to 35m from the Neq value and the PS logging result. ***A*** and ***B*** formations are firmly cemented, therefore these formations are regarded as an engineering seismic bedrock from their surface. In addition, ***R*** formations are regarded as engineering seismic bedrock from the ground surface.

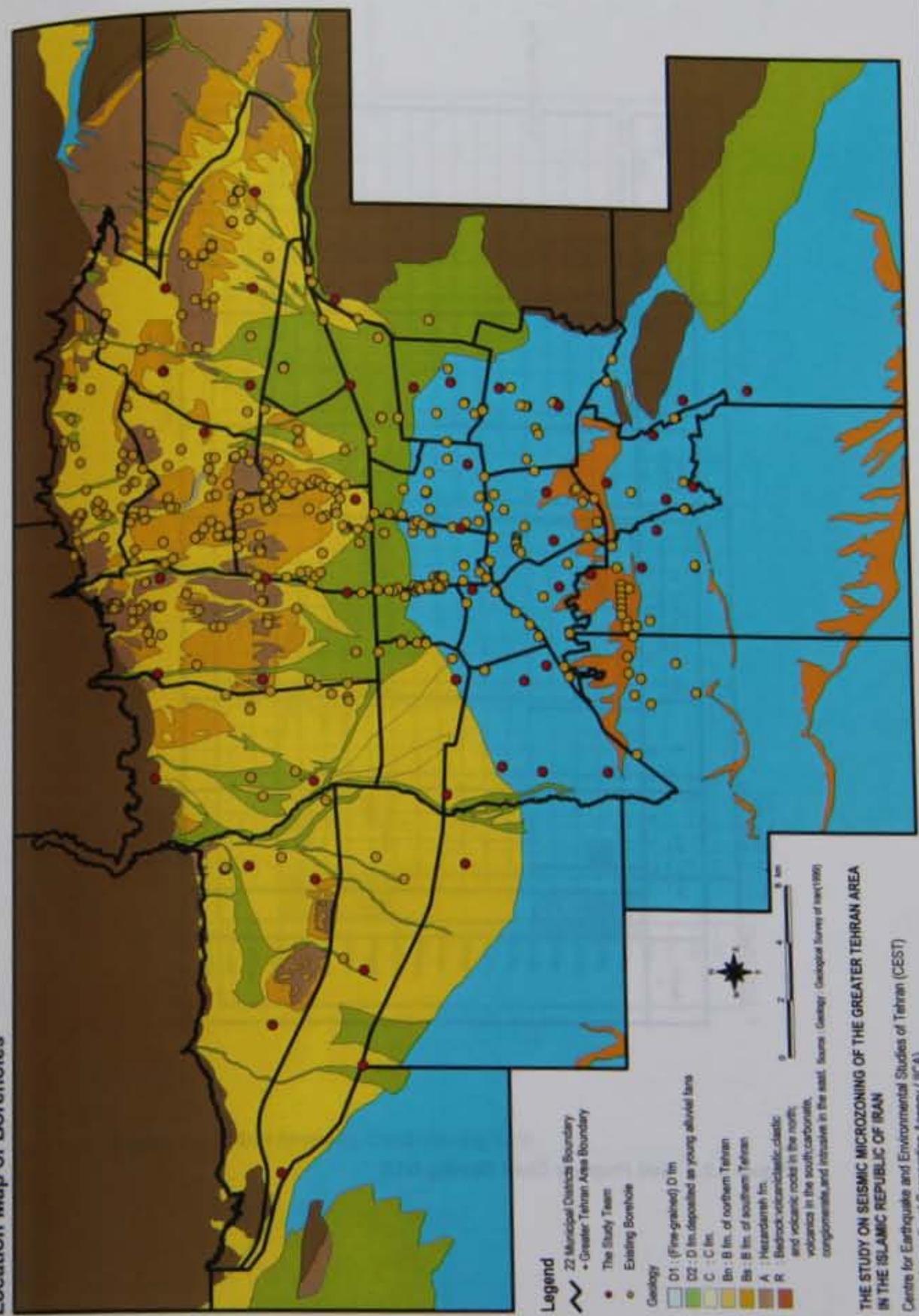

Figure 3.2.1 Location Map of Boreholes

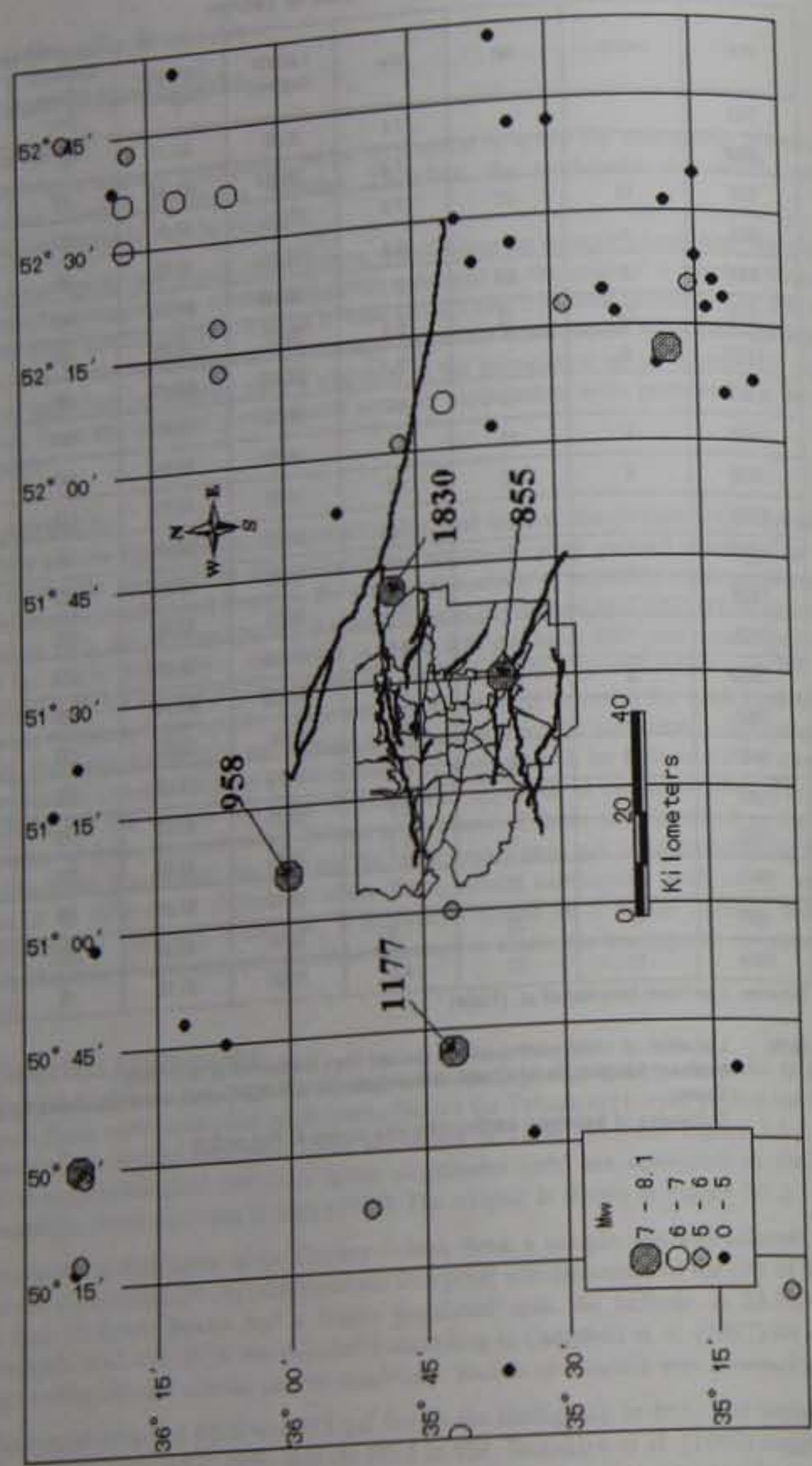

Figure 3.3.1 Historical Earthquake Distribution around Tehran

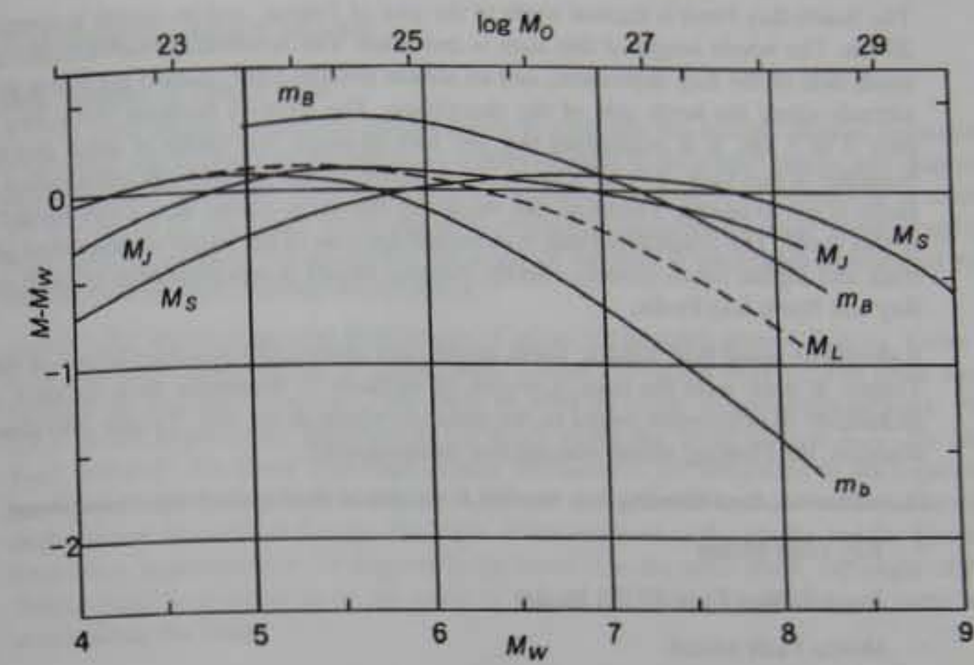

Figure 3.3.2 Relationship between Surface Wave Magnitude(Ms), Body Wave Magnitude(mb) and Moment Magnitude(Mw)

Source: Utsu (1982)

(4) Proposed Scenario Earthquake

Among the many active faults in the area, the most probable hazardous faults are the following:

- Mosha Fault (length: approximately 200km)
- North Tehran Fault (length: approximately 90km)
- South Ray Fault (length: approximately 20km).

The Mosha Fault is a major fault over 200km long, and it consists of several segments. The earthquake in 1830 corresponded to activity on the eastern segment of the Mosha Fault. Therefore, a part of the eastern Mosha Fault was selected as one of the scenario earthquake sources.

The largest historical earthquake occurred in 958 with Mw=7.7, at about 50km from the centre of Tehran. This earthquake corresponded to activity on the western segment of the Mosha Fault. The North Tehran Fault is located between the western segment of the Mosha Fault and the city of Tehran. If the North Tehran Fault is activated, the damage, which the resulting earthquake could cause, will be heavier than that which would be due to the re-occurrence of the event in 958. Thus, for the scenario earthquake, the North Tehran Fault should be considered instead of the western segment of the Mosha Fault.

The North Tehran Fault lies on the boundary between the northern mountainous area and the city area. This fault extends over 90 km, but the northwestern part of it is far from the city of Tehran. Therefore, the eastern part was selected as a source of one of the scenario earthquakes.

Table 3.3.2 Fault Model Parameters

		Ray Fault model	NTF (North Tehran Fault) model	Mosha Fault model	Floating model
Length (km)		26	58	68	13
Width (km)		16	27	30	10
Moment Magnitude (Mw)		6.7	7.2	7.2	6.4
Origin	N (degrees)	35.8255	35.6815	35.5876	-
	E (degrees)	51.7392	52.4955	51.5061	-
Azimuth (Clockwise from North) (degrees)		263	263	283	263
Dip angle (degrees)		75	75	75	75
Depth of upper edge (km)		5	0	0	5

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Moinfar, A.A., Mahdavian, A. and Maleky, E., 1994, Historical and Instrumental Data Collection of Iran, Iranian cultural fairs institute.

Utsu, T., 1982, Relationships Between Earthquake Magnitude Scales, Bull. Earthq. Res. Inst., Vol.57. No.3, (in Japanese with English abstract).

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Table 3.4.1 The Parameters for Green's Function Method

Parameters		1st. step	2nd. Step			
			Ray Fault model	NTF model	Mosha Fault model	Floating model
Main Fault	Strike (degrees)	257	277	277	257	277
	Dip (degrees)	45	75	75	75	75
	Rake Angle (degrees)	90	90	90	90	90
	Depth (km)	3.9	19.1	24.4	26.9	13.5
Small Fault	Strike (degrees)	257	257	257	257	257
	Dip (degrees)	45	45	45	45	45
	Rake Angle (degrees)	90	90	90	90	90
	Depth (km)	18.5	3.9	3.9	3.9	3.9
N		5	5	8	9	3
Initial rupture point		east of lower end	centre of lower end	centre of lower end	east of lower end	centre of lower end
Shear Wave Velocity (km/s)		3.0	3.0	3.0	3.0	3.0
Rupture Propagation Velocity (km/s)		2.16	2.16	2.16	2.16	2.16

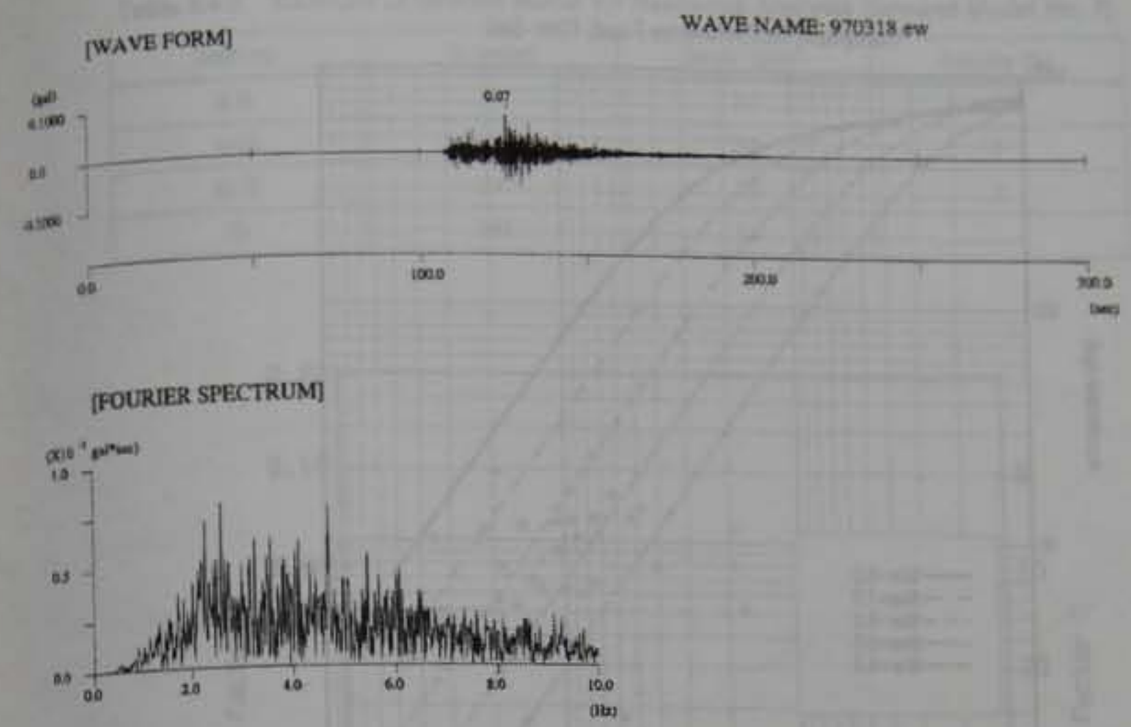

Figure 3.4.2 Waveform of Small Event

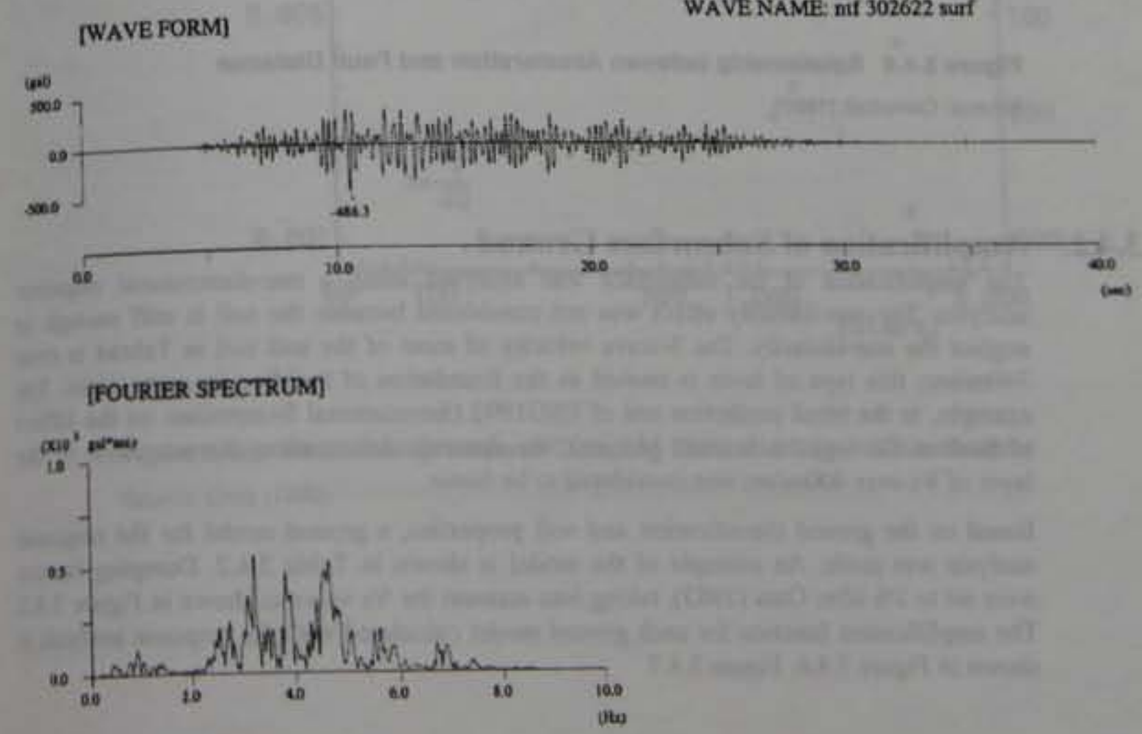

Figure 3.4.3 Synthesised Waveform

References for section 3.4

Campbell, K.W., 1997, Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Ground Velocity, and Pseydo-Absolute Acceleration Response Spectra, Seismological Research Letters, Vol.68, No.1.

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3.5. Calculation of Earthquake Ground Motion

The waveform at the ground surface is calculated from the waveform at the engineering bedrock and subsurface amplification function.

3.5.1. Peak Ground Acceleration

The peak ground acceleration (PGA) distribution maps are shown in Figure 3.5.2 to Figure 3.5.5 .

(1) Ray Fault Model

According to this model, the southern area of the city experiences over 400 gal.

The northern area experiences less than 200 gal.

(2) NTF Model

According to this model, ground acceleration in the northern area of the city reaches over 400 gal.

The southern area experiences fewer than 200gal.

(3) Mosha Fault Model

According to this model, the majority of the city experiences less than 200 gal.

(4) Floating Model

In this model, the difference of resulting PGA is affected only by subsurface amplification. It is pointed out that areas of high amplification distribute at several areas. The majority of the city experiences acceleration between 300 and 400 gal.

3.5.2. Seismic Intensity

The seismic intensity (MMI) scale is a subjective one, based on human observation of shaking and damage during an earthquake. The relation of seismic intensity and physical parameters of seismic waves, such as acceleration, velocity and spectral intensity, is studied by many researchers. In this study, the consideration of Trifunac and Brady (1975) was adopted. The relation between PGA and MMI is shown in Figure 3.5.1.

The seismic intensity distribution maps are shown in Figure 3.5.6 to Figure 3.5.9.

(1) Ray Fault Model

According to this model, the southern area of the city experiences a seismic intensity of 9 and the northern area experiences intensities of 7 to 8.

(2) NTF Model

According to this model, seismic intensity in the northern area of the city reaches 9 and in the southern area reaches 7.

The majority of the city experiences a seismic intensity of 8.

(3) Mosha Fault Model

According to this model, the majority of the city experiences a seismic intensity of 7.

(4) Floating Model

According to this model, the majority of the city experiences a seismic intensity of 8. Several areas experience a seismic intensity of 9.

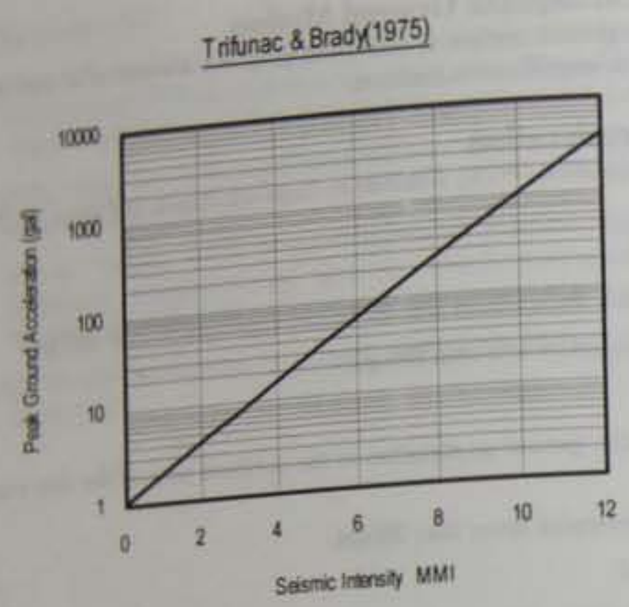


Figure 3.5.1 Relation between Peak Ground Acceleration (PGA) and Seismic Intensity (MMI)

Source: Trifunac and Brady (1975)

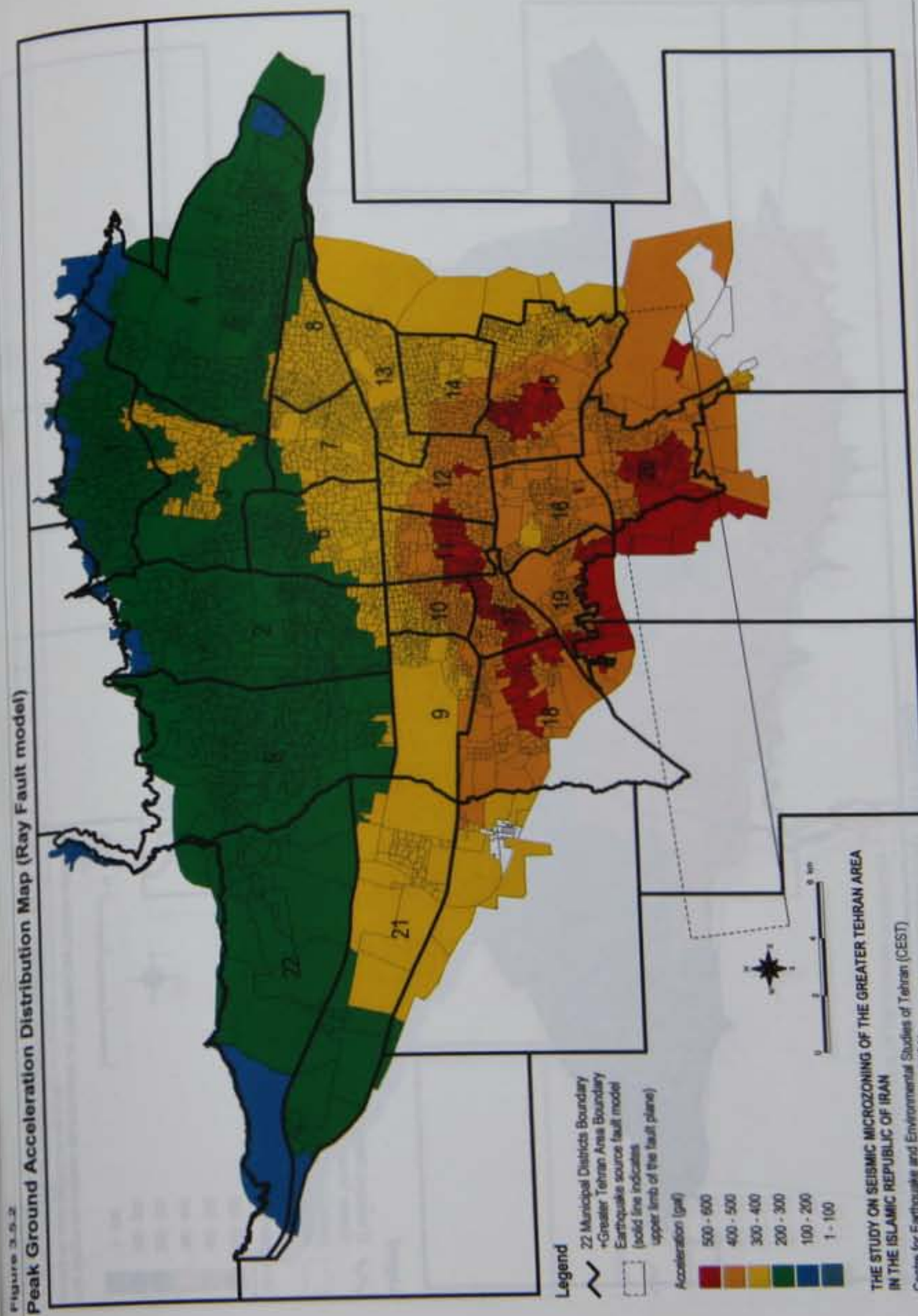


Figure 3.5.3

Peak Ground Acceleration Distribution Map (NTF model)

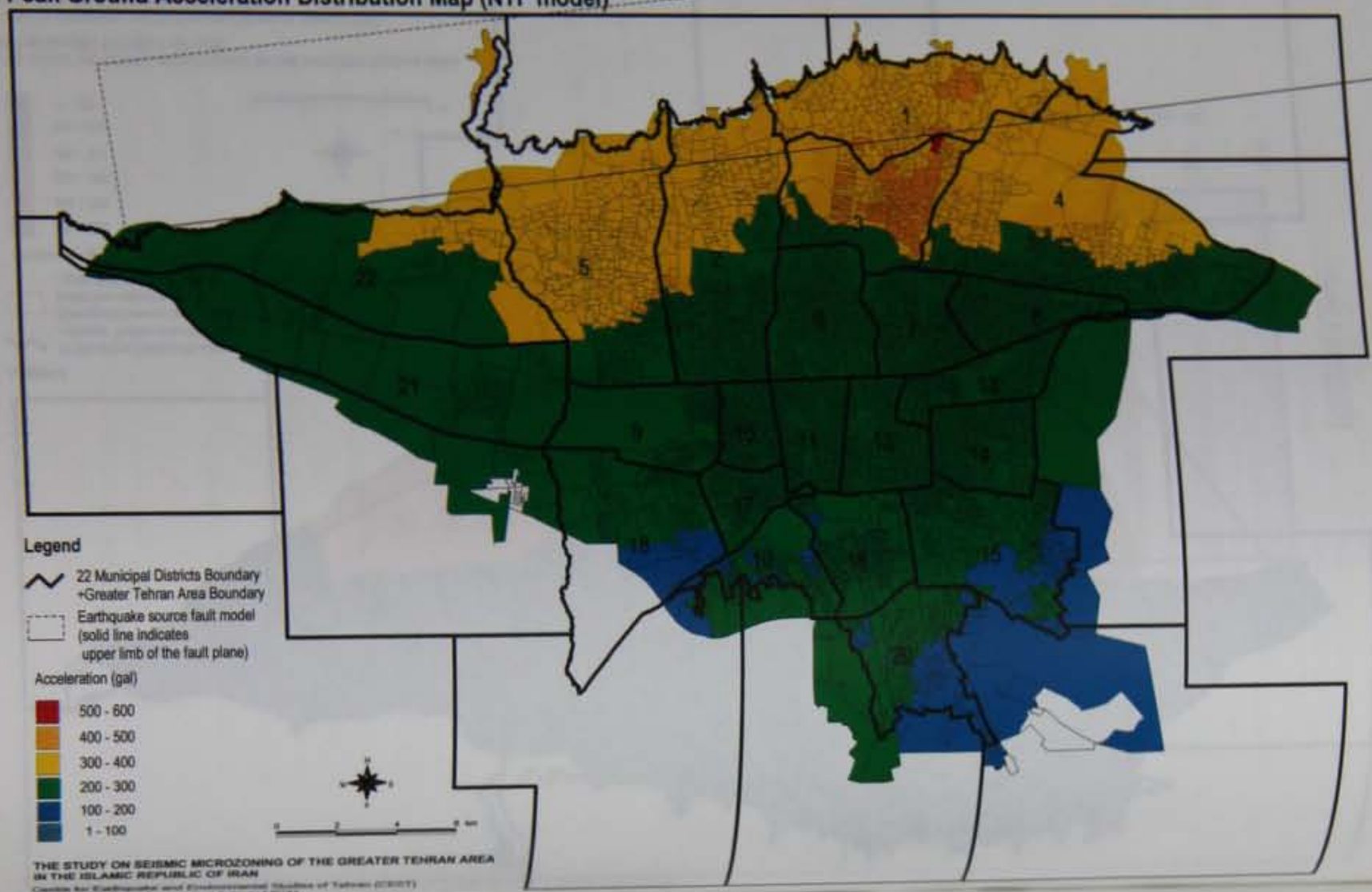


Figure 3.5.4

Peak Ground Acceleration Distribution Map (Mosha Fault model)

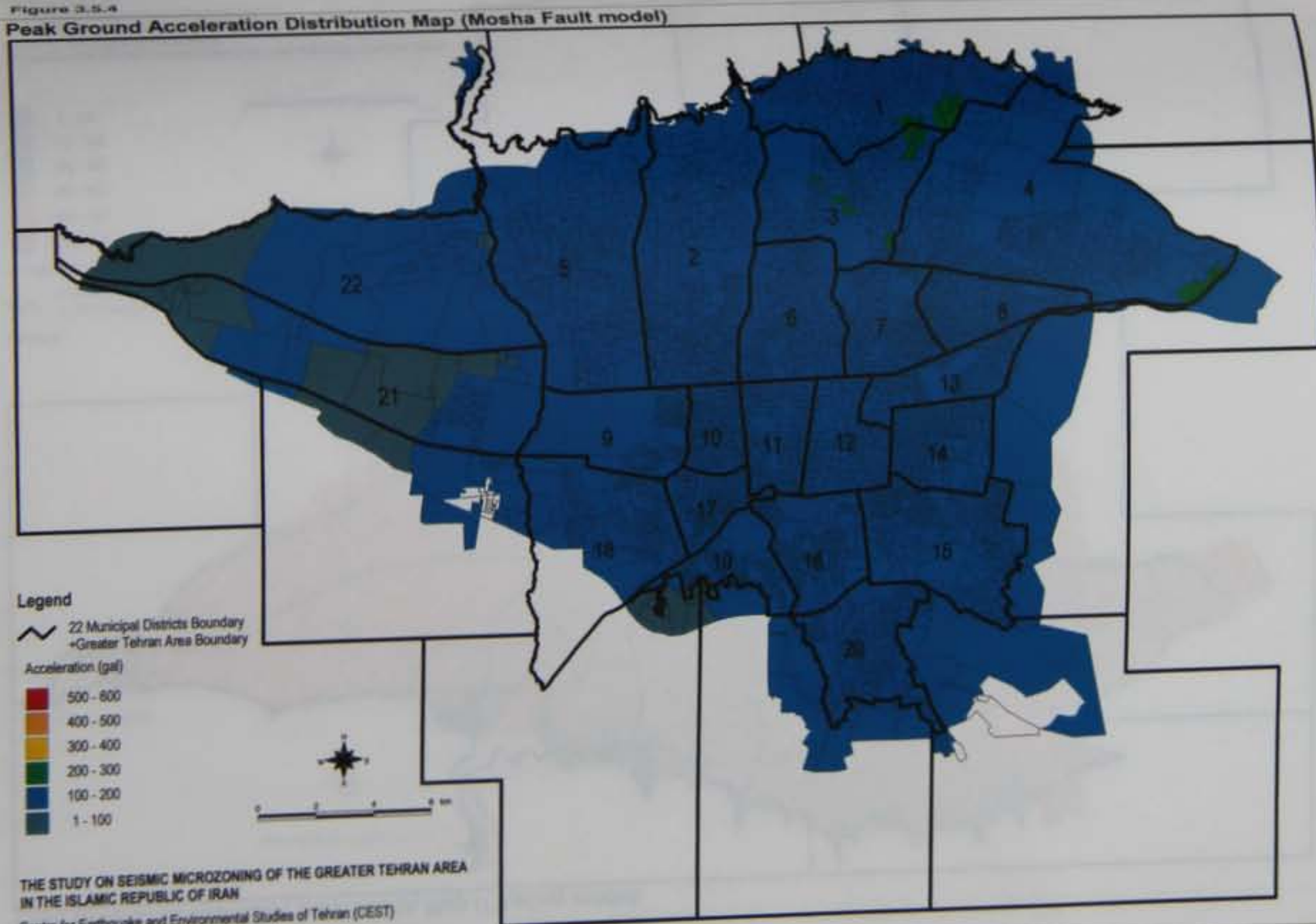


Figure 3.5.5

Peak Ground Acceleration Distribution Map (Floating model)

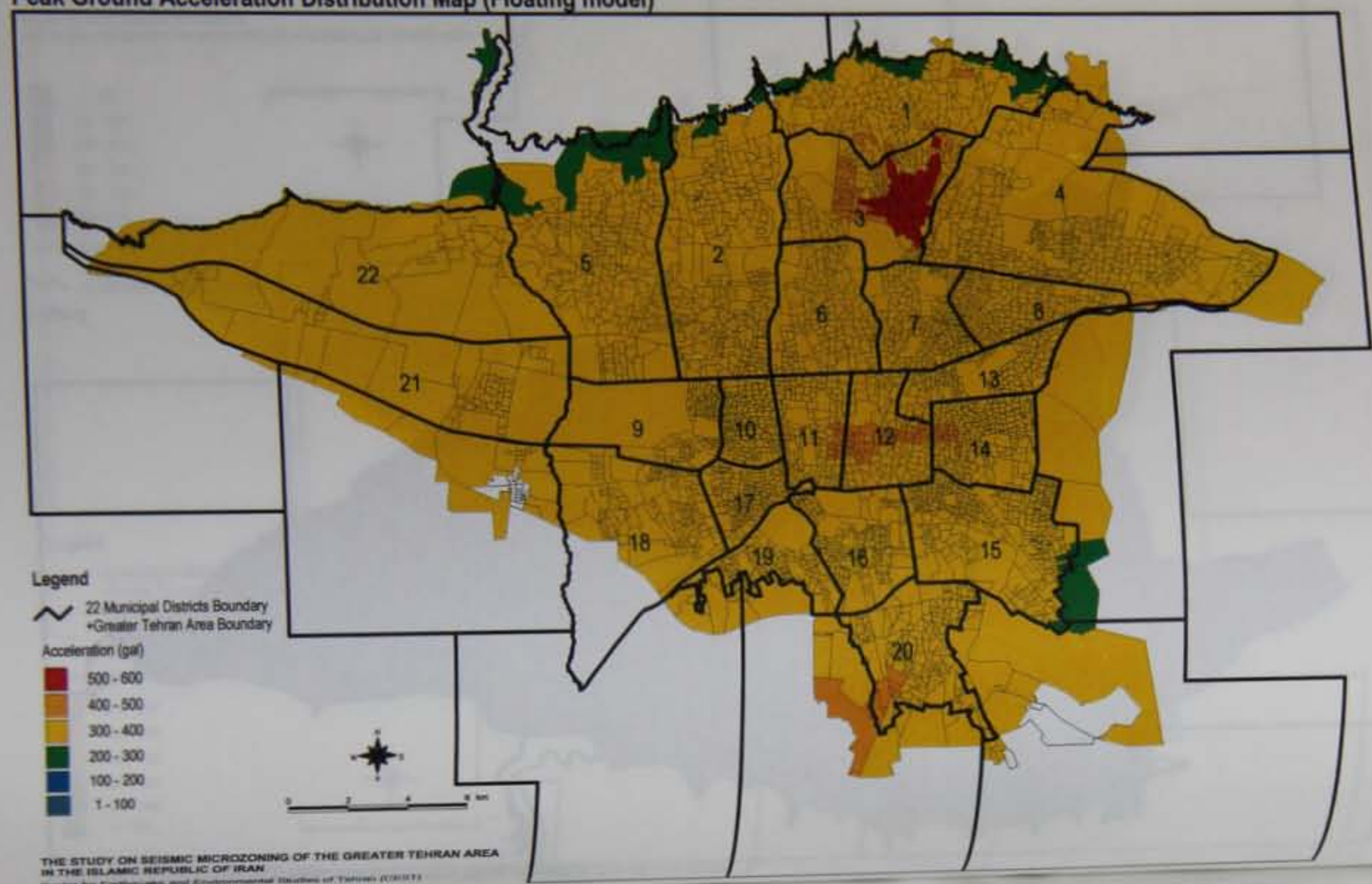


Figure 3.5.6

Seismic Intensity Distribution Map (Ray Fault model)

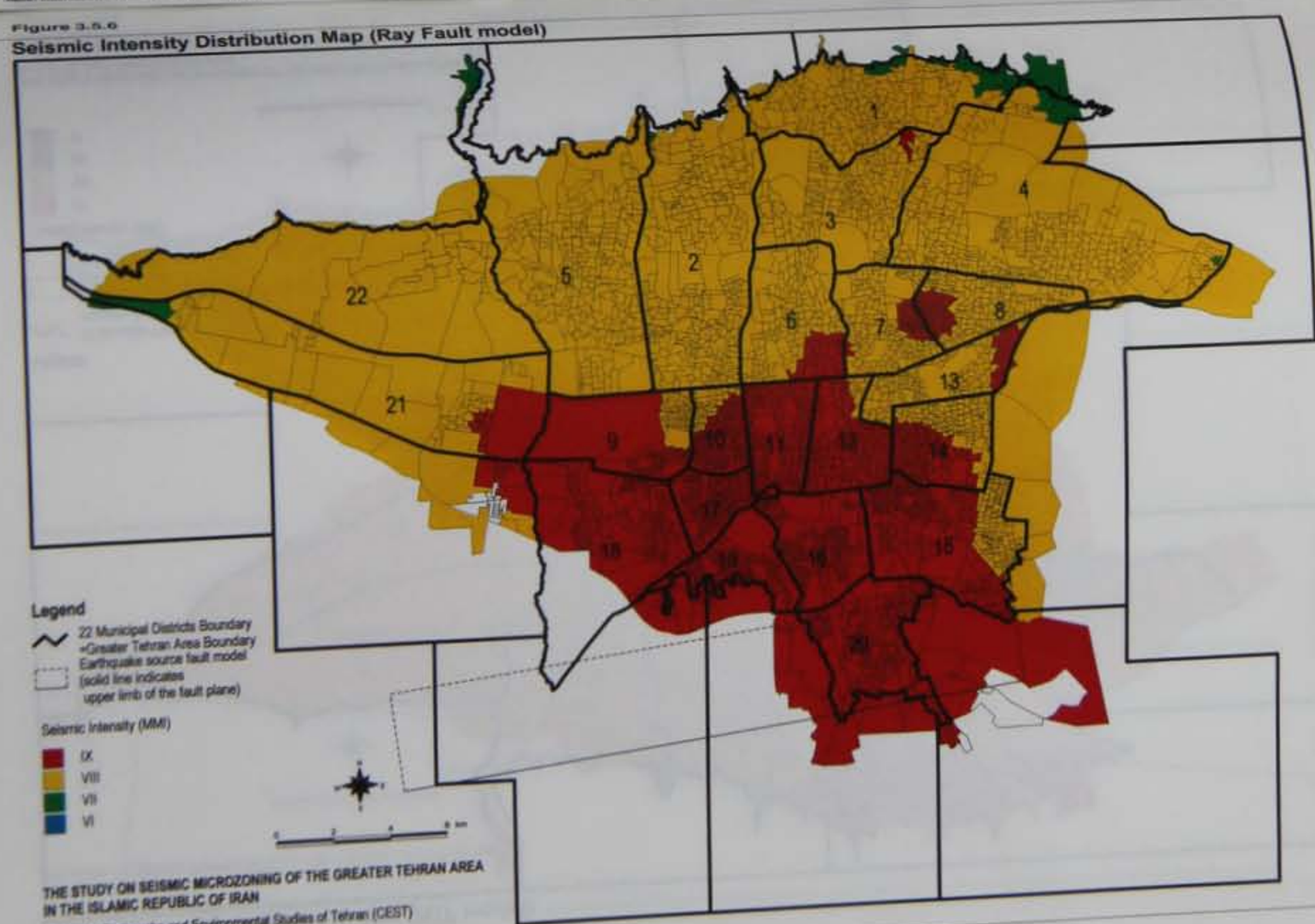


Figure 3.5.7

Seismic Intensity Distribution Map (NTF model)

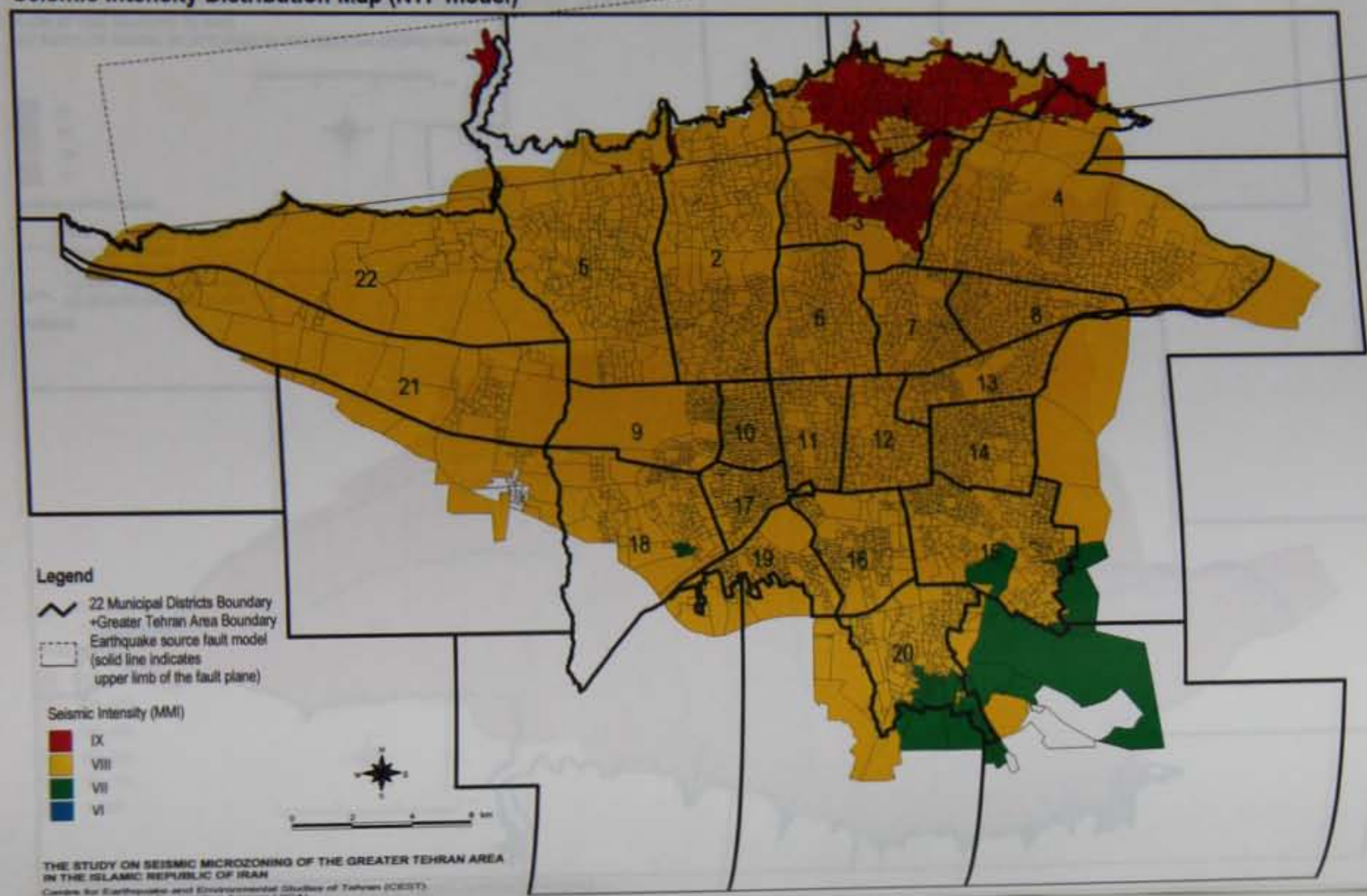


Figure 3.5.8

Seismic Intensity Distribution Map (Mosha Fault model)

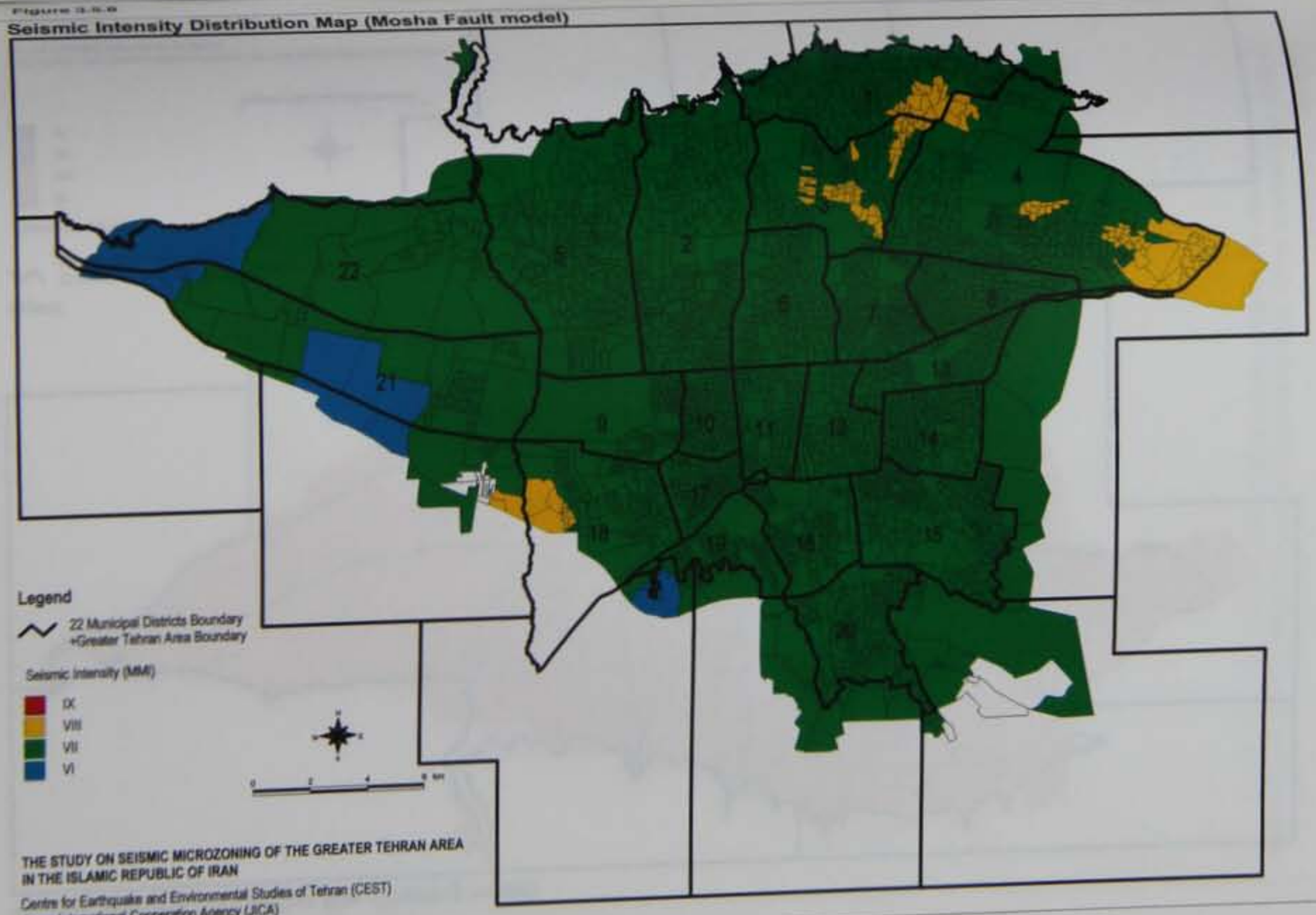
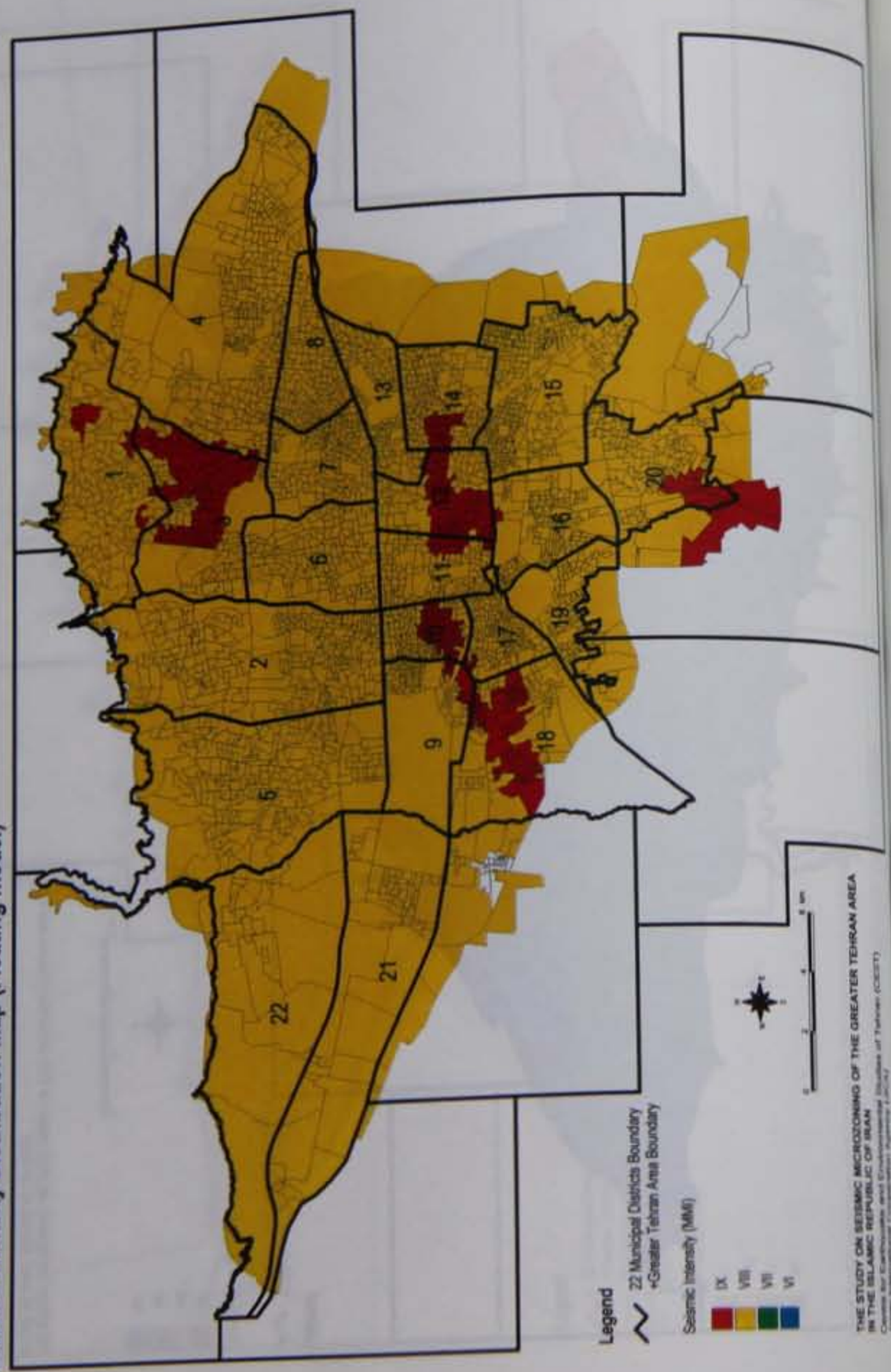


Figure 3.5.9

Seismic Intensity Distribution Map (Floating model)



References for section 3.5

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Chapter 4:

Seismic Damage Estimation

4.1.1. Method of Damage Estimation

As described in section 2.2.8, the residential building database was established based on the 1996 Housing Census data. It is complemented by building storey information supplied by the Post Office. This database has the following information items for each building:

- Census zone number and block ID number
- Construction year (interval)
- Number of stories
- Structural type
- Number of rooms
- Number of inhabitants

The construction years, number of stories and the structural type are the basic information items that describe a building's structural properties. A damage estimation method that can utilise these three items was selected.

Generally, for the damage estimation of buildings, it is desirable to use dynamic parameters such as the natural periods of each building height and structure, i.e. dynamic response, during an earthquake. However, such parameters were not available for buildings in Iran and, therefore, not taken into account in the Study.

(1) General Features of the Building Structures in Tehran

Based on the residential building database and site reconnaissance, the features of the residential buildings of the Study Area are shown in Figure 4.1.2 and summarised as follows:

1) 45 % of the buildings are steel and brick structures, 40 % are steel structures, 10% are RC structures and only a small percent are adobe structures.
2) There has been a recent increase in the number of steel structure buildings. 60 % of the steel structure residential buildings have been built during the last 10 years.
3) The moment resisting frames of the steel structures are recognised as effective in the current aseismic design code. On the other hand, pillars and beams are connected using field welding and this leads to a low reliability of the connection. Therefore, the perceived effectiveness of steel structures is not fully expected.
4) Many steel pillars are not of adequate size and most of the RC (reinforced concrete) pillars do not have adequate reinforcement.
5) There are two types of RC structures. One type has RC pillars and walls. Another type has RC pillars and brick walls. RC structures, and not brick structures, are expected to serve as shear walls.
6) There are only few buildings with adequate shear walls. This is recognised for both steel structures and RC structures. The walls of steel and brick structures are constructed of thin bricks. Obviously, this type of wall does not function as shear wall.

Further, the following features are recognised in the design criteria:

1) The current aseismic code was issued in 1990. Therefore, it is considered that the level of earthquake-resistance is different for buildings constructed before 1991 and after 1991.
2) There are some structural differences in high and low residential buildings; it may follow that earthquake resistance property varies between the two.

Consequently, it is considered that most of the buildings in the Study Area do not have adequate earthquake resistance.

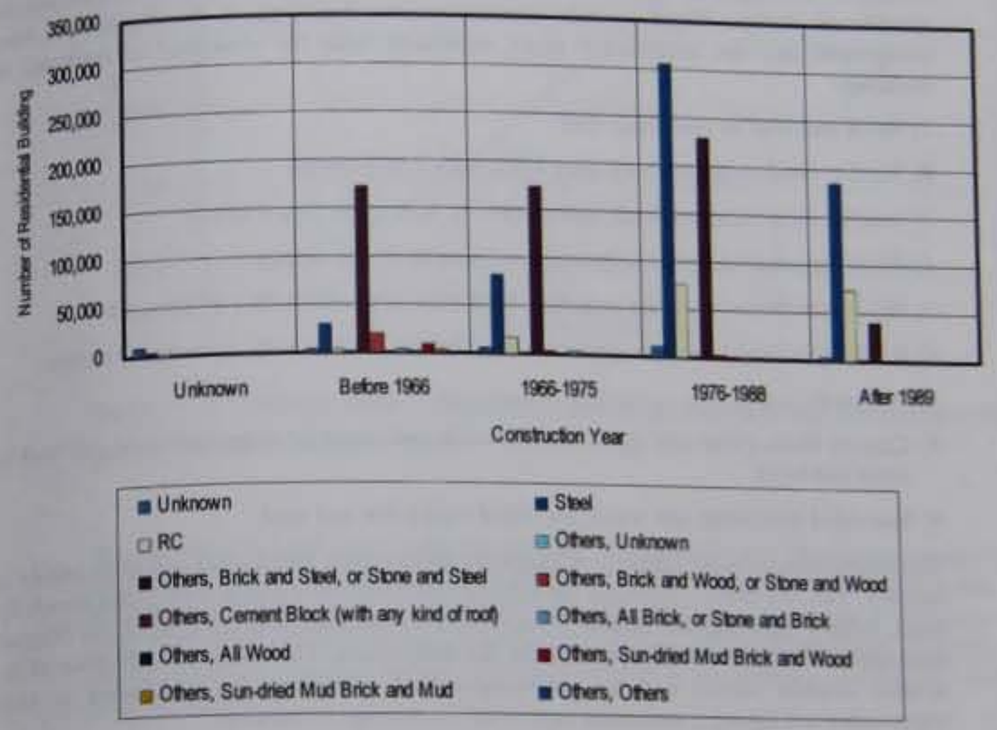


Figure 4.1.2 Number of Residential Building by Structure and Year Interval

Source: 1996 Housing Census

(2) Basic Idea of the Damage Estimation Method for Tehran Residential Buildings

The damage estimation method for the buildings with the above-mentioned problems was studied. Generally, a structure is destroyed when the earthquake force exceeds the structure's resistance. Here, the earthquake force is defined as the seismic force at the ground surface or at the structure's foundation together with the response property of the structure. The response spectrum is one example of a simple expression of the earthquake force. It is possible to calculate the resistance of the structure with information on the size and type of the structure. In other words, definite damage can be estimated when a seismic force, such as acceleration, MMI, etc., at the ground surface and the structure of the buildings are determined. The estimation shall be expressed as a probability because the difference in each construction condition is not difficult to take into account. This type of method is applicable to evaluate stability of individual, critical buildings, but it is not suitable for the estimation of damage of a huge number of buildings, considering that Tehran has approximately 900,000 buildings.

The seismic force on a building can be estimated based on information on the earthquake motion and the building structure. If buildings are categorised according to their structure,

- all brick, or stone and brick: made of brick, stone (considering the roof has a jack arch structure)

It is considered that these types of structures are somewhat more seismically resistant than sun-dried mud brick structures, category number 9. In the description of the MSK scale, most of the structures in category B, ordinary brick, suffer Grade 3 damage (heavy damage) under an intensity 8 and Grade 4 damage (destruction) under an intensity 9. Furthermore, the MMI intensity scale and MSK intensity scale are almost the same in these ranges.

9) Sun-dried mud brick and wood, sun-dried mud brick and mud :

The ratio for these types of construction is 2.0 units to the left of the basic damage ratio on the MMI scale, i.e., damage ratio is defined as 1.0 for MMI 7.5.

The structures considered as both of these types of construction are the following:

- sun-dried mud brick and wood
- typical adobe structure (part of the roof is made of wood)
- sun-dried mud brick and mud
- typical adobe structure (whole roof is made of mud)

In the description of the MSK scale, most of the structures of category A, adobe and clay, suffer Grade 3 damage (heavy damage) under an intensity 7 and Grade 4 damage (destruction) under intensity 8. Furthermore, the MMI intensity scale and MSK intensity scale are almost the same in these ranges.

The damage functions are summarised on Figure 4.1.5.

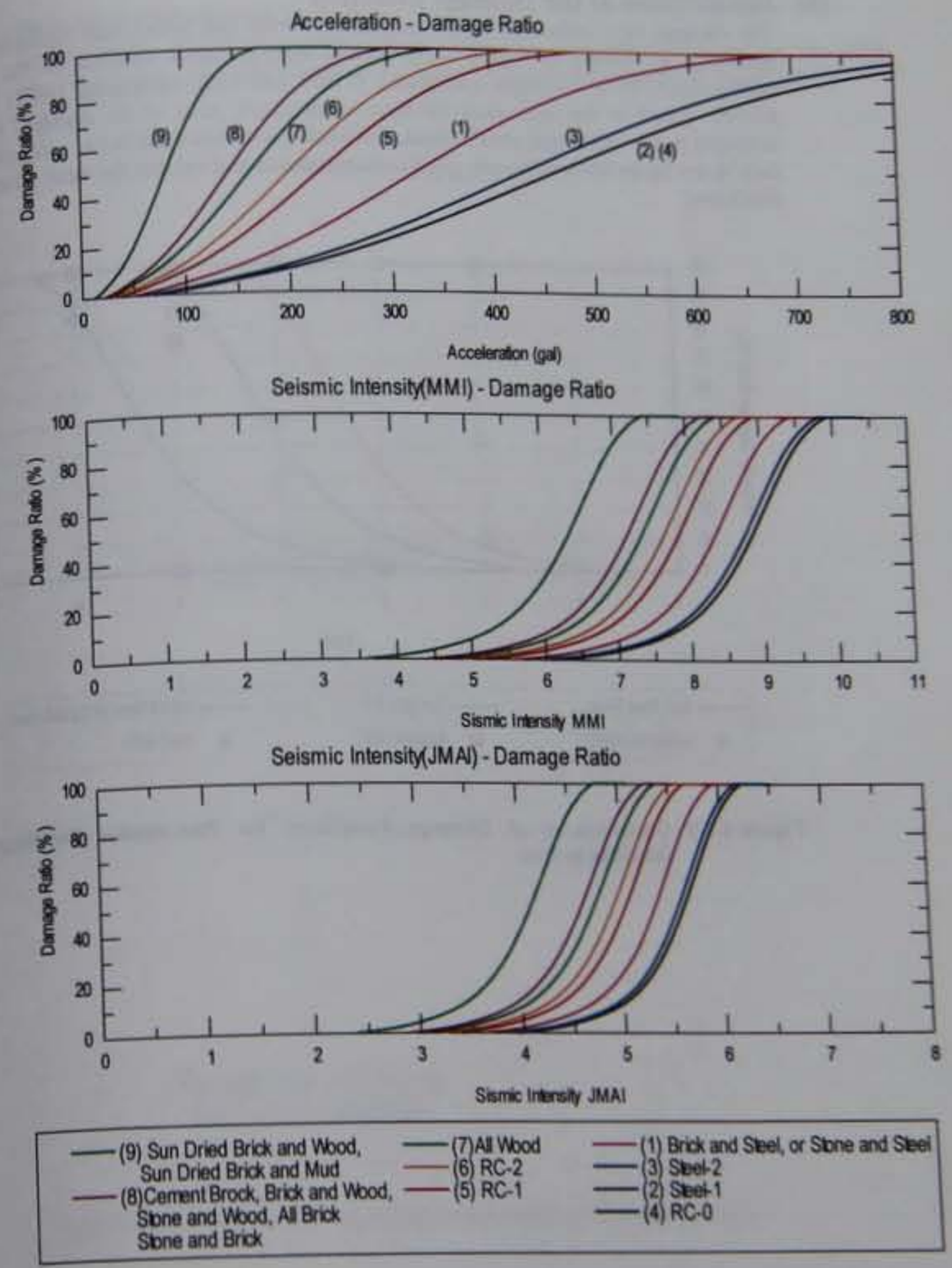


Figure 4.1.5 Vulnerability Function of Residential Buildings Applied in the Study

(5) Justification of the Damage Function

The damage ratio curves of 'brick and steel', 'block and brick', and 'sun-dried brick' structures are shown in Figure 4.1.6. Actual damage ratios observed in the Ardekul earthquake (1997), Lofdegan earthquake (1992) and Ghir earthquake (1972) are also plotted. Based on the references for these earthquakes, most of the damaged buildings belonged to the 'brick and steel', 'block and brick', and 'sun-dried brick' categories. Both data in the figure show relatively good correspondence and validity for these functions are confirmed.

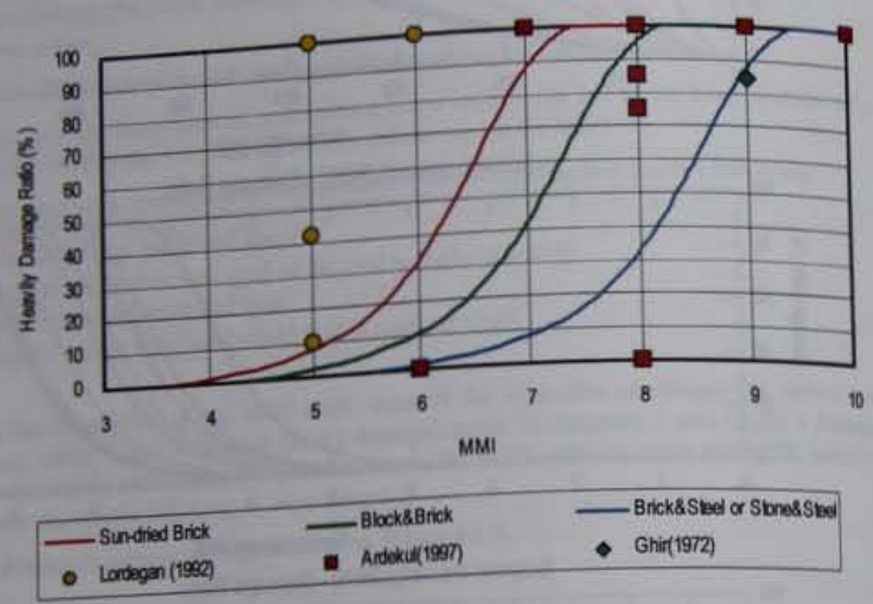


Figure 4.1.6 Comparison of Damage Functions for Residential Buildings and Damage in Iran

4.1.2. Inventory Database Set-up

In this Study, the dwelling unit inventory database was prepared based on the 1996 Housing Census data. The flowchart of database preparation is shown in Figure 4.1.7.

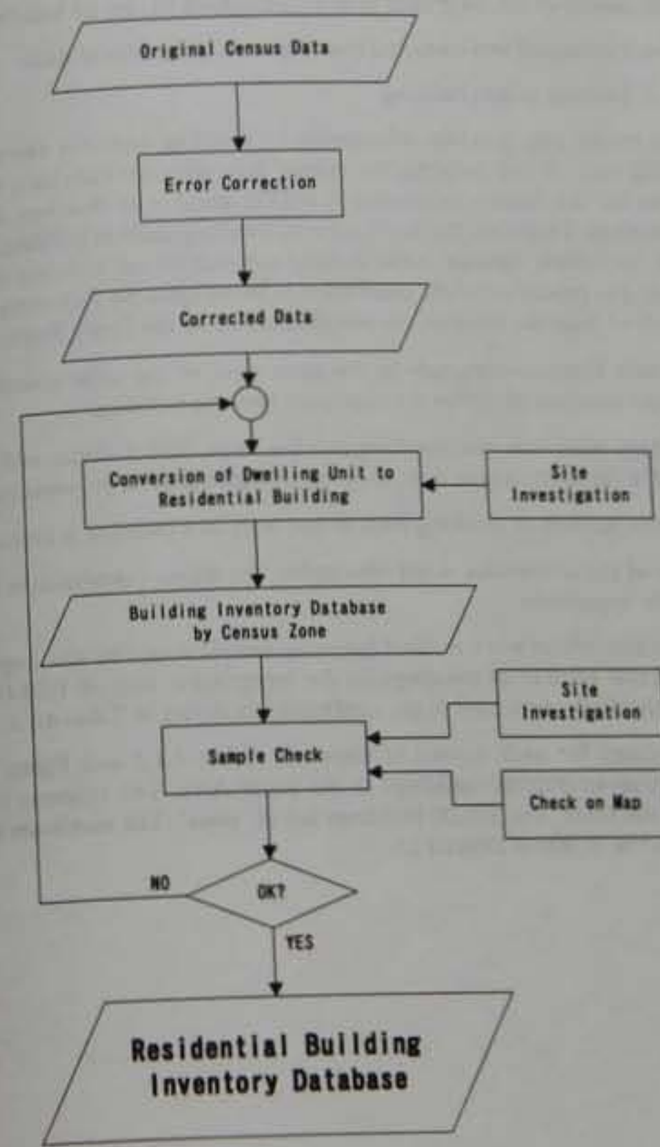


Figure 4.1.7 Flowchart of Dwelling Unit Inventory Database Set-up

Original 1996 Housing Census data is vast in quantity and valuable. It includes such information as building structure, number of residents, construction year, etc. for each dwelling unit. Some data, however, were considered inapplicable to the seismic disaster estimation because of some problems and limitations. Therefore, this census data was arranged for the new database as follows:

1) Error Correction

In the original census data, there were some simple input errors such as follows:

- Entries with negative values for number of stories
- Entries with number of stories greater than 31, maximum 91, for 63 buildings

These data were estimated and corrected based upon neighbourhood data.

2) Conversion of dwelling unit to building

Basically, the census data provides information by dwelling unit. For example, if there are 30 dwelling units in one building, the census data gives 30 individual data entries. Necessary data for the disaster estimation is not the number of dwelling units but the number of buildings. Therefore, the conversion of dwelling units to buildings is required. Without such conversion, damage in the densely constructed tall building areas will be over-evaluated. The procedure of the conversion is based upon the following hypothesis, which was derived from the result of site reconnaissance by the Study Team:

- Dwelling units listed continuously as the same type, of the same construction year and the same numbers of stories are converted into one building;
- In cases where more than one dwelling unit has more than 5 stories and these units are located in the same census zone, they are considered to be the same building.
- The maximum number of dwelling units in one story of a building is limited to 5; and
- If the result of the conversion is not reasonable, the above calculation is iterated by changing the hypothesis.

The results of this conversion were verified for some sample zones by site inspection and by counting the actual number of buildings on the topographic map of 1:5000 scale. An example of a sample check sheet used in the verification is shown in Table 4.1.1.

The database tabulated for each district is shown in Table 4.1.2 and Figure 4.1.8. As indicated, there are about 900,000 buildings in the Study Area. The structure of 400,000 buildings is 'steel and brick' and 350,00 buildings are of 'steel'. The maximum number of buildings per district is 75,000 in District 15.

Table 4.1.1 Sample of Check Sheet for Dwelling Unit Inventory Database

District	Census Zone	Number of buildings			Structure (Raw Data)	Remarks (Raw Data)	Confirmation		
		Raw Data (Dwelling Unit)	4/24 method	5/26 method			Number of buildings counted on map	Number of doors counted in the field	Researched items in the field
1	136	363	254	255	S,RC,S&B	Floor Unknown	208		
2	161	388	207	206	S,RC	2,3F	161		
	165	441	299	293	S,RC	2,3F	207		
	166	835	132	122	RC	27F			
	168	790	58	51	RC	27F, 26F			
	183	391	272	272	S,RC	3,4F apartment	299		
	192	413	332	332	S,RC	3,4F			
	193	393	325	325	S,RC	3,4F			
	194	445	337	338	S,RC	3,4F			
	223	826	178	177	RC	10F, 20F, 23F		1482<	6 27F, 6 20F, 6 11F
4	18	1878	93	83	RC	10 of 12F			Military base
	47	420	263	255	S, S&B	2,3F	233		
	108	485	332	333	S, S&B	2-4F	238		
5	25	1630	56	47	RC	10 of 11-14F	50	1780	20 5F, 20 9F, 10 12F
8	62	641	413	413	S&Brick	2,3F	342		
10	110	502	196	234	S&Brick	2,3F			
12	45	419	307	318	S	2,3F	276		
17	89	324	175	272	S&Brick	2,3F	342		
18	1	237	176	195	S&Brick	2,3F		0	Factory only, inhabitants=1994 ?
Total				2,644			2,356		

Table 4.1.2 Number of Buildings in Each District by Structure

District	Type of Main Structure											Sum
	?	1	2	3	4	5	6	7	8	9	10	
1	1,398	17,610	7,202	10,950	1,074	213	689	23	216	196	63	39,634
2	2,115	32,960	17,101	11,253	166	202	612	12	21	27	172	64,641
3	1,112	20,548	5,576	8,712	251	76	295	8	97	91	35	36,801
4	3,215	40,498	6,515	30,936	369	276	655	41	45	37	55	82,642
5	1,645	29,250	11,763	9,875	269	260	152	8	76	11	43	53,352
6	756	14,278	2,577	10,233	286	34	180	54	14	33	8	28,453
7	1,576	18,710	1,907	20,914	1,070	124	376	12	122	48	33	44,892
8	1,700	18,985	1,352	28,309	188	28	721	13	8	25	10	51,339
9	503	4,747	557	14,500	171	12	121	1	2	60	6	20,680
10	1,186	8,117	218	28,682	986	18	708	6	296	70	42	40,329
11	1,051	9,975	492	15,338	3,137	31	472	53	1,249	330	136	32,264
12	958	8,493	436	9,648	4,698	59	493	205	2,710	850	141	28,691
13	1,133	11,781	580	20,459	1,148	23	196	12	104	84	8	35,528
14	1,716	19,946	839	29,726	1,822	82	158	111	639	284	25	55,348
15	2,714	27,203	1,945	38,546	2,286	114	292	99	508	308	1,240	75,255
16	1,408	8,852	424	23,399	1,495	144	462	70	967	208	9	37,438
17	1,229	7,490	148	23,401	385	14	336	4	95	98	12	33,212
18	1,306	11,496	269	22,247	132	12	164	1	20	26	3	35,676
19	759	9,273	292	16,086	107	16	134	5	20	30	8	26,730
20	1,381	16,480	2,082	21,139	713	307	440	24	377	273	62	43,278
21	741	8,798	1,831	10,366	55	479	29	1	18	28	21	22,367
22	132	4,312	1,500	740	11	7	32	2	0	1	1	6,738
City	29,734	349,802	65,606	405,459	20,819	2,531	7,717	765	7,604	3,118	2,133	895,288

Legend for Structure Type
?:Unknown 1:Steel 2:RC 3: Others, Steel & Brick or Steel & Stone
4: Others, Wood & Brick or Wood & Stone 5: Others, Cement Block 6: Others, All Brick or Brick & Stone
7: Others, All Wood 8:Sun-dried Mud Brick & Wood 9:Sun-dried Mud Brick & Mud
10:Others

Note: After Conversion from Dwelling Unit to Residential Building

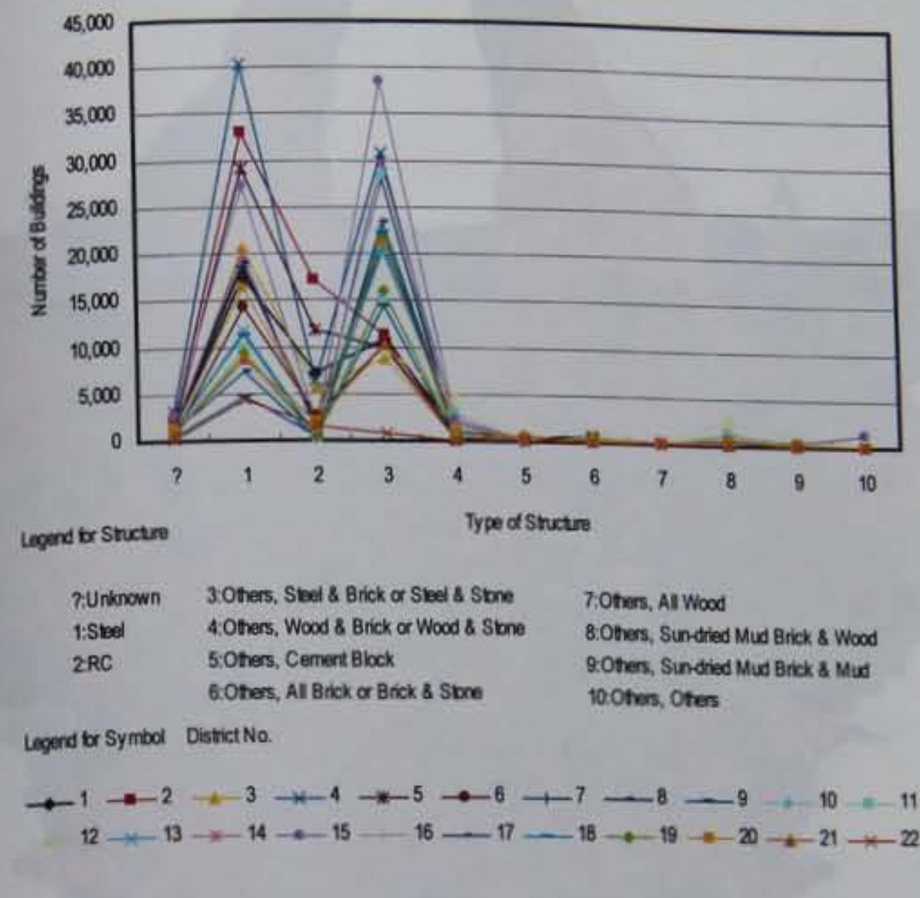


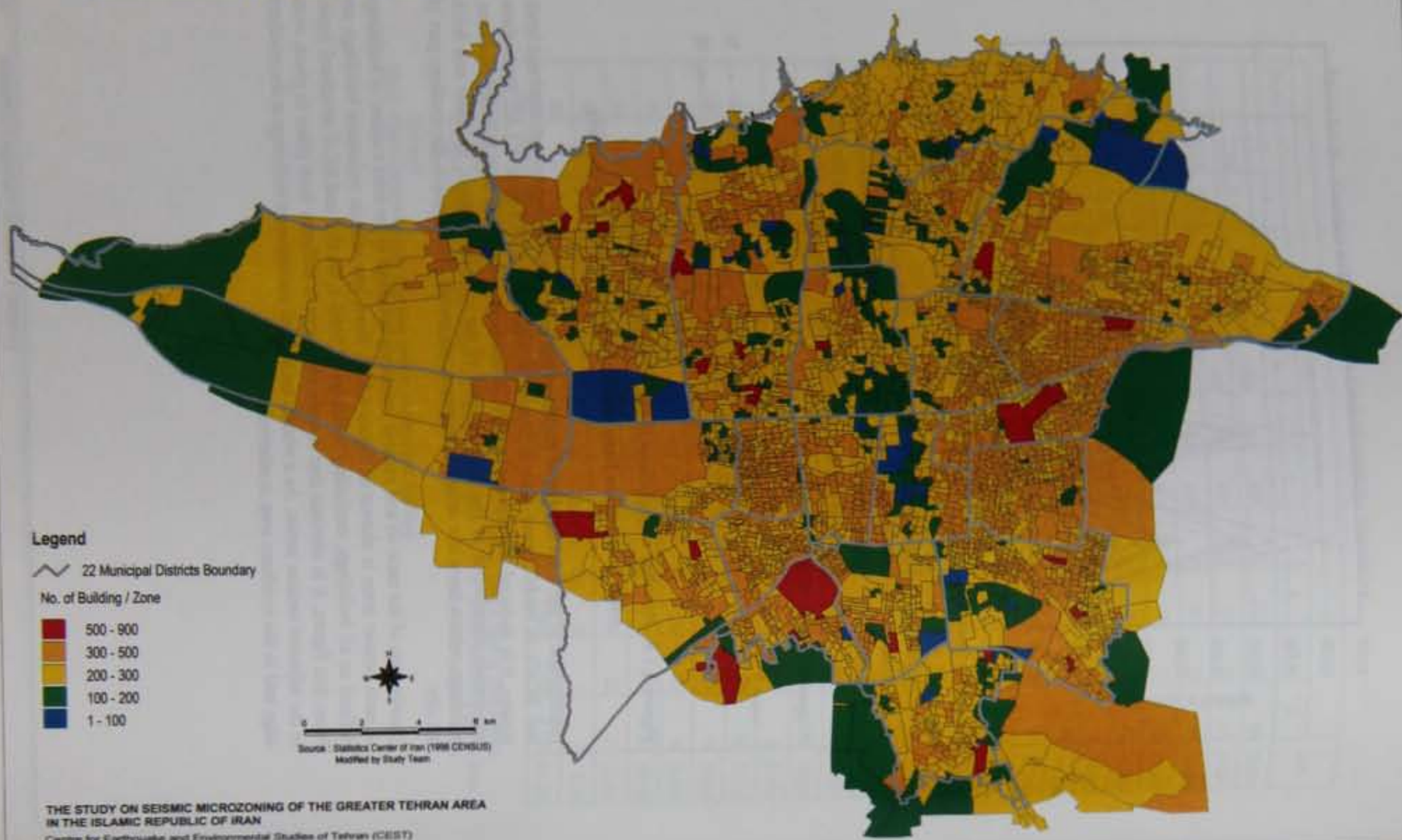
Figure 4.1.8 Number of Buildings in Each District by Structure After Conversion from Dwelling Unit to Residential Building

Distribution of the total number of buildings and each structural type (steel, steel and brick and RC-0) in each census zone is shown in Figure 4.1.9 to Figure 4.1.12. From these figures, it is deduced that the steel and RC-0 buildings, which have high seismic resistance, are mainly distributed in the northern part of the city. In addition, the steel and brick buildings, which have low seismic resistance, are mainly distributed in the southern part of the city.

Distribution of the ratio of low seismic resistance buildings to the total number of buildings in each census zone is shown in Figure 4.1.13. Here, low seismic resistance buildings are defined as all buildings, excluding buildings of Steel-1, Steel-2 and RC-0 structural types. From this figure, it is obvious that seismic resistance is different from place to place, even in the adjacent census zones. As a whole, the seismic resistance of buildings at the northern edge and in the southern area is relatively low.

Figure 4.1.9

Building Distribution by Structure (Total)



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA
IN THE ISLAMIC REPUBLIC OF IRAN

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Figure 4.1.10

Building Distribution by Structure (Steel Frame)

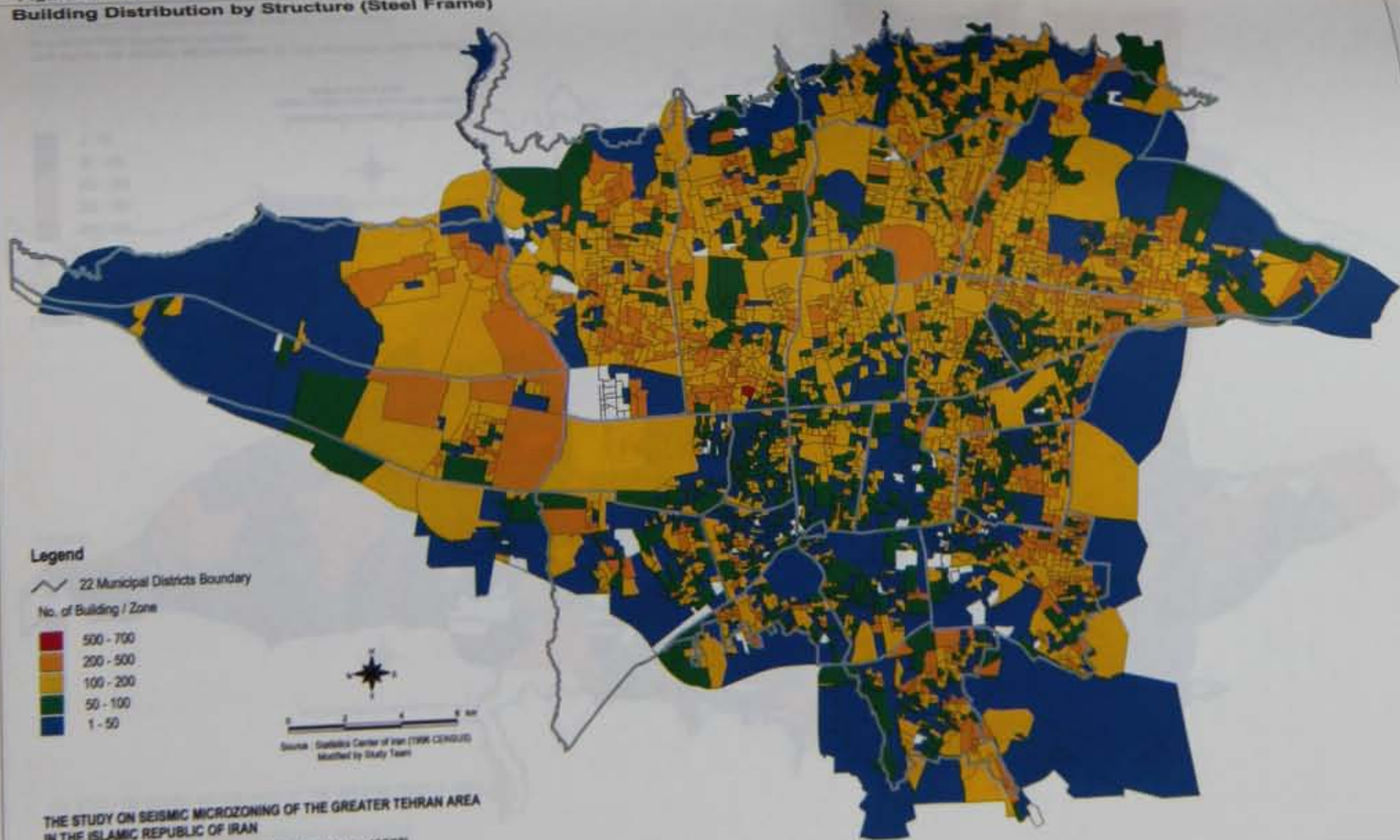

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Figure 4.1.11

Building Distribution by Structure (Steel & Brick)

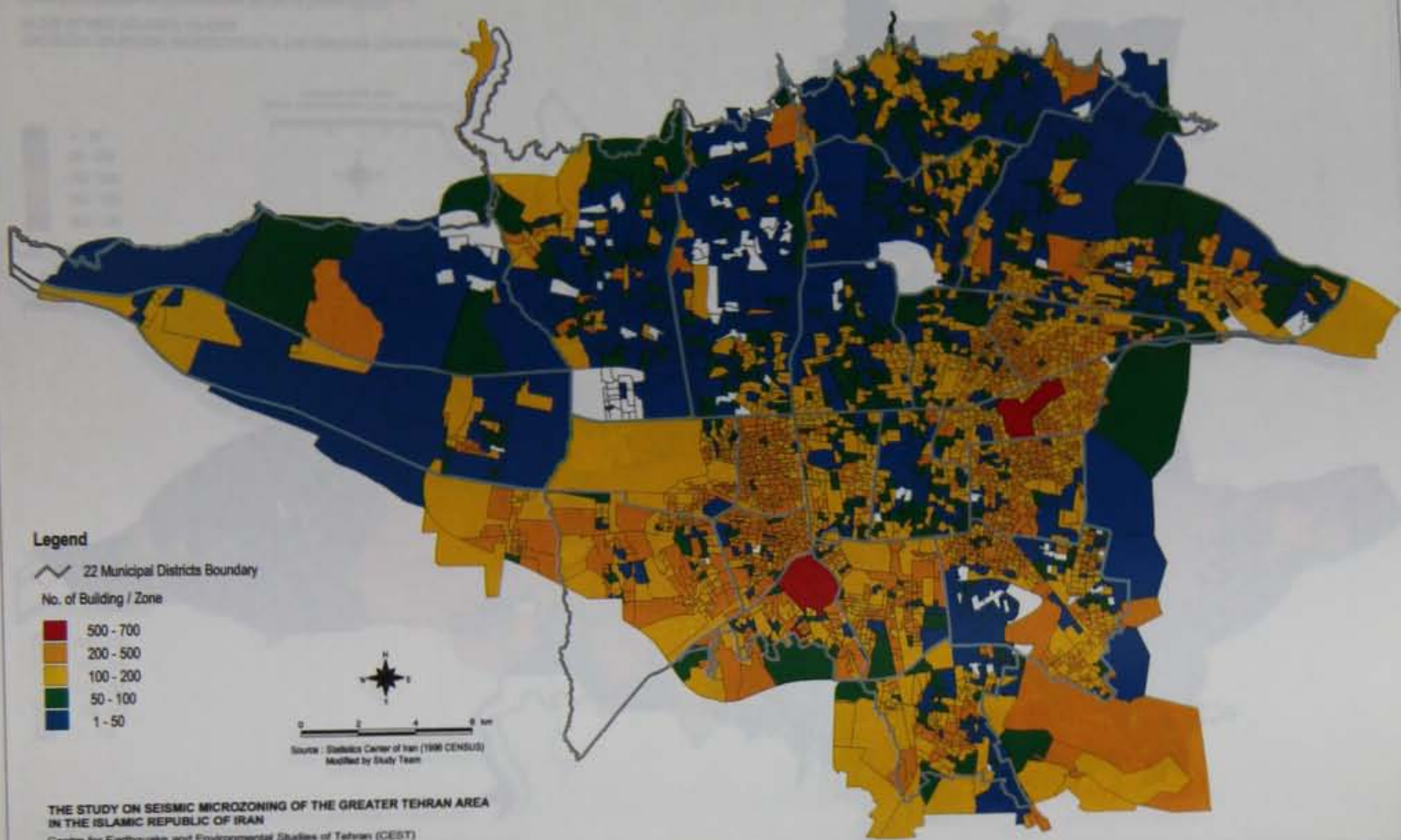

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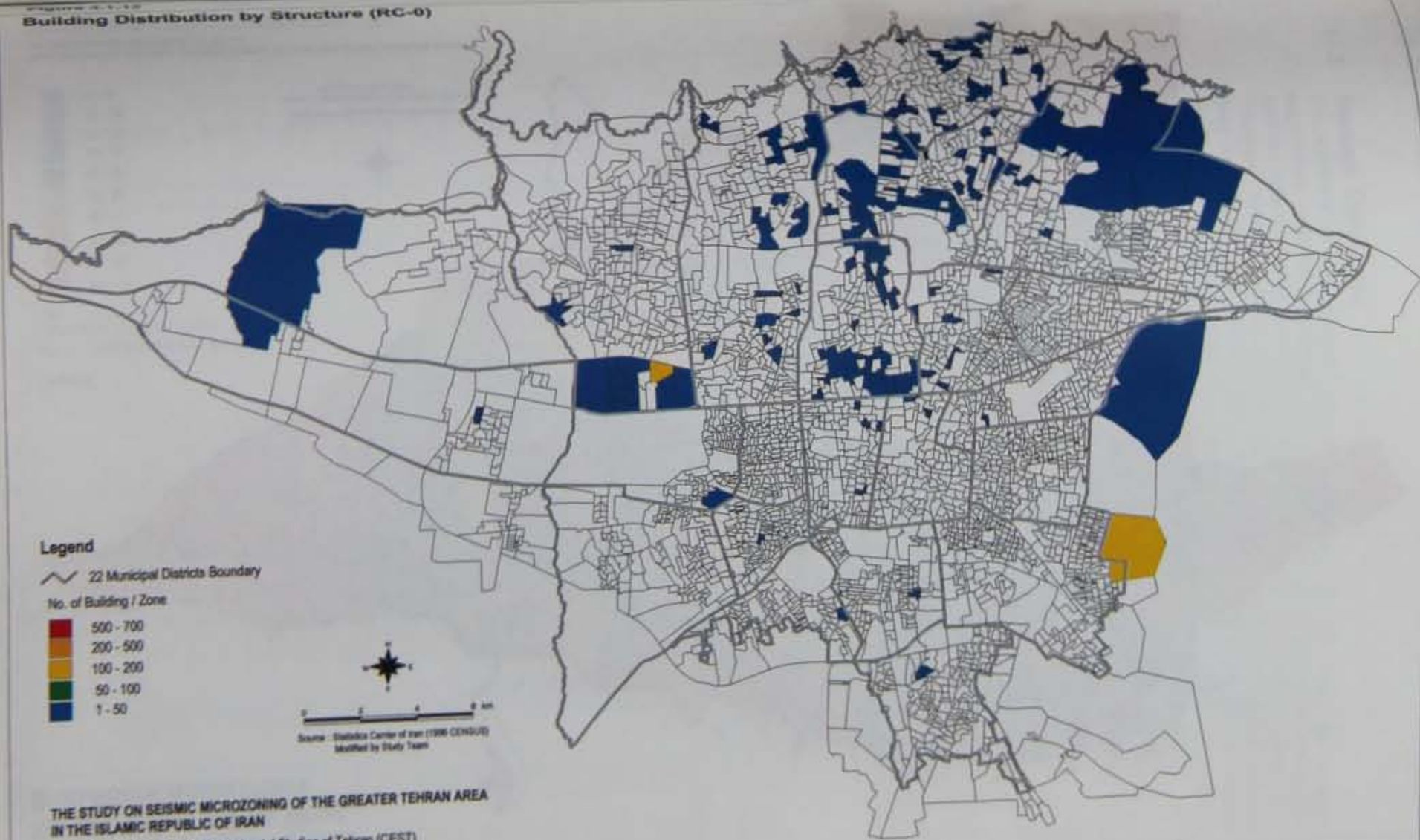
Figure 4.1.12

Building Distribution by Structure (RC-0)



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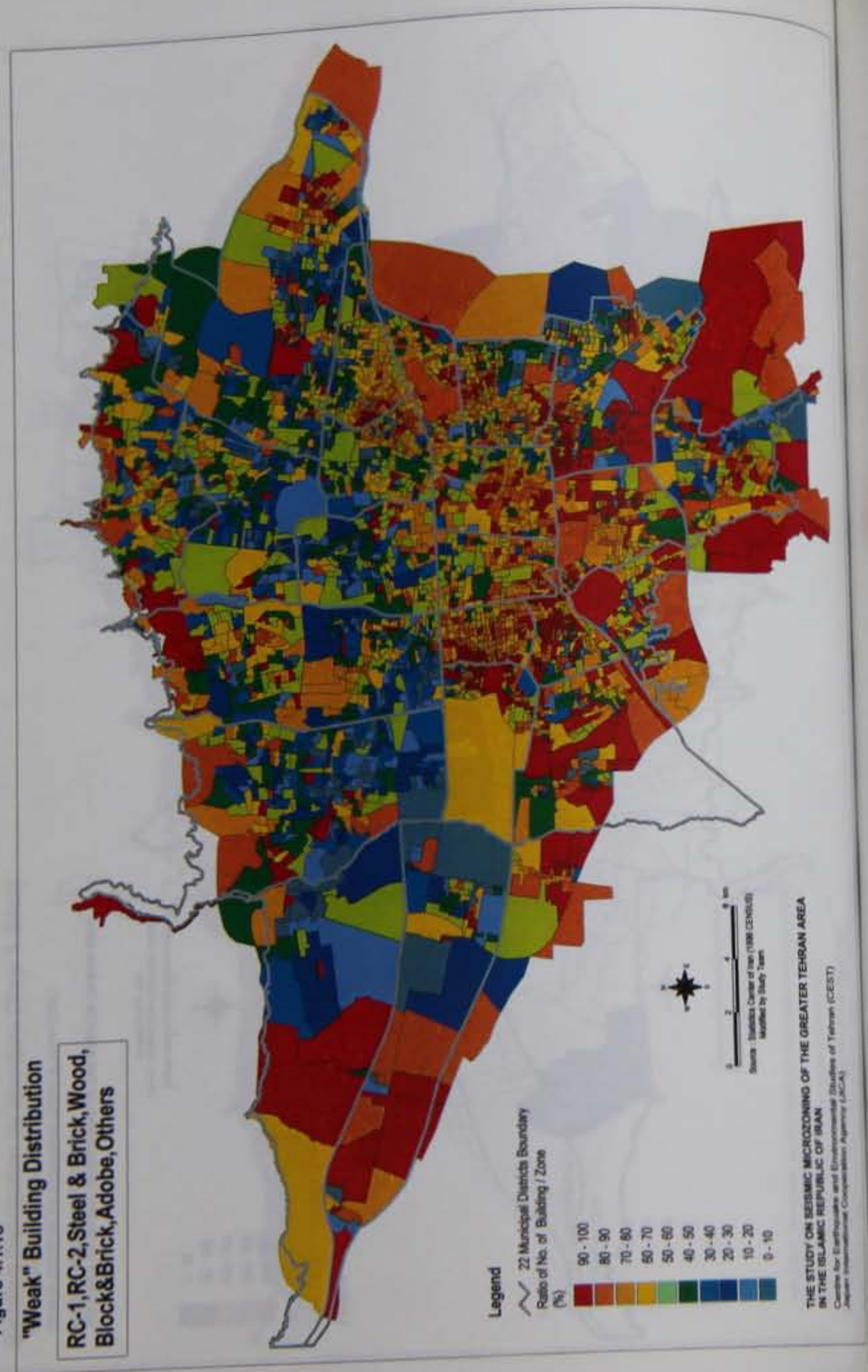

Figure 4.1.13

4.1.3. Damage Estimation

The residential building damages were calculated for 4 scenario earthquakes. In these calculations, commercial buildings and factories were not included. Important public facilities such as schools, hospitals and fire fighting stations are studied in section 4.4.1. 'Damaged' buildings implies that buildings are heavily damaged or collapsed and that these are unfit for living without proper repair. Further, the cause of the damage is limited to the seismic vibration itself. The damages caused by secondary disasters such as liquefaction, landslides, fire and explosions are not included in this calculation.

The definition and contents of damage for residential buildings are as follows:

Damage of residential buildings	Heavily damaged or collapsed, unfit for living without repair
Calculation unit	Each residential building
Cause of damage	Seismic vibration

The damages were calculated for each census zone and structural type. Results are shown in Table 4.1.3 and Figure 4.1.14. It must be noted that the total number of buildings in Table 4.1.3 does not correspond with that of the inventory data since some census zones are located outside of the boundary of Tehran's 22 districts. These data were excluded from Table 4.1.3. Further, there was not enough data on some buildings for the damage estimation. These were also excluded.

Table 4.1.3 Damage of Residential Buildings by District

District	Ray Fault Model		NTF Model		Mosha Fault Model		Floating Model		Total Number of Buildings
	Number	Ratio %	Number	Ratio %	Number	Ratio %	Number	Ratio %	
1	11,665	30.4	23,633	61.6	6,869	17.9	19,905	51.9	38,365
2	26,980	41.3	29,862	45.7	7,248	11.1	33,617	51.5	65,335
3	13,974	40.5	19,231	55.7	5,656	16.4	20,928	60.6	34,513
4	23,060	28.0	31,697	38.5	11,328	13.8	37,296	45.3	82,320
5	18,996	35.8	25,111	47.3	4,553	8.6	25,345	47.7	53,083
6	13,842	45.0	10,884	35.4	3,894	12.7	13,997	45.5	30,741
7	23,061	51.4	15,585	34.7	5,712	12.7	21,116	47.0	44,892
8	26,115	51.4	17,092	33.6	5,631	11.1	23,737	46.7	50,798
9	11,936	58.2	5,559	27.1	1,759	8.6	10,621	51.8	20,514
10	27,450	68.1	12,382	30.7	4,014	10.0	22,502	55.8	40,329
11	25,920	78.6	12,818	38.9	6,316	19.1	19,643	59.5	32,991
12	22,118	77.1	14,115	49.2	9,056	31.6	19,418	67.7	28,691
13	17,958	50.8	10,423	29.5	4,295	12.2	17,123	48.5	35,332
14	31,484	57.6	14,653	26.8	7,197	13.2	27,969	51.2	54,636
15	48,707	65.7	19,141	25.8	9,057	12.2	35,985	48.5	74,159
16	27,673	77.2	10,812	30.2	5,248	14.6	19,920	55.6	35,845
17	28,025	82.2	10,086	29.6	4,288	12.6	19,235	56.4	34,078
18	27,446	77.5	8,942	25.3	3,618	10.2	18,437	52.1	35,399
19	18,437	75.0	4,817	19.6	1,669	6.8	10,381	42.2	24,578
20	29,306	78.6	8,379	22.5	4,121	11.1	18,887	50.6	37,295
21	7,009	46.9	4,944	33.1	1,148	7.7	6,857	45.9	14,931
22	2,051	30.7	2,785	41.7	456	6.8	3,039	45.5	6,684
Sum	483,212	55.2	312,951	35.7	113,132	12.9	445,958	50.9	875,509

Characteristics of damage for the four earthquake models are as follows:

Ray Fault Model

The total number of damaged buildings is estimated as 480,000 in the entire city of Tehran. The total damage ratio is 55%. It should be noted that the number of damaged buildings in District 15 is the largest. The total number of the buildings is also largest in this district. The damage ratio in Districts 11, 12, 16 to 20 is a very high value of approximately 80%. The reason for this high damage ratio is the existence of many vulnerable buildings and the strong seismic motion, MMI = 9, in these Districts. The damage ratio in Districts 1 to 5, located in the northern part of the Tehran, is relatively small, approximately 30%.

NTF Model

The total number of damaged buildings is estimated as 310,000 in the entire city of Tehran. The total damage ratio is 36%. The damage ratio in Districts 1 to 5, located in the northern part of the city, is approximately 50%. The damage ratio of the southern part of the city is less than 30%. The difference in damage between the south and the north is not as big as observed in the Ray Fault Model. In the case of the NTF model, seismic intensity is high in the northern area, where vulnerable buildings are not prevalent. In the case of the Ray Fault Model, seismic intensity is high in the southern area, where vulnerable buildings are prevalent. This is the reason for the difference in the damage ratios of the northern and southern parts of the city.

Mosha Fault Model

The damage ratio for most of the districts is almost 10% except in the case of District 12. The damage ratio of District 12 is approximately 30%. As shown in Table 4.1.2, the number of vulnerable 'adobe' or 'wood and brick' structures in District 12 is higher than in other districts and it is the reason for its high damage ratio. This tendency is also observed in the results of Floating Model.

Floating Model

A uniform input motion on the seismic bedrock for the entire Study Area is hypothesised for the calculations of the Floating Model. Therefore, this calculation does not reflect a specific earthquake and the results indicate a relative vulnerability in the entire Study Area. The damage ratio of Districts 12 and 3 is relatively high. The major reason for the high damage ratio in these districts is that relatively soft soil is deposited in these areas and the seismic motion is amplified by this soil.

The distribution of the number of damaged buildings in each census zone is shown in Figure 4.1.15 to Figure 4.1.18, for each scenario earthquake. As for the Ray Fault Model, a big disaster, with damaged buildings exceeding 200 in each census zone, is estimated for a wide area of the southern part of the city. For the NTF Model, location of census zones where the number of damaged building exceeds 200, is limited only to the northern edge of the city. For the Mosha Fault Model, damages are relatively small for the whole city. In southern zones of Districts 11 and 12, the number of damaged buildings exceeds 100.

The distributions of the damage ratio for each census zone are shown in Figure 4.1.19 to Figure 4.1.22. Above-mentioned characteristics are obvious. In the case of the Ray Fault Model, zones with a very high damage ratio, more than 80%, are widely distributed in the southern part of the city. In the case of the NTF model, zones with a very high damage ratio are observed but limited. The high damage zones of Districts 12 and 15 under the NTF Model are the zones where the proportion of 'adobe' building structures is about 80%.

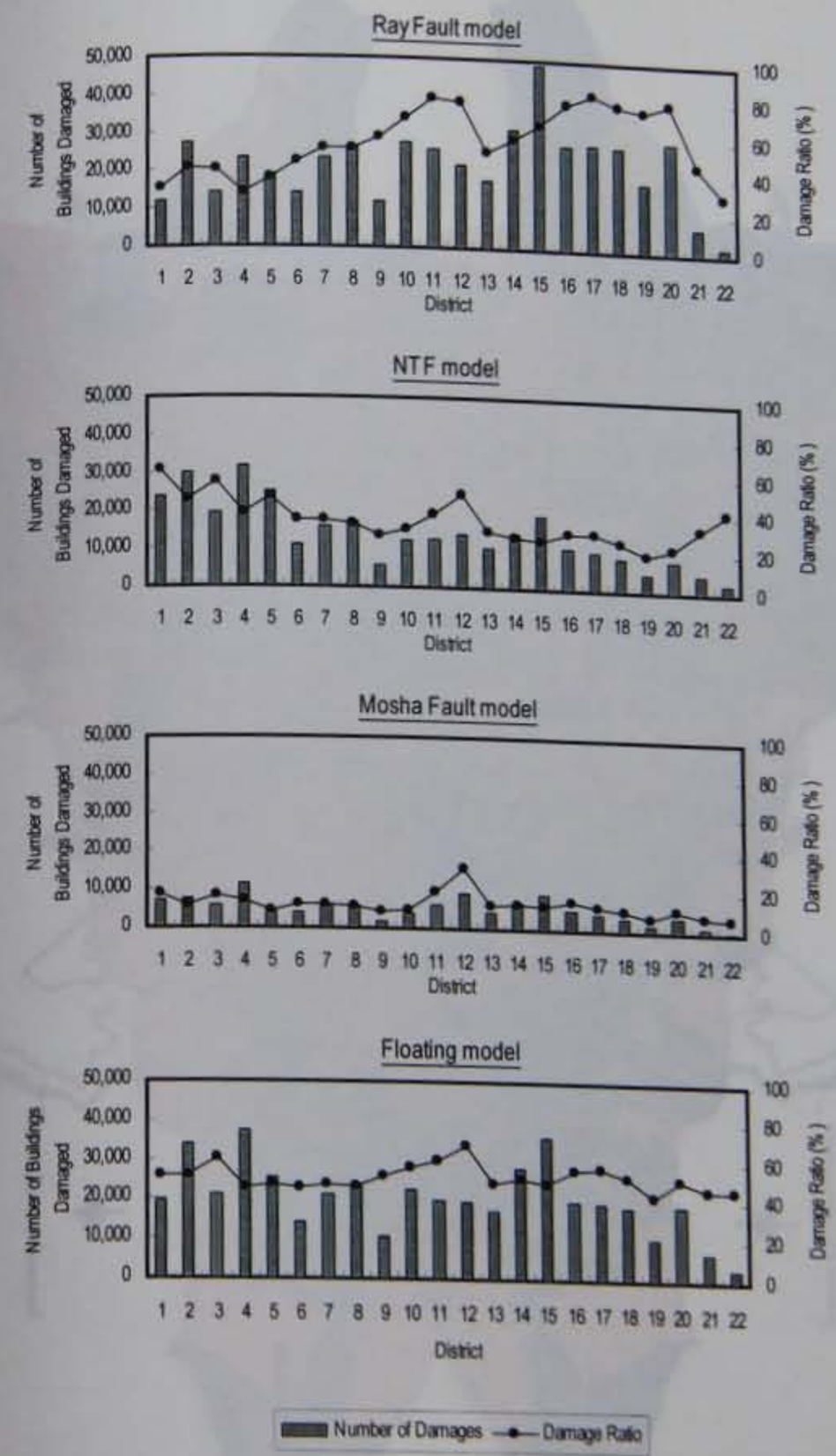

Figure 4.1.14 Damage of Residential Buildings by District

Figure 4.1.15

Heavily Damaged or Collapsed Building Number Distribution (Ray Fault model)

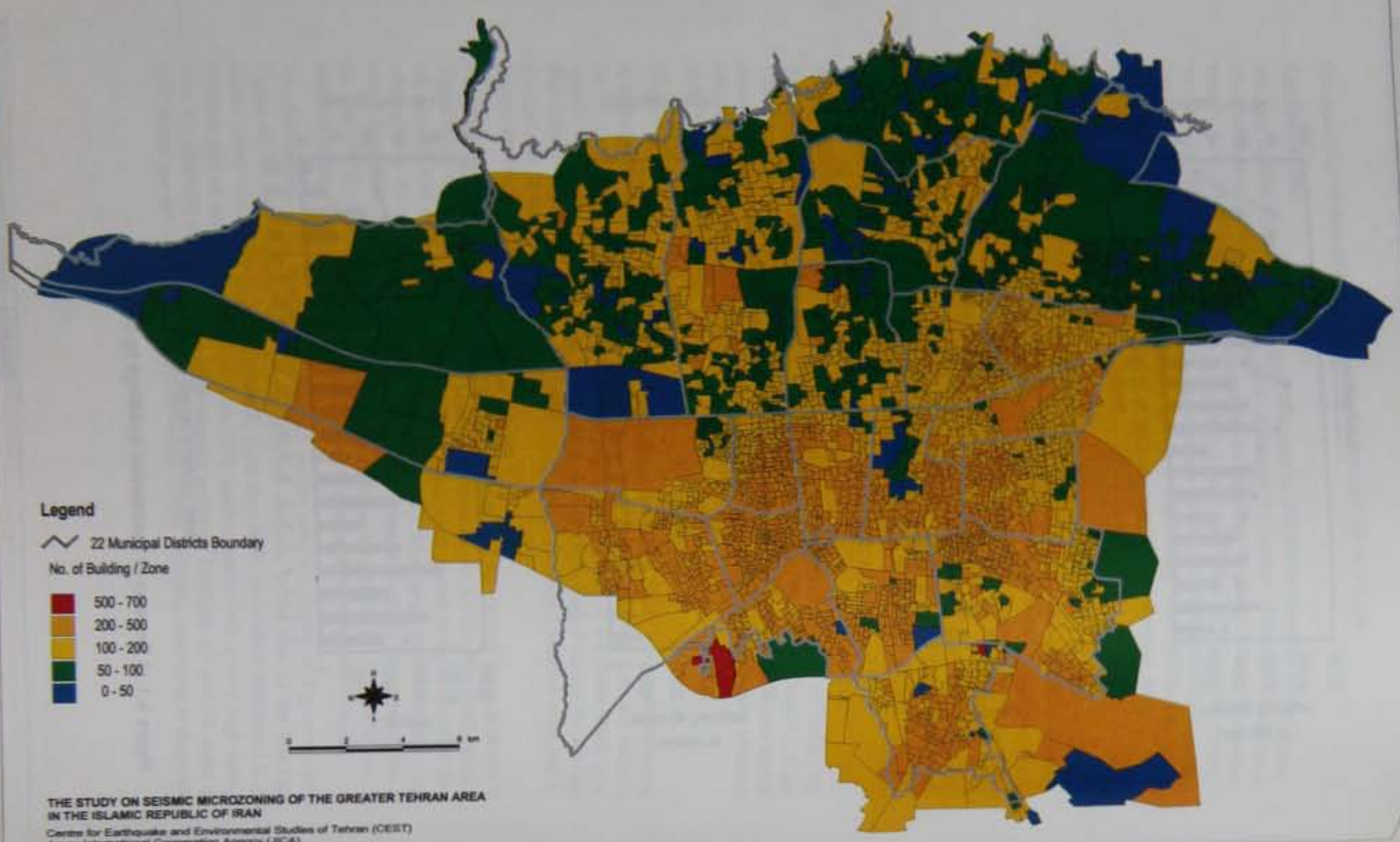

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Figure 4.1.16

Heavily Damaged or Collapsed Building Number Distribution (NTF model)

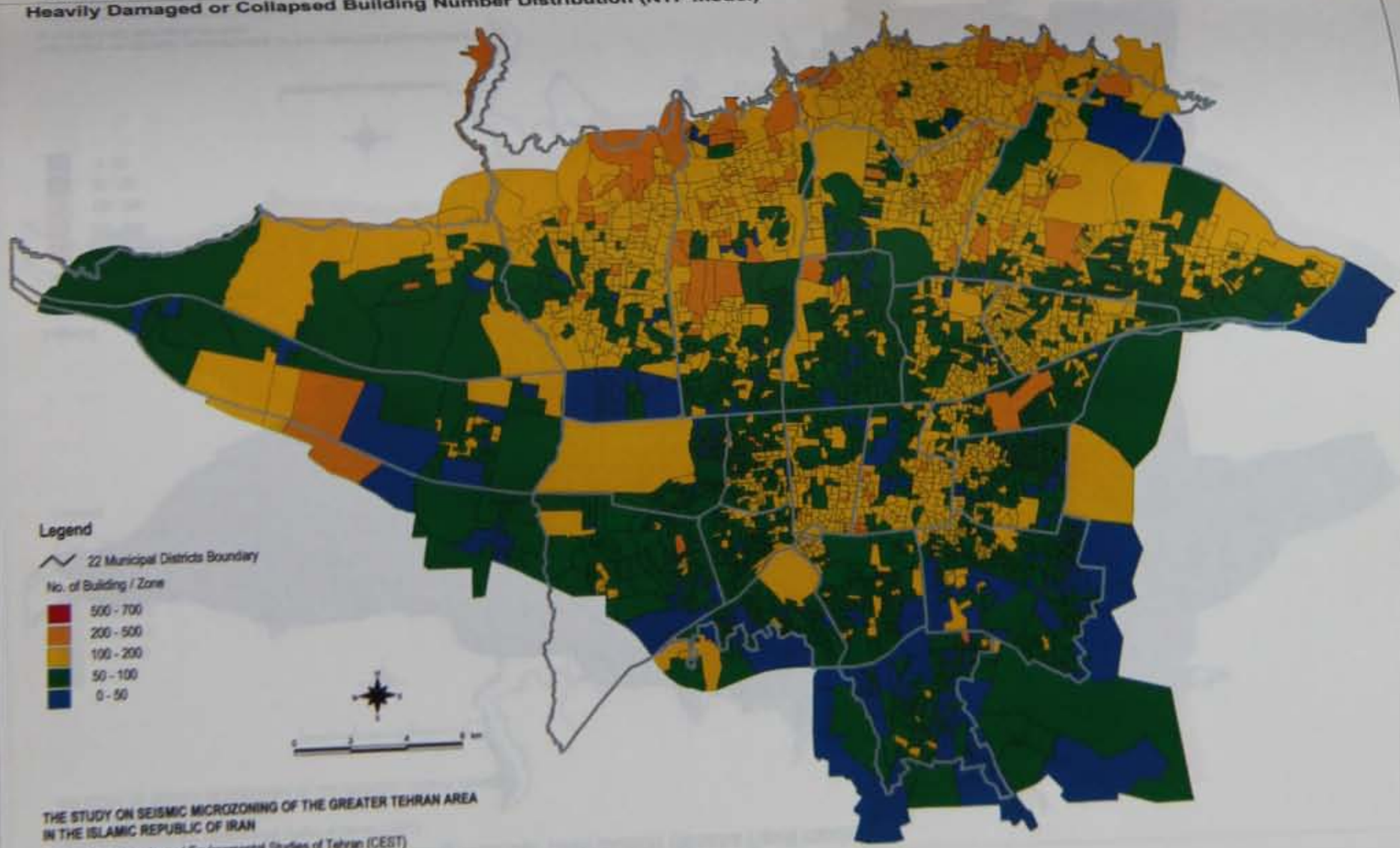

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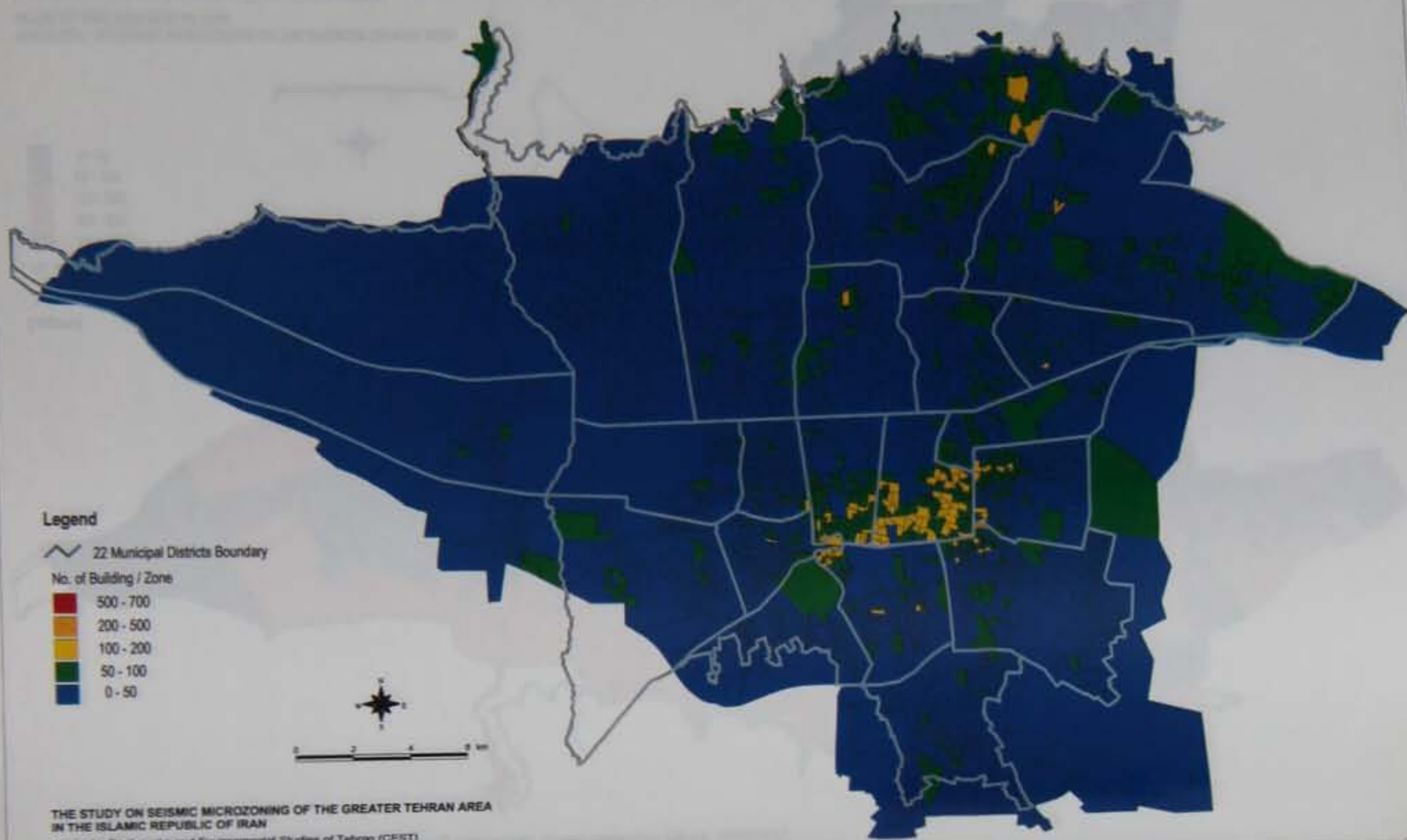
Figure 4.1.17

Heavily Damaged or Collapsed Building Number Distribution (Mosha Fault model)



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Heavily Damaged or Collapsed Building Number Distribution (Floating model)

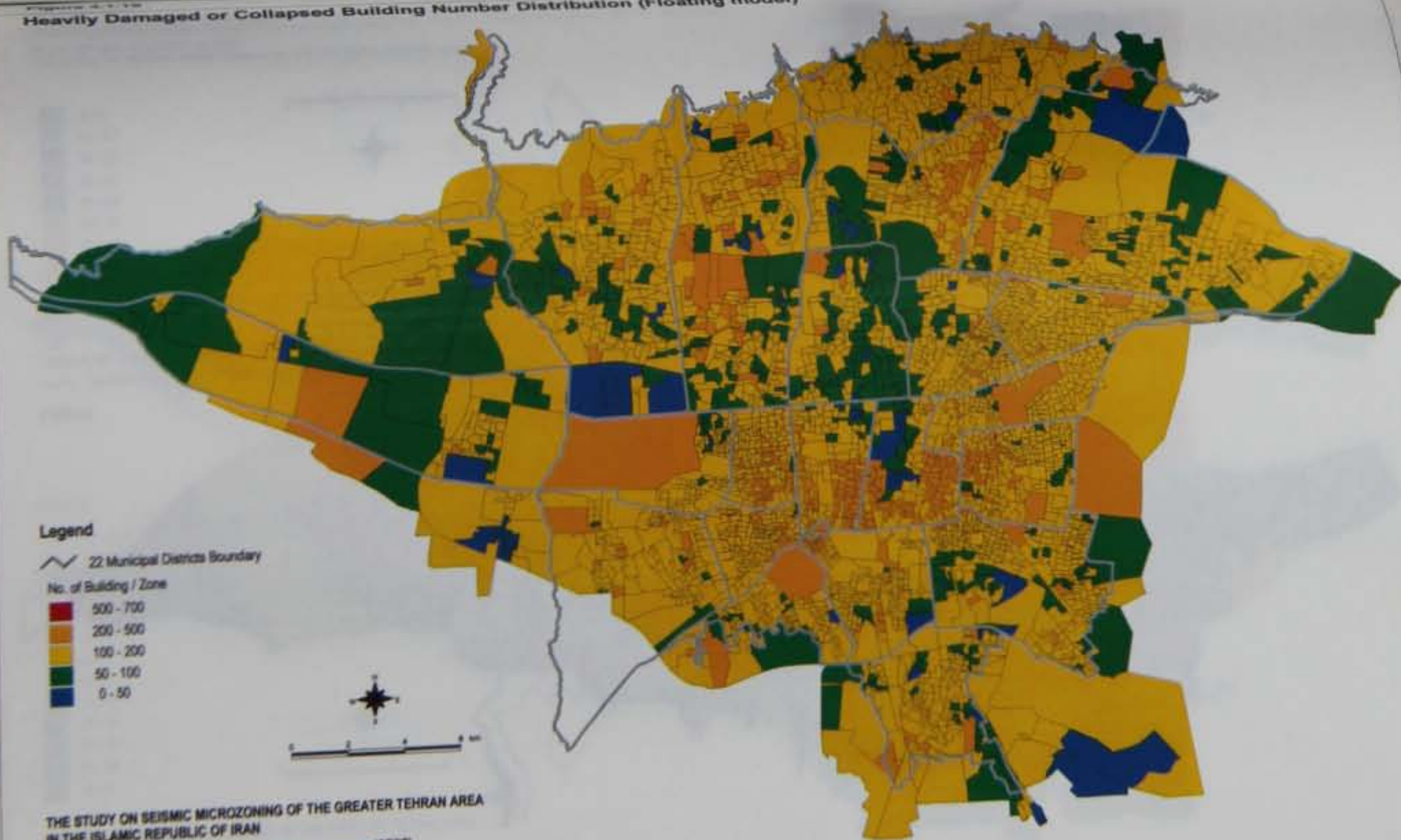

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Figure 4.1.19

Heavily Damaged or Collapsed Building Ratio Distribution (Ray Fault model)

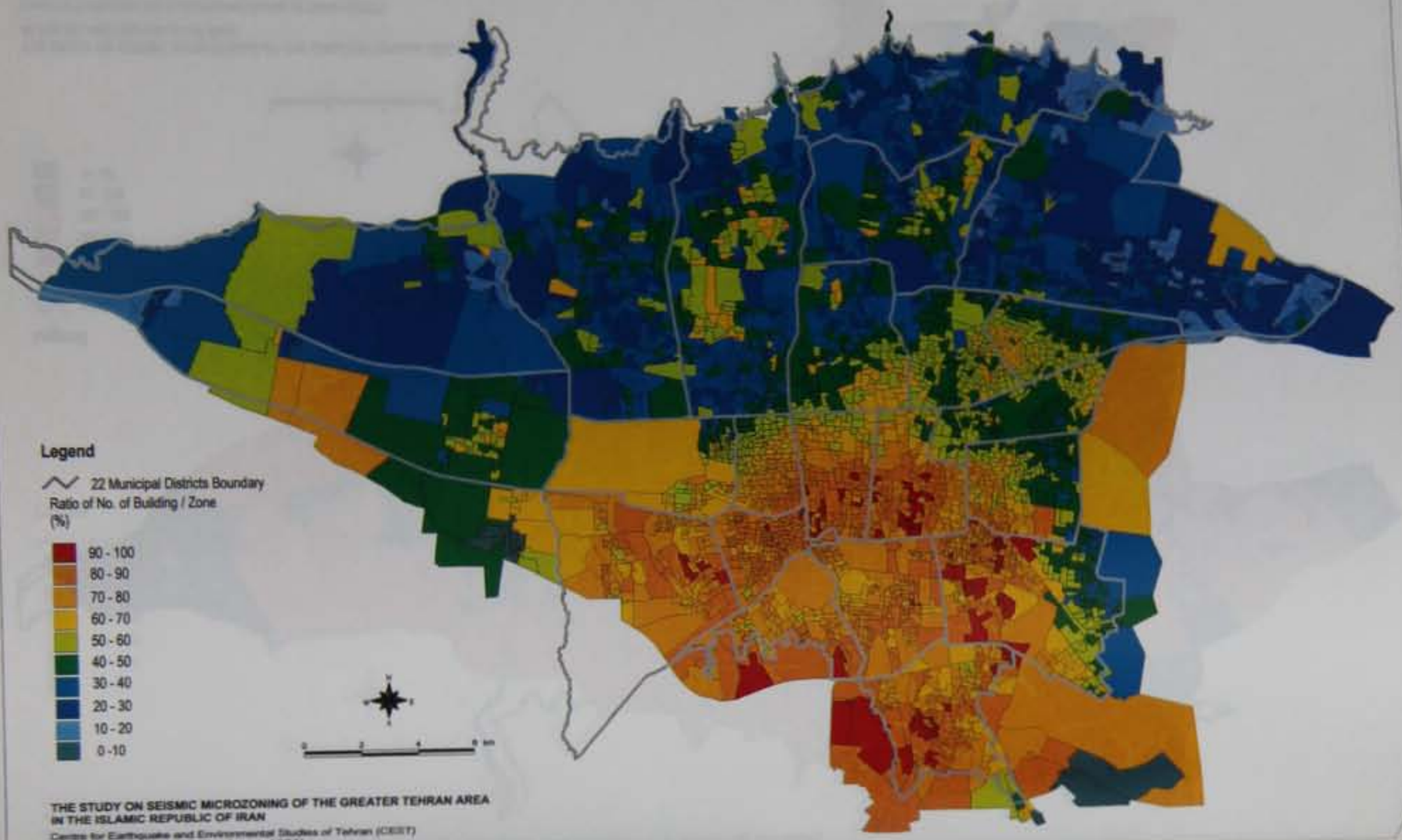

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Figure 4.1.20

Heavily Damaged or Collapsed Building Ratio Distribution (NTF model)

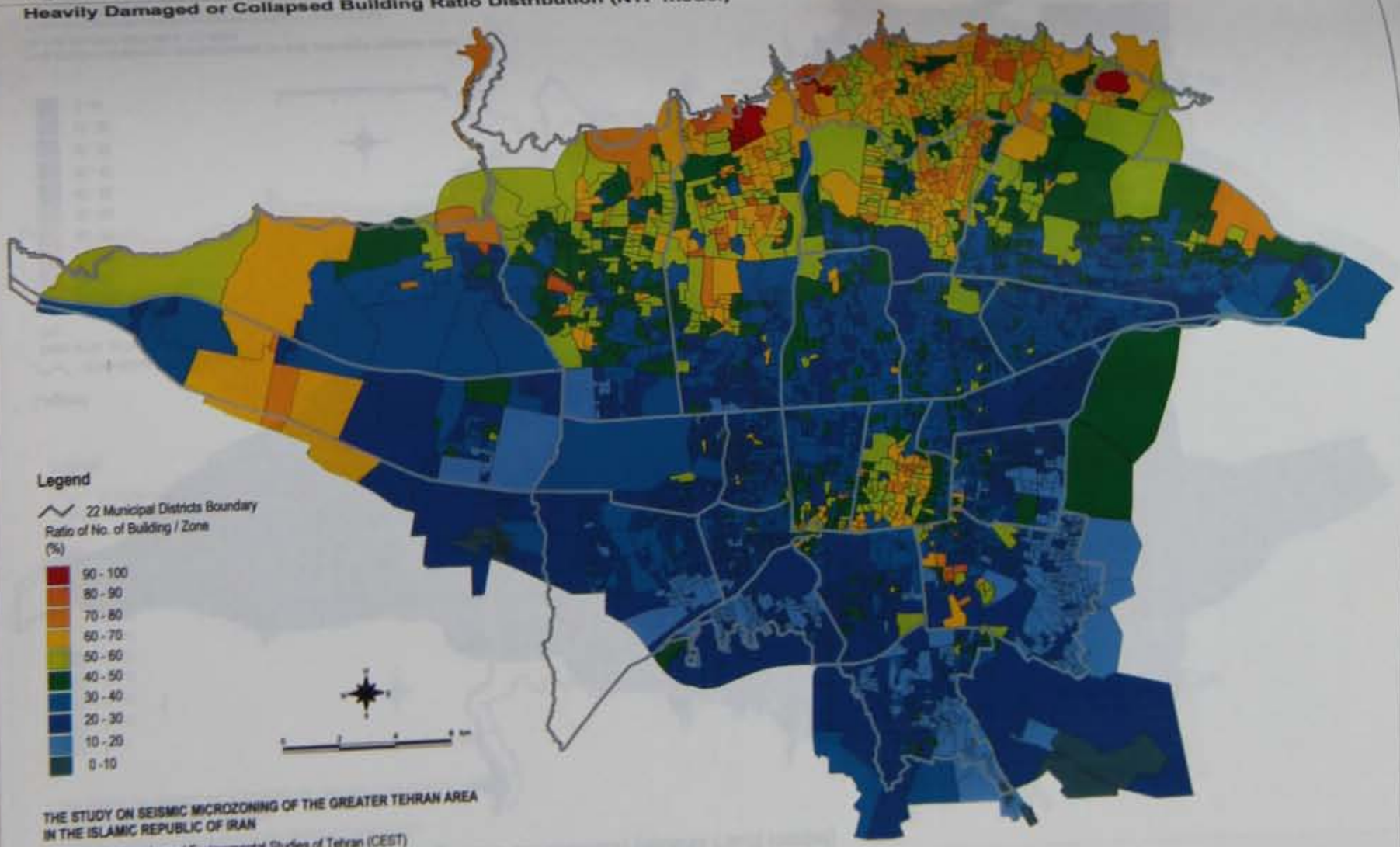

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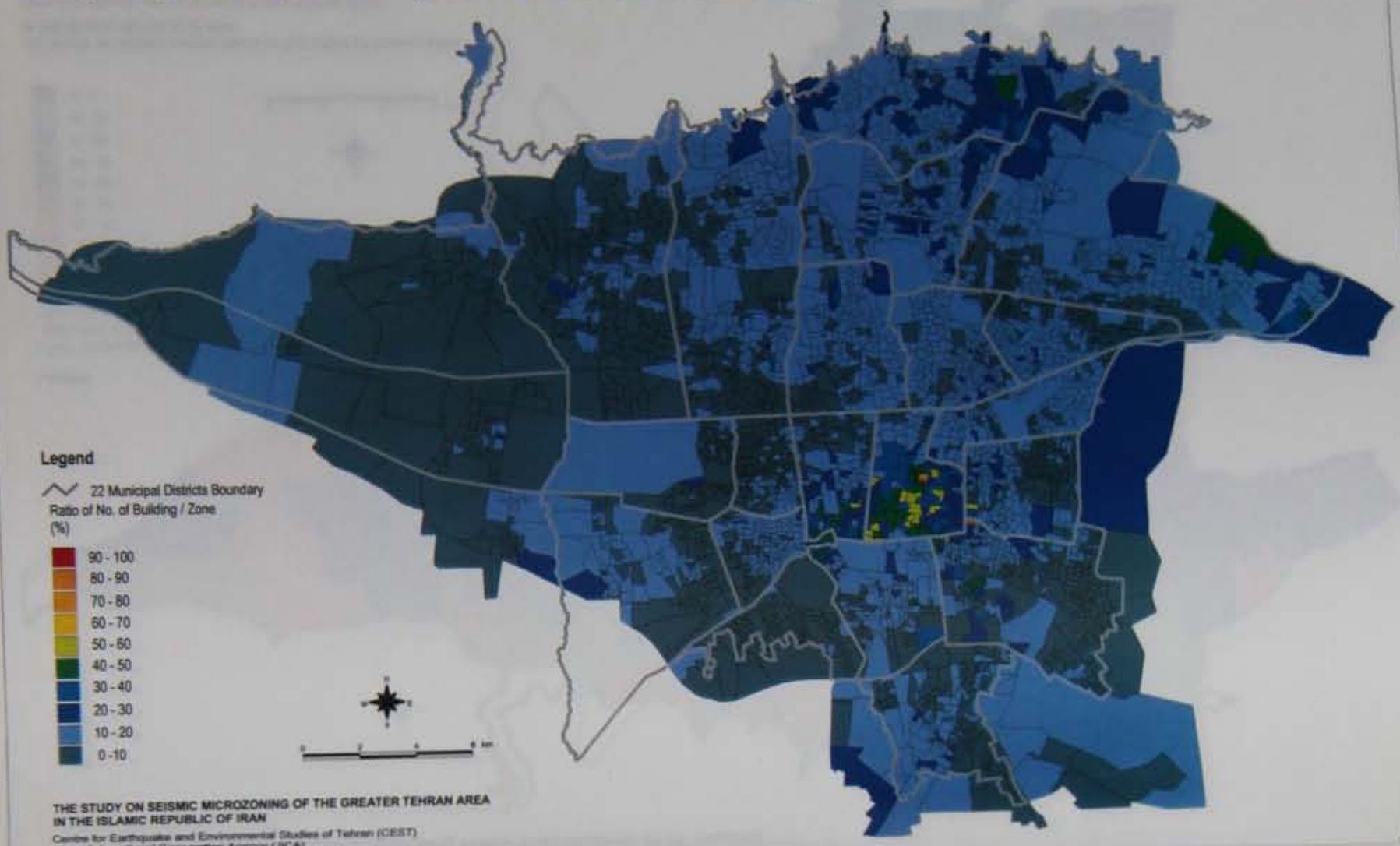
Figure 4.1.21

Heavily Damaged or Collapsed Building Ratio Distribution (Mosha Fault model)



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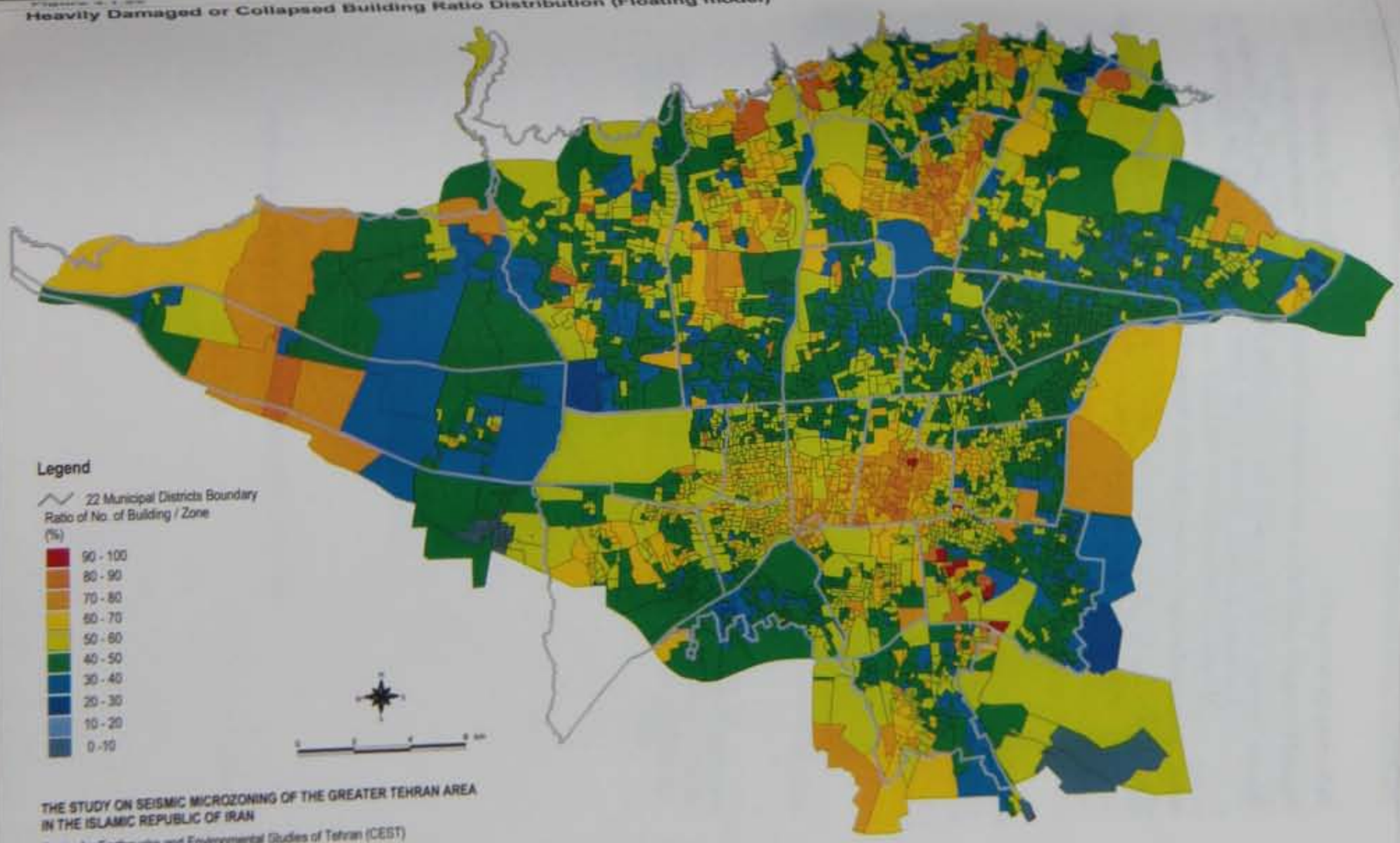
Heavily Damaged or Collapsed Building Ratio Distribution (Floating model)



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M5: Post-collapse mortality (ratio of the injured that subsequently die before they can be rescued)

The coefficient of Coburn et al.(1992) was adjusted to satisfy the relationship between the seismic intensity (MMI) and the death ratio in past earthquake damages in Iran.

The building structures were categorised into the following eight types, considering building properties:

1) Adobe
2) Block and brick
3) All wood
4) RC-2
5) RC-1
6) Brick and steel
7) Steel-2
8) Steel-1, RC-0

Emergency rescue activities were defined as the following four cases:

1) No rescue
2) Community rescue

   People who were not trapped rescue nearby trapped inhabitants.

   Hands or simple tools are used.

3) Community + emergency squads

   In addition to the community rescue, the Red Crescent Society and the fire fighting teams join the rescue activities. Systematic operations with devices such as jackhammers and chainsaws are undertaken.

4) Community + emergency squads + experts

   In addition to the above-mentioned operations, experts and emergency rescue squads coming from other areas, including foreign countries, join the rescue operations. Fiberscopes, rescue dogs and other special measures are used.

(3) Death Ratios of Past Disastrous Iranian Earthquakes

The relationship between seismic intensity (MMI) and the death ratio for earthquake damage in Iran was reviewed in order to establish a damage function. The review was carried out by CEST. The data of six earthquakes is shown in Table 4.2.1. Two earthquakes occurred during the day, when workers and students were absent from their homes. The other four earthquakes occurred in the early morning or during the night, when almost all residents were in their homes. Figure 4.2.3 shows the relationship between seismic intensity (MMI) and the death ratio at different times. Very few people died in case of MMI 6 or less. The death ratio in case of MMI 8 was 10% and less. The death ratio suddenly increases in the case of MMI 9 or over. It differs widely depending on the individual earthquakes. There is a distinct difference in death ratio in case of daytime or night-time earthquakes. It is considered that many people were outside their residential buildings and/or many people were in office buildings with stronger anti-seismic structures during the daytime. In addition, the number of people who are trapped under collapsed buildings increases according to intensity of earthquake, unless they could escape from the

buildings within a short time after the occurrence of the earthquake. Furthermore, quick escape is difficult during the night-time because many people are asleep, and this leads to an increased death ratio.

Figure 4.2.4 shows the relationship between the death ratio at night-time and in the daytime. The data is given in Figure 4.2.3. The death ratio in the daytime is about one fourth (0.25) of that of night-time for MMI 10. These results were derived from past damage experiences and the effects of movements of the population and other variables were not considered. In this Study, the human casualties in the daytime were estimated from casualties at night-time, by applying the relationship shown in Figure 4.2.4 as an index.

Table 4.2.1 Death Ratio by Earthquake in Iran

Earthquake	Ghir		Tabas			Golbaft		Sirch		Manjil		Ardekul	
Year	1972		1978			1981		1981		1990		1997	
Time	6:36		20:06			11:54		21:52		1:30		12:27	
Daytime / Night-time	Night-time		Night-time			Daytime		Night-time		Night-time		Daytime	
Major Structure	Adobe, Masonry					Adobe		Adobe				Adobe, Masonry	
	MMI	Death	MMI	Death	Injured	MMI	Death	MMI	Death	MMI	Death	MMI	Death
Data For Each Village	9	67.1	10	84.3	3.8	7	9.2	9	57.1	6	0.795	10	2.7
	9	20.4	9	42.8	4.2			9	32.1	6	0.103	10	13.4
			9	19.2	4.0			8	9.8	6	0.0	9	23.1
			8	8.7	3.9			8	2.1	9	90.0	10	45.5
								7	0.08	10	90.0	8	6.5
								7	0.8	7	9.0	8	11.0
										10	66.7	8	1.7
										8	13.3	7	5.8
												8	3.0

MMI: Seismic Intensity, Death: Death Ratio (%), Injured: Injured Ratio (%)

Source:
Ghir: Ghir Earthquake of 10 April 1992, Ambraysys, N.N., A.A. Moinfar and J.S.Tchalenko, UNESCO, Serial No. 2789/RMO. RD/SCE
Tabas: Berberian, M., 1979a, 1979b, 1979c, B.S.S.A., No.69
Golbaft: Hojjat Adeli: The Sirch(Kerman, Iran) Earthquake of 28 July 1981 - A Field Investigation, B.S.S.A., Vol. 72, No. 3, 1982
Sirch: Hojjat Adeli: The Sirch(Kerman, Iran) Earthquake of 28 July 1981 - A Field Investigation, B.S.S.A., Vol. 72, No. 3, 1982
Manjil: Tsukuda, T. et al.: A Field Study on Variou Phenomena Associated with the 1990 Rudbar, Northwest Iran, Earthquake of M7.3, B.E.R.I., Vol.66, 1991.
Ardekul: Zirkouh (Ghaenat) Earthquake of May 10th, 1997, BHRC Report #255.

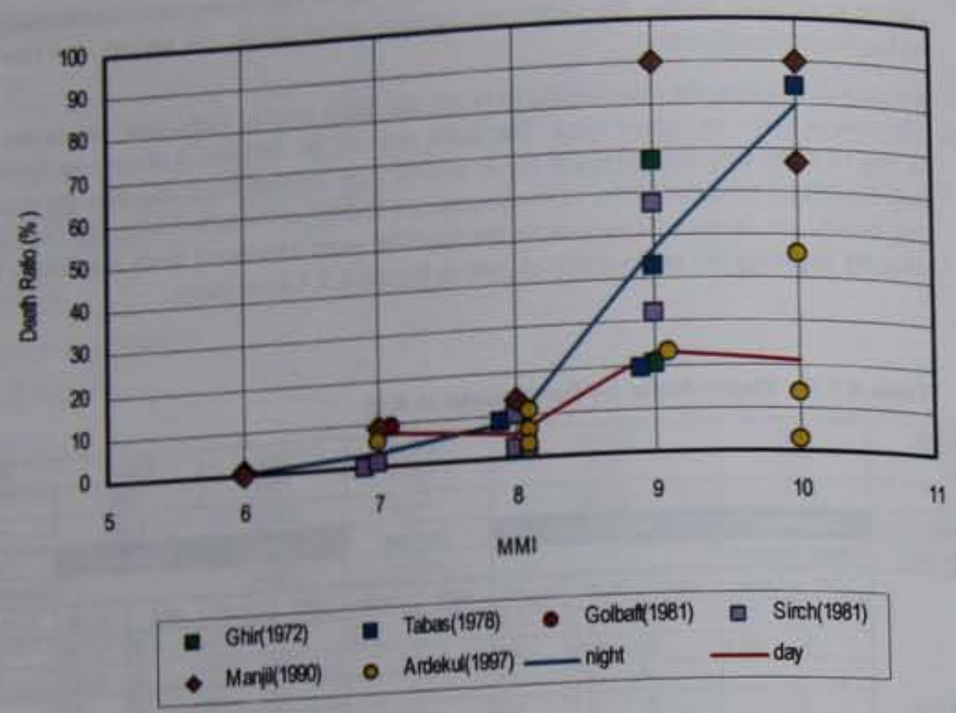

Figure 4.2.3 Death Ratio by Earthquake in Iran

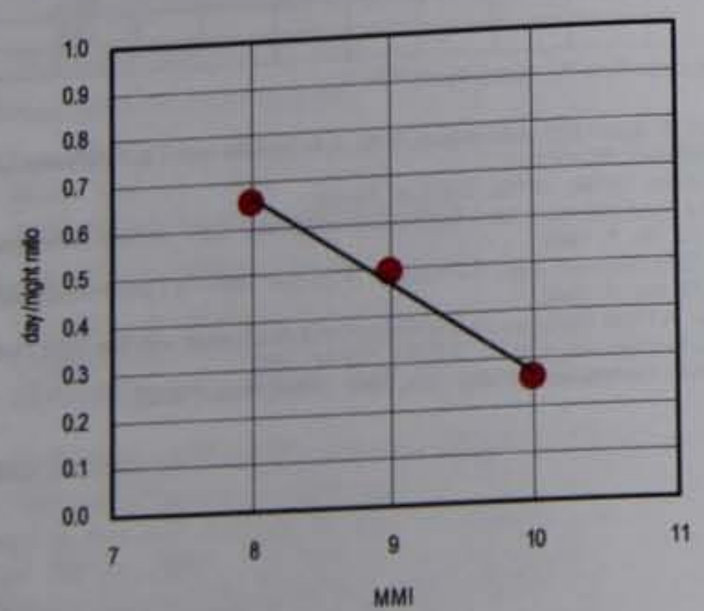

Figure 4.2.4 Daytime/Night-time Ratio for Number of Dead

(4) Parameter Setting of M3, M4d, M5

The coefficients of Coburn were modified to satisfy the relationship between the death ratio and seismic intensity (MMI) for cases of earthquake damage during the night-time in Iran (refer to Table 4.2.1). Since the damaged structures and their distribution ratio are not identified, by taking into account the local characteristics, it was assumed that three types of structures (adobe, block and brick, and brick and steel) were evenly distributed. Figure 4.2.5 shows the relationship between seismic intensity and the death ratio of earthquake damages in Iran, together with those of the established death ratio functions and those of Coburn et al. (1992). The established death ratio functions are average values for the cases of adobe, block and brick, and brick and steel structures. They consist of four types of emergency rescue activities.

In case of relatively strong structures, i.e., RC-0 and Steel-1, the death ratio function was determined in the following way:

- Preparation of relationship between damage ratio and death ratio on relatively older RC structures in Japan (Figure 4.2.6);
- Correction of the death ratio function based upon the actual damage ratio of RC-0 structures (Japan ratio x 1); and
- Correction of the death ratio function considering the effect of the difference in wall materials, as double the above function (Japan ratio x 2).

The items considered for the adjustments of the coefficients are the following:

M3: Number of occupants trapped by collapsed buildings

- Adobe structures break into pieces and generate dust of adobe upon collapsing, which prevent the formation of space, thus increasing the rate of entrapment.
- Block and brick structures are better than adobe structures. However, block and brick structures have less number of beams, which prevents space formation, thus also increasing the rate of entrapment.
- Wood, RC, and brick and steel structures offer possibilities of escape, owing to the formation of space by beams.
- Steel structures should provide much more space, due to the use of lots of steel skeletons.
- RC-0 and Steel-1 structures form space by the bracing and wall materials, thus providing a higher rate of escape.

M4d: Death ratio at 0-hrs after the collapse of buildings

- Adobe structures induce death by suffocation under collapsed roofs and walls.
- Block and brick and brick and steel structures also yield high death ratios from suffocation under collapsed bricks.
- Wood, RC, and steel structures form space, which results in less suffocation and a smaller ratio of instantaneous death.
- RC-0 and Steel-1 structures give a very low ratio of instantaneous death.

M5a: Post-collapse mortality with no rescue operations

- In case of absence of rescue, 95% of the entrapped people will die later.

M5b: Post-collapse mortality with community operations

- The rescue by the inhabitants is mainly done by hand. The work gives a high rescue ratio in wood structures, which rescue work can more easily be applied to, followed by block and brick, brick and steel, and RC-2 structures, in which bricks and blocks can be removed by hand.
- Adobe structures give a high ratio of instantaneous death and a low rescue ratio.
- RC-0 and Steel-1 structures are difficult for rescue, unless adequate tools are available.

M5c: Post-collapse mortality with community operations and emergency squads

- Since the rescue work by fire fighting teams and the Red Crescent Society make use of relatively large-scale equipment, the rescue ratio is high in RC-1, RC-0, and Steel-1 structures.

M5d: Post-collapse mortality with community operations, emergency squads and experts

- The activities by emergency rescue teams, including those of foreign countries, concentrate on the rescue of people who are entrapped in large buildings, owing to the use of special tools and rescue dogs. Thus, they are effective in Steel-1 and RC-0 structures. In other structures, however, the rescue ratio is low.

The parameters and the death ratio functions established in the Study are shown in Figure 4.2.7 to Figure 4.2.9 and Table 4.2.2 to Table 4.2.3.

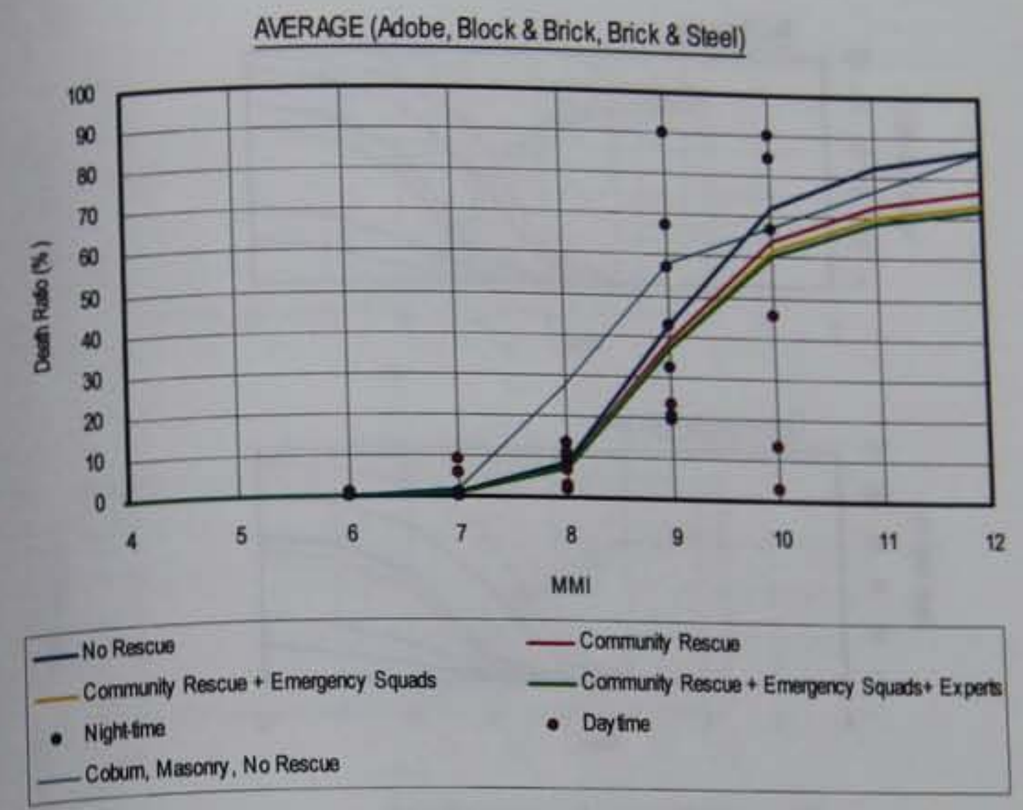

Figure 4.2.5 Comparison of Death Ratios by Iranian Earthquakes and Casualty Functions

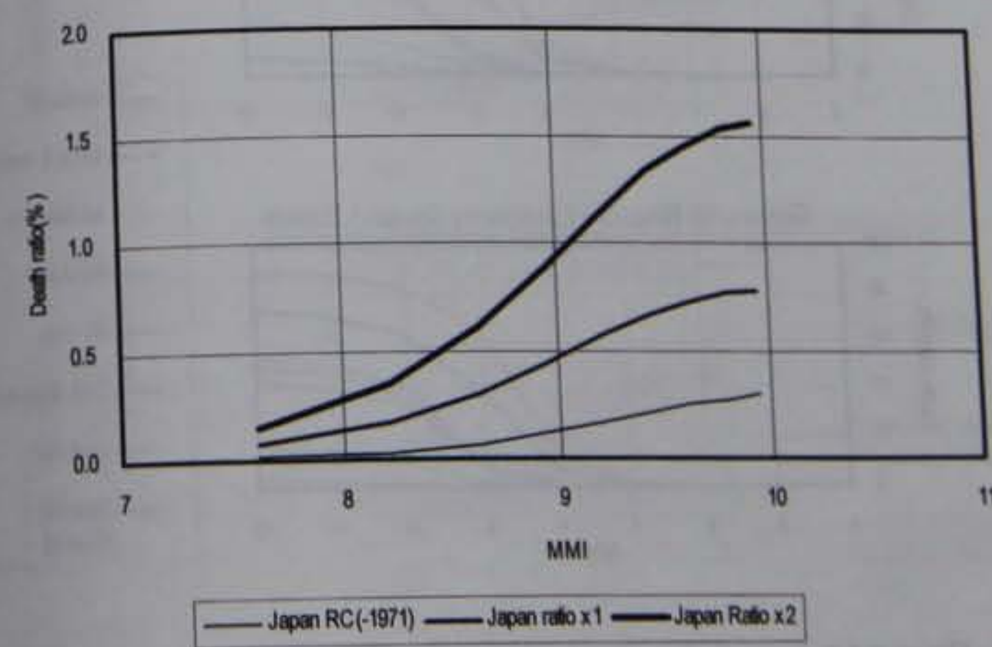

Figure 4.2.6 Death Ratio in Engineered Structures

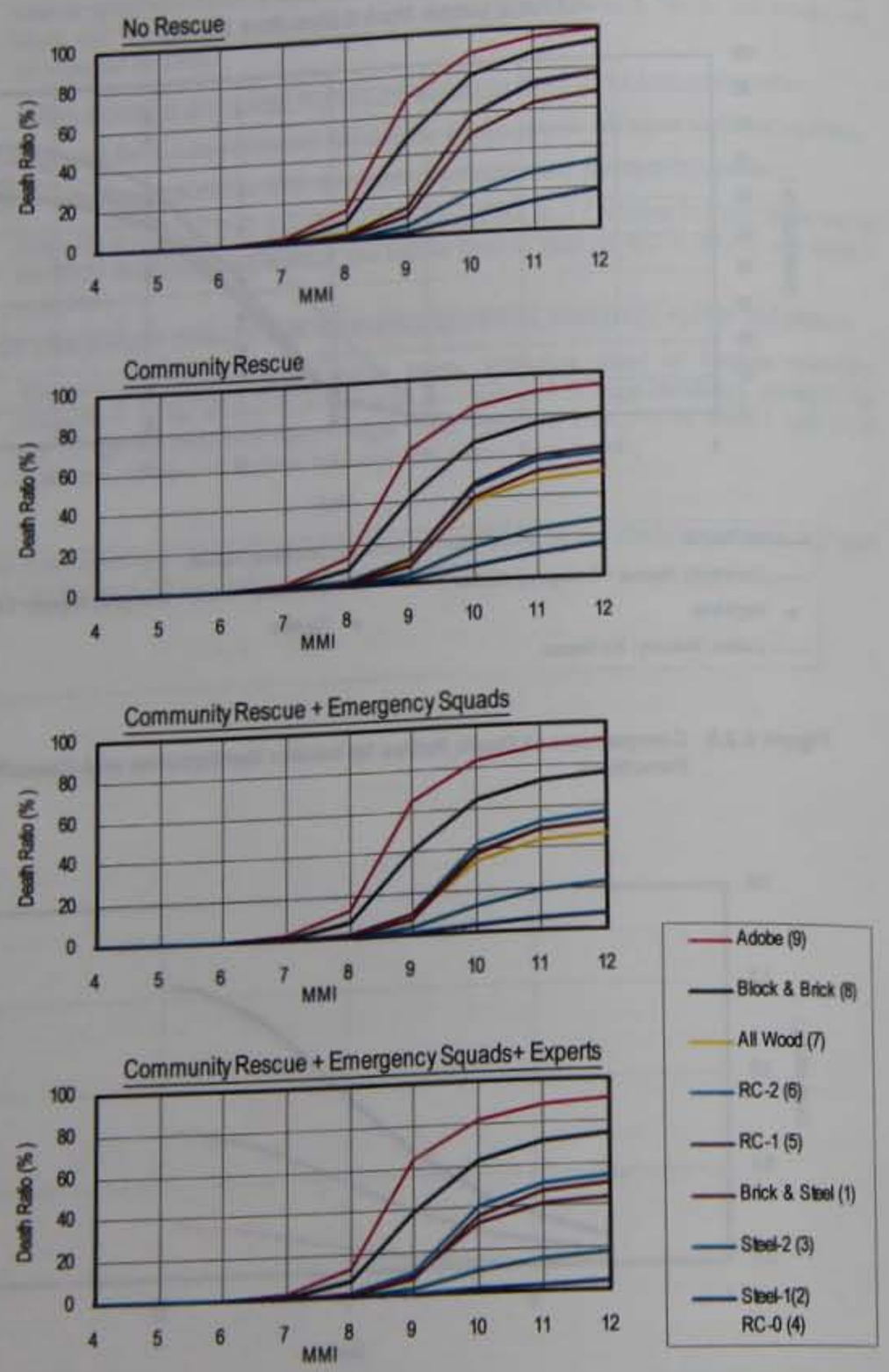

Figure 4.2.7 Casualty Function by Rescue Type

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

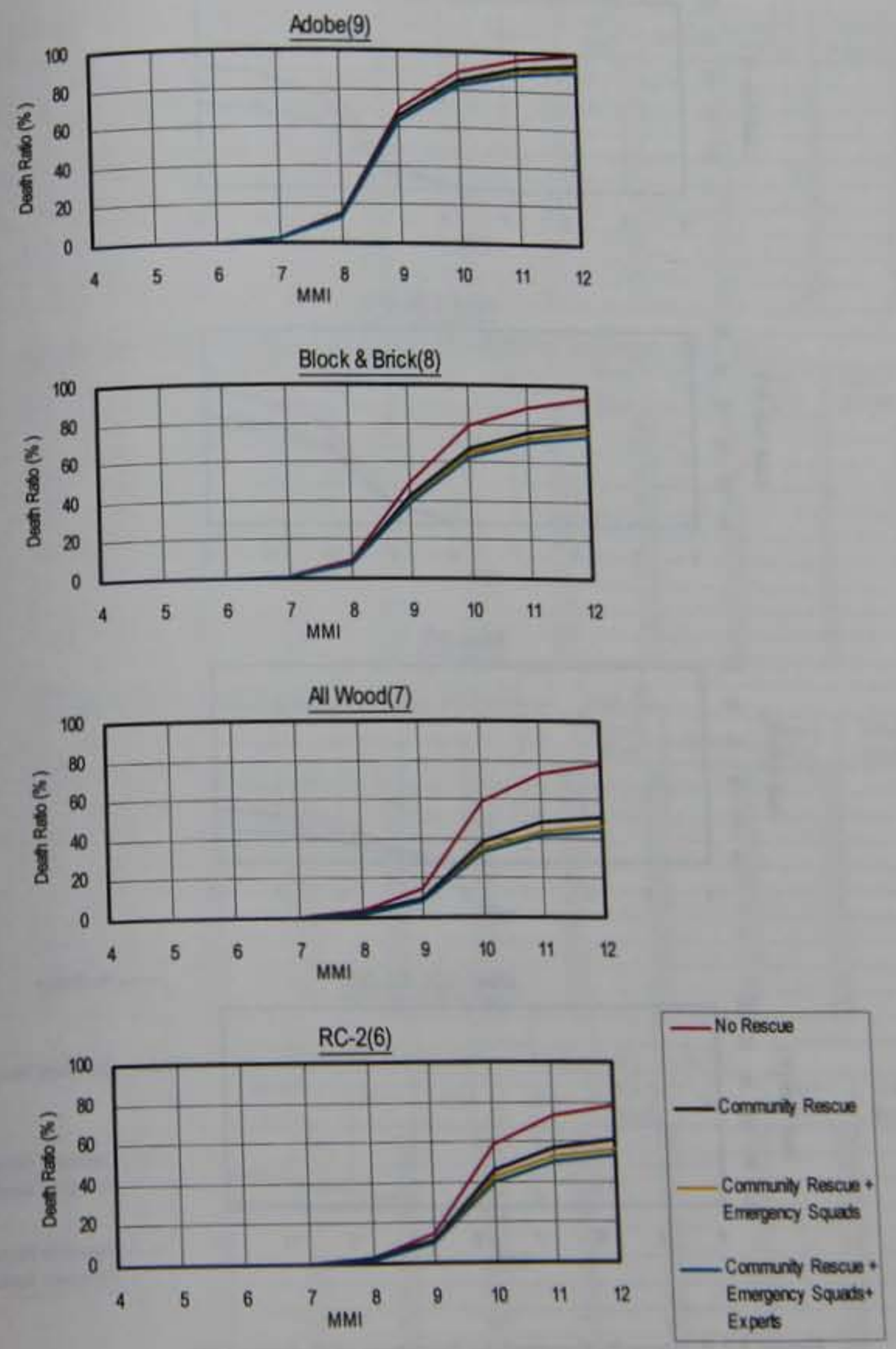

Figure 4.2.8 Casualty Function by Structure of Buildings (1)

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

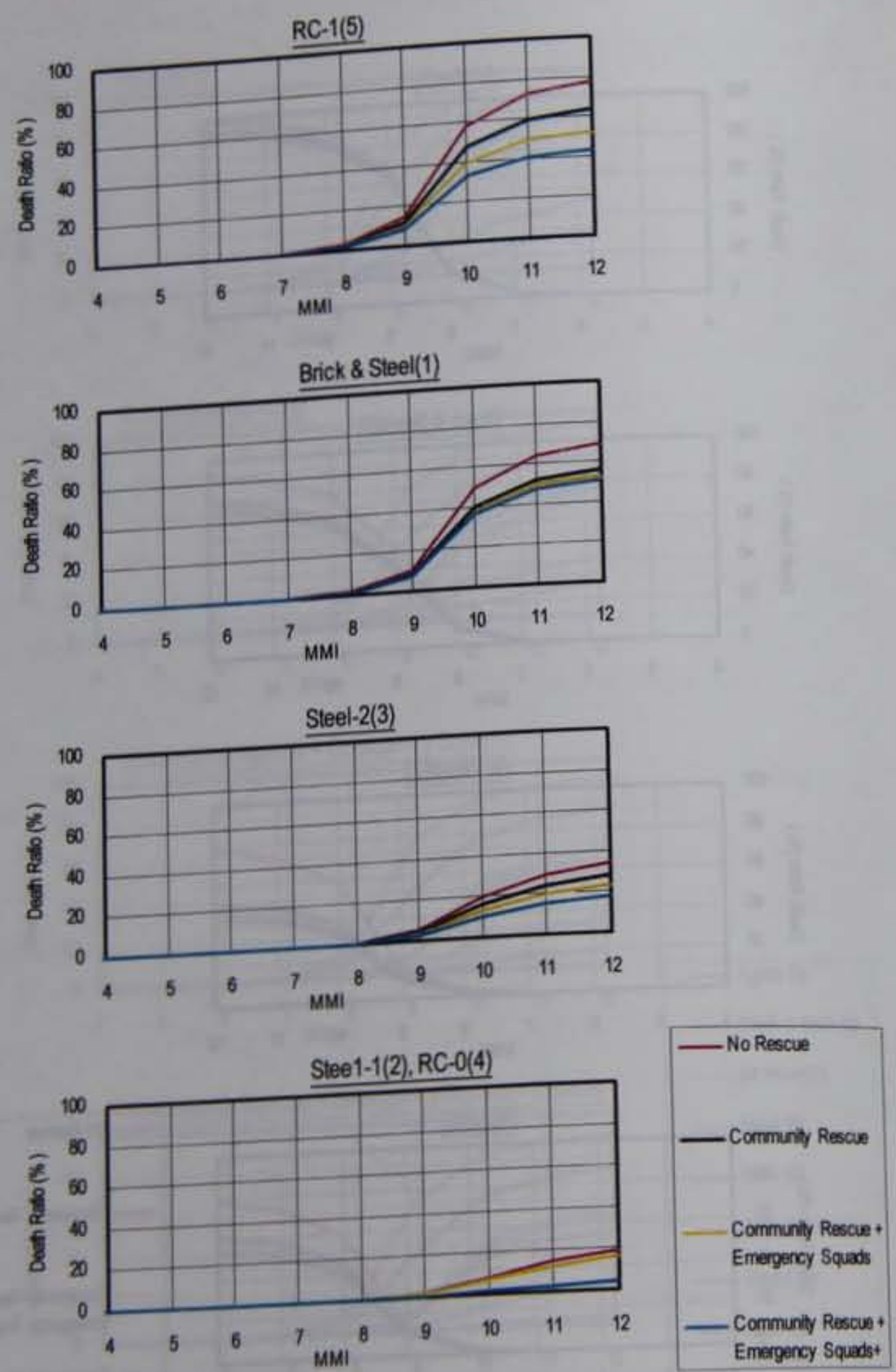

Figure 4.2.9 Casualty Function by Structure of Buildings (2)

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

Table 4.2.2 Parameters of M3, M4d, M5 (1)

Coefficient M3 (Number of trapped by collapsed buildings) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	3	2	1	1	1	1	1	0.5	5
8	15	10	4	4	4	4	2	1	30
9	70	50	15	15	15	12	8	3	60
10	90	80	60	60	60	50	20	8	70
11	97	90	75	75	75	65	30	15	80
12	100	95	80	80	80	70	35	20	90

Coefficient M4d (Death ratio at 0-hrs after the collapse of buildings) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	80	60	40	40	30	50	30	5	20
4	80	60	40	40	30	50	30	5	20
5	80	60	40	40	30	50	30	5	20
6	80	60	40	40	30	50	30	5	20
7	80	60	40	40	30	50	30	5	20
8	80	60	40	40	30	50	30	5	20
9	80	60	40	40	30	50	30	5	20
10	80	60	40	40	30	50	30	5	20
11	80	60	40	40	30	50	30	5	20
12	80	60	40	40	30	50	30	5	20

Coefficient M5 a (Post-collapse mortality, No Rescue) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	95	95	95	95	95	95	95	95	95
4	95	95	95	95	95	95	95	95	95
5	95	95	95	95	95	95	95	95	95
6	95	95	95	95	95	95	95	95	95
7	95	95	95	95	95	95	95	95	95
8	95	95	95	95	95	95	95	95	95
9	95	95	95	95	95	95	95	95	95
10	95	95	95	95	95	95	95	95	95
11	95	95	95	95	95	95	95	95	95
12	95	95	95	95	95	95	95	95	95

Coefficient M5b (Post-collapse mortality, Community Rescue) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	70	60	40	60	70	60	70	80	60
4	70	60	40	60	70	60	70	80	60
5	70	60	40	60	70	60	70	80	60
6	70	60	40	60	70	60	70	80	60
7	70	60	40	60	70	60	70	80	60
8	70	60	40	60	70	60	70	80	60
9	70	60	40	60	70	60	70	80	60
10	70	60	40	60	70	60	70	80	60
11	70	60	40	60	70	60	70	80	60
12	70	60	40	60	70	60	70	80	60

Table 4.2.3 Parameters of M3, M4d, M5 (2)

Coefficient M5c (Post-collapse mortality ,Community + Emergency Squads) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	60	50	30	50	50	50	50	35	50
4	60	50	30	50	50	50	50	35	50
5	60	50	30	50	50	50	50	35	50
6	60	50	30	50	50	50	50	35	50
7	60	50	30	50	50	50	50	35	50
8	60	50	30	50	50	50	50	35	50
9	60	50	30	50	50	50	50	35	50
10	60	50	30	50	50	50	50	35	50
11	60	50	30	50	50	50	50	35	50
12	60	50	30	50	50	50	50	35	50

Coefficient M5d(Post-collapse mortality ,Community + Emergency Squads + Experts) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	55	45	25	45	35	45	30	15	45
4	55	45	25	45	35	45	30	15	45
5	55	45	25	45	35	45	30	15	45
6	55	45	25	45	35	45	30	15	45
7	55	45	25	45	35	45	30	15	45
8	55	45	25	45	35	45	30	15	45
9	55	45	25	45	35	45	30	15	45
10	55	45	25	45	35	45	30	15	45
11	55	45	25	45	35	45	30	15	45
12	55	45	25	45	35	45	30	15	45

4.2.2. Damage Estimation

The number of fatalities due to the scenario earthquakes was estimated. The definition of fatalities is those people killed only as a result of building collapse and not because of any other cause. Particularly, in large-scale earthquakes, people may die from diseases in refugee camps and, therefore, those people are not accounted for by the Study.

Definition of Damage	
Human Casualties	Fatalities
Unit	Persons
Cause of Damage	Collapse of Buildings

The human casualty damage was estimated for every building structure in each census zone, and the results were aggregated into district data. The census zones include cases extending outside the 22 districts, and these were excluded from the total district figures. The number of fatalities, with distinction of night-time and daytime and types of emergency rescue activities, is summarised in Table 4.2.4 to Table 4.2.7 and Figure 4.2.10 to Figure 4.2.22. The four types of emergency rescue activities during night-time and daytime earthquakes lead to eight kinds of estimations against each scenario earthquake. The case of a night-time earthquake with no rescue activity results in the most serious damage.

From all the fault models, the Ray Fault Model yields the largest damages. In this case, about 380 thousand inhabitants, or about 6% of the total population will die. The casualties in District 15 will be vast because of the large number of its inhabitants. The death ratio in Districts 11 and 12 will be as high as 15 to 20% because there are many vulnerable

buildings in the area and high seismic intensity 9 in MMI scale. The death ratio in the northern part of the city, i.e., in Districts 1 to 5 shall only be about 2%.

In case of the NTF Model, the worst case indicates about 130 thousand fatalities, or about 2% of the total population. The death ratio in the northern part of the city, in Districts 1 to 5, shall be high, approximately 3%. The death ratio in the southern part shall be low, approximately 1%.

In case of the Mosha Fault Model, the death ratio does not exceed 0.3 % of the total population of the city. The casualties in District 12 shall be vast, approximately 1.7%. This is due to the existence of many vulnerable buildings of adobe and wood and brick structure, the high damage ratio of these buildings and the low rescue ratio. Such a tendency is also observed in the case of the Floating Model.

The distribution of numbers of human casualties by district at night-time for the Ray Fault Model and the NTF Model are shown in Figure 4.2.14 to Figure 4.2.17. The 'no rescue' and 'full rescue' cases are presented in these figures. A 'full rescue' case is a case where a combination of the community rescue, emergency squads and expert operations is available.

In the Ray Fault Model, human casualties are estimated to culminate in the southern part of the city. In some census zones, the number of dead will exceed 1,000.

On the contrary, in the NTF Model, many human casualties are estimated to occur in the northern part of the city. In some census zones, the number of dead will amount to 100 or more. This area corresponds to Districts 11 and 12, where vulnerable buildings such as adobe are prevailing and emergency rescue activities are not effective for these kinds of structures.

The distributions of death ratios for the above cases are shown in Figure 4.2.18 to Figure 4.2.21.

In case of the Ray Fault Model, the death ratio in several census zones in Districts 11 and 12 shall be enormous, 40% or more. In these districts, the emergency rescue activities are not effective. In the NTF Model, the high-death ratio area is limited. If sufficient rescue activities are undertaken, the death ratio would drop to 20% or below for the entire census zone.

Table 4.2.4 Casualties by District – Ray Fault model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		—		—		—		No Rescue		—		—		—		
	—		CR		CR		CR		—		CR		CR		CR		
	—		—		ES		ES		—		—		ES		ES		
	—		—		—		EX		—		—		—		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	2,719	1.2	2,242	1.0	2,065	0.9	1,953	0.9	1,925	0.9	1,588	0.7	1,464	0.7	1,385	0.6	221,552
2	8,812	2.0	7,125	1.6	6,395	1.4	5,879	1.3	5,692	1.3	4,601	1.0	4,131	0.9	3,800	0.8	448,997
3	5,187	2.4	4,241	2.0	3,812	1.8	3,491	1.6	3,181	1.5	2,602	1.2	2,338	1.1	2,143	1.0	217,416
4	6,777	1.1	5,549	0.9	5,043	0.8	4,703	0.7	4,617	0.7	3,780	0.6	3,436	0.5	3,205	0.5	641,614
5	5,768	1.4	4,668	1.1	4,083	1.0	3,710	0.9	3,788	0.9	3,066	0.7	2,684	0.6	2,442	0.6	423,537
6	6,517	3.1	5,335	2.5	4,814	2.3	4,431	2.1	3,879	1.8	3,175	1.5	2,864	1.4	2,635	1.3	209,704
7	12,817	4.6	10,592	3.8	9,688	3.5	9,053	3.3	7,432	2.7	6,142	2.2	5,618	2.0	5,249	1.9	276,809
8	14,610	4.4	12,018	3.7	11,005	3.3	10,318	3.1	8,391	2.6	6,903	2.1	6,318	1.9	5,920	1.8	328,538
9	9,755	5.7	7,999	4.7	7,393	4.3	7,019	4.1	5,447	3.2	4,468	2.6	4,129	2.4	3,919	2.3	171,721
10	21,983	7.9	18,328	6.6	17,075	6.1	16,329	5.9	11,558	4.1	9,631	3.5	8,973	3.2	8,581	3.1	278,902
11	31,635	14.7	27,175	12.6	25,560	11.9	24,549	11.4	15,265	7.1	13,108	6.1	12,324	5.7	11,832	5.5	215,160
12	37,058	20.1	32,747	17.8	31,234	16.9	30,344	16.5	18,632	10.1	16,461	8.9	15,697	8.5	15,247	8.3	184,325
13	10,312	4.6	8,553	3.8	7,876	3.5	7,430	3.3	6,049	2.7	5,018	2.2	4,622	2.1	4,361	1.9	225,166
14	22,968	6.3	19,303	5.3	17,840	4.9	16,864	4.6	12,510	3.4	10,505	2.9	9,704	2.7	9,170	2.5	365,924
15	50,973	8.6	42,520	7.2	39,382	6.6	37,378	6.3	25,436	4.3	21,212	3.6	19,628	3.3	18,610	3.1	593,217
16	29,732	10.5	25,107	8.8	23,467	8.3	22,449	7.9	14,869	5.2	12,557	4.4	11,738	4.1	11,230	4.0	283,869
17	28,547	9.8	23,681	8.2	21,957	7.6	20,874	7.2	13,651	4.7	11,326	3.9	10,502	3.6	9,986	3.4	290,539
18	24,564	8.4	20,202	6.9	18,505	6.3	17,383	5.9	11,862	4.1	9,755	3.3	8,936	3.1	8,395	2.9	292,207
19	16,472	7.9	13,523	6.5	12,362	5.9	11,590	5.6	8,038	3.9	6,599	3.2	6,033	2.9	5,655	2.7	208,230
20	30,188	10.1	25,061	8.4	22,954	7.7	21,513	7.2	14,398	4.8	11,953	4.0	10,946	3.6	10,257	3.4	299,931
21	4,776	3.8	3,934	3.1	3,548	2.8	3,275	2.6	2,810	2.2	2,315	1.8	2,088	1.7	1,929	1.5	125,939
22	651	1.2	521	0.9	462	0.8	423	0.8	446	0.8	357	0.6	317	0.6	290	0.5	55,758
Sum	382,822	6.0	320,424	5.0	296,518	4.7	280,958	4.4	199,876	3.1	167,121	2.6	154,490	2.4	146,239	2.3	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.5 Casualties by District – NTF Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		—		—		—		No Rescue		—		—		—		
	—		CR		CR		CR		—		CR		CR		CR		
	—		—		ES		ES		—		—		ES		ES		
	—		—		—		EX		—		—		—		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	14,032	6.3	11,564	5.2	10,543	4.8	9,830	4.4	7,829	3.5	6,451	2.9	5,881	2.7	5,483	2.5	221,552
2	11,914	2.7	9,618	2.1	8,642	1.9	7,997	1.8	7,308	1.6	5,899	1.3	5,301	1.2	4,904	1.1	448,997
3	10,290	4.7	8,419	3.9	7,531	3.5	6,852	3.2	5,642	2.6	4,617	2.1	4,129	1.9	3,757	1.7	217,416
4	15,277	2.4	12,504	1.9	11,272	1.8	10,430	1.6	9,476	1.5	7,757	1.2	6,995	1.1	6,473	1.0	641,614
5	12,217	2.9	9,915	2.3	8,779	2.1	7,992	1.9	7,383	1.7	5,991	1.4	5,302	1.3	4,825	1.1	423,537
6	3,144	1.5	2,569	1.2	2,321	1.1	2,142	1.0	2,050	1.0	1,675	0.8	1,514	0.7	1,397	0.7	209,704
7	4,337	1.6	3,589	1.3	3,296	1.2	3,097	1.1	2,845	1.0	2,355	0.9	2,163	0.8	2,033	0.7	276,809
8	4,750	1.4	3,910	1.2	3,595	1.1	3,388	1.0	3,115	0.9	2,565	0.8	2,358	0.7	2,222	0.7	328,538
9	1,880	1.1	1,544	0.9	1,434	0.8	1,370	0.8	1,316	0.8	1,081	0.6	1,004	0.6	959	0.6	171,721
10	3,701	1.3	3,103	1.1	2,911	1.0	2,805	1.0	2,557	0.9	2,144	0.8	2,011	0.7	1,938	0.7	278,902
11	5,128	2.4	4,457	2.1	4,233	2.0	4,105	1.9	3,496	1.6	3,038	1.4	2,885	1.3	2,798	1.3	215,160
12	7,722	4.2	6,883	3.7	6,605	3.6	6,454	3.5	5,232	2.8	4,664	2.5	4,476	2.4	4,373	2.4	184,325
13	2,614	1.2	2,180	1.0	2,028	0.9	1,936	0.9	1,794	0.8	1,496	0.7	1,392	0.6	1,329	0.6	225,166
14	4,191	1.1	3,551	1.0	3,321	0.9	3,181	0.9	2,946	0.8	2,495	0.7	2,333	0.6	2,234	0.6	365,924
15	7,177	1.2	6,037	1.0	5,646	1.0	5,414	0.9	5,022	0.8	4,221	0.7	3,946	0.7	3,782	0.6	593,217
16	4,213	1.5	3,604	1.3	3,404	1.2	3,291	1.2	2,960	1.0	2,532	0.9	2,392	0.8	2,312	0.8	283,869
17	3,433	1.2	2,868	1.0	2,683	0.9	2,576	0.9	2,368	0.8	1,978	0.7	1,850	0.6	1,777	0.6	290,539
18	2,622	0.9	2,160	0.7	1,994	0.7	1,892	0.6	1,826	0.6	1,504	0.5	1,389	0.5	1,318	0.5	292,207
19	1,466	0.7	1,205	0.6	1,111	0.5	1,054	0.5	1,075	0.5	883	0.4	815	0.4	773	0.4	208,230
20	2,797	0.9	2,341	0.8	2,173	0.7	2,068	0.7	2,063	0.7	1,727	0.6	1,603	0.5	1,525	0.5	299,931
21	1,761	1.4	1,450	1.2	1,325	1.1	1,244	1.0	1,176	0.9	968	0.8	885	0.7	831	0.7	125,939
22	1,540	2.8	1,237	2.2	1,081	1.9	970	1.7	956	1.7	768	1.4	672	1.2	603	1.1	55,758
Sum	126,204	2.0	104,705	1.6	95,927	1.5	90,086	1.4	80,435	1.3	66,809	1.1	61,294	1.0	57,645	0.9	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.6 Casualties by District – Mosha Fault Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		—		—		—		No Rescue		—		—		—		
	—		CR		CR		CR		—		CR		CR		CR		
	—		—		ES		ES		—		—		ES		ES		
	—		—		—		EX		—		—		—		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	1,174	0.5	968	0.4	892	0.4	844	0.4	932	0.4	769	0.3	709	0.3	671	0.3	221,552
2	627	0.1	509	0.1	459	0.1	425	0.1	540	0.1	438	0.1	395	0.1	366	0.1	448,997
3	944	0.4	772	0.4	701	0.3	652	0.3	732	0.3	599	0.3	544	0.3	506	0.2	217,416
4	2,444	0.4	2,002	0.3	1,821	0.3	1,705	0.3	1,922	0.3	1,574	0.2	1,432	0.2	1,340	0.2	641,614
5	313	0.1	255	0.1	224	0.1	204	0.0	280	0.1	228	0.1	200	0.0	182	0.0	423,537
6	570	0.3	466	0.2	423	0.2	391	0.2	466	0.2	381	0.2	345	0.2	320	0.2	209,704
7	831	0.3	688	0.2	634	0.2	598	0.2	683	0.2	566	0.2	521	0.2	491	0.2	276,809
8	786	0.2	648	0.2	596	0.2	563	0.2	653	0.2	538	0.2	495	0.2	468	0.1	328,538
9	158	0.1	130	0.1	120	0.1	114	0.1	139	0.1	115	0.1	106	0.1	101	0.1	171,721
10	373	0.1	319	0.1	300	0.1	290	0.1	323	0.1	276	0.1	260	0.1	251	0.1	278,902
11	1,520	0.7	1,337	0.6	1,276	0.6	1,242	0.6	1,241	0.6	1,091	0.5	1,041	0.5	1,013	0.5	215,160
12	3,095	1.7	2,777	1.5	2,672	1.4	2,614	1.4	2,483	1.3	2,229	1.2	2,144	1.2	2,098	1.1	184,325
13	599	0.3	499	0.2	463	0.2	441	0.2	499	0.2	416	0.2	386	0.2	367	0.2	225,166
14	1,265	0.3	1,084	0.3	1,016	0.3	975	0.3	1,039	0.3	890	0.2	834	0.2	800	0.2	365,924
15	1,841	0.3	1,566	0.3	1,468	0.2	1,410	0.2	1,515	0.3	1,287	0.2	1,207	0.2	1,159	0.2	593,217
16	1,140	0.4	991	0.3	941	0.3	912	0.3	945	0.3	821	0.3	779	0.3	755	0.3	283,869
17	935	0.3	785	0.3	735	0.3	707	0.2	769	0.3	645	0.2	605	0.2	581	0.2	290,539
18	631	0.2	520	0.2	479	0.2	453	0.2	511	0.2	422	0.1	388	0.1	367	0.1	292,207
19	131	0.1	108	0.1	99	0.0	93	0.0	118	0.1	97	0.0	89	0.0	83	0.0	208,230
20	584	0.2	493	0.2	458	0.2	436	0.1	494	0.2	418	0.1	388	0.1	369	0.1	299,931
21	104	0.1	87	0.1	79	0.1	73	0.1	94	0.1	78	0.1	71	0.1	66	0.1	125,939
22	41	0.1	33	0.1	29	0.1	26	0.0	37	0.1	30	0.1	26	0.0	24	0.0	55,758
Sum	20,107	0.3	17,036	0.3	15,886	0.2	15,166	0.2	16,415	0.3	13,906	0.2	12,965	0.2	12,377	0.2	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.7 Casualties by District – Floating Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		—		—		—		No Rescue		—		—		—		
	—		CR		CR		CR		—		CR		CR		CR		
	—		—		ES		ES		—		—		ES		ES		
	—		—		—		EX		—		—		—		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	9,581	4.3	7,894	3.6	7,203	3.3	6,724	3.0	5,749	2.6	4,736	2.1	4,322	2.0	4,035	1.8	221,552
2	16,183	3.6	13,086	2.9	11,695	2.6	10,711	2.4	9,793	2.2	7,919	1.8	7,078	1.6	6,483	1.4	448,997
3	11,902	5.5	9,734	4.5	8,691	4.0	7,887	3.6	6,232	2.9	5,098	2.3	4,552	2.1	4,133	1.9	217,416
4	21,804	3.4	17,858	2.8	16,075	2.5	14,818	2.3	13,114	2.0	10,740	1.7	9,668	1.5	8,911	1.4	641,614
5	12,973	3.1	10,524	2.5	9,203	2.2	8,309	2.0	7,844	1.9	6,363	1.5	5,565	1.3	5,025	1.2	423,537
6	6,828	3.3	5,585	2.7	5,017	2.4	4,592	2.2	4,125	2.0	3,374	1.6	3,030	1.4	2,773	1.3	209,704
7	10,902	3.9	9,015	3.3	8,249	3.0	7,712	2.8	6,537	2.4	5,405	2.0	4,946	1.8	4,623	1.7	276,809
8	12,173	3.7	10,013	3.0	9,144	2.8	8,544	2.6	7,293	2.2	5,999	1.8	5,479	1.7	5,119	1.6	328,538
9	8,000	4.7	6,560	3.8	6,062	3.5	5,754	3.4	4,696	2.7	3,852	2.2	3,560	2.1	3,378	2.0	171,721
10	15,778	5.7	13,149	4.7	12,259	4.4	11,733	4.2	9,121	3.3	7,600	2.7	7,086	2.5	6,782	2.4	278,902
11	18,654	8.7	16,068	7.5	15,142	7.0	14,568	6.8	10,661	5.0	9,181	4.3	8,650	4.0	8,321	3.9	215,160
12	27,264	14.8	24,121	13.1	23,024	12.5	22,384	12.1	15,186	8.2	13,432	7.3	12,820	7.0	12,462	6.8	184,325
13	9,551	4.2	7,926	3.5	7,307	3.2	6,902	3.1	5,709	2.5	4,738	2.1	4,368	1.9	4,126	1.8	225,166
14	18,495	5.1	15,529	4.2	14,356	3.9	13,578	3.7	10,731	2.9	9,006	2.5	8,324	2.3	7,871	2.2	365,924
15	27,765	4.7	23,174	3.9	21,430	3.6	20,298	3.4	16,517	2.8	13,784	2.3	12,745	2.1	12,071	2.0	593,217
16	17,507	6.2	14,820	5.2	13,881	4.9	13,307	4.7	10,176	3.6	8,613	3.0	8,067	2.8	7,733	2.7	283,869
17	15,955	5.5	13,251	4.6	12,309	4.2	11,726	4.0	9,137	3.1	7,588	2.6	7,048	2.4	6,714	2.3	290,539
18	13,052	4.5	10,735	3.7	9,839	3.4	9,248	3.2	7,512	2.6	6,179	2.1	5,664	1.9	5,325	1.8	292,207
19	6,512	3.1	5,347	2.6	4,900	2.4	4,610	2.2	3,976	1.9	3,264	1.6	2,992	1.4	2,814	1.4	208,230
20	14,207	4.7	11,820	3.9	10,850	3.6	10,193	3.4	8,348	2.8	6,945	2.3	6,375	2.1	5,988	2.0	299,931
21	4,524	3.6	3,724	3.0	3,369	2.7	3,120	2.5	2,752	2.2	2,265	1.8	2,050	1.6	1,898	1.5	125,939
22	1,906	3.4	1,533	2.7	1,342	2.4	1,206	2.2	1,158	2.1	931	1.7	815	1.5	733	1.3	55,758
Sum	301,515	4.7	251,462	4.0	231,345	3.6	217,924	3.4	176,366	2.8	147,014	2.3	135,202	2.1	127,320	2.0	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

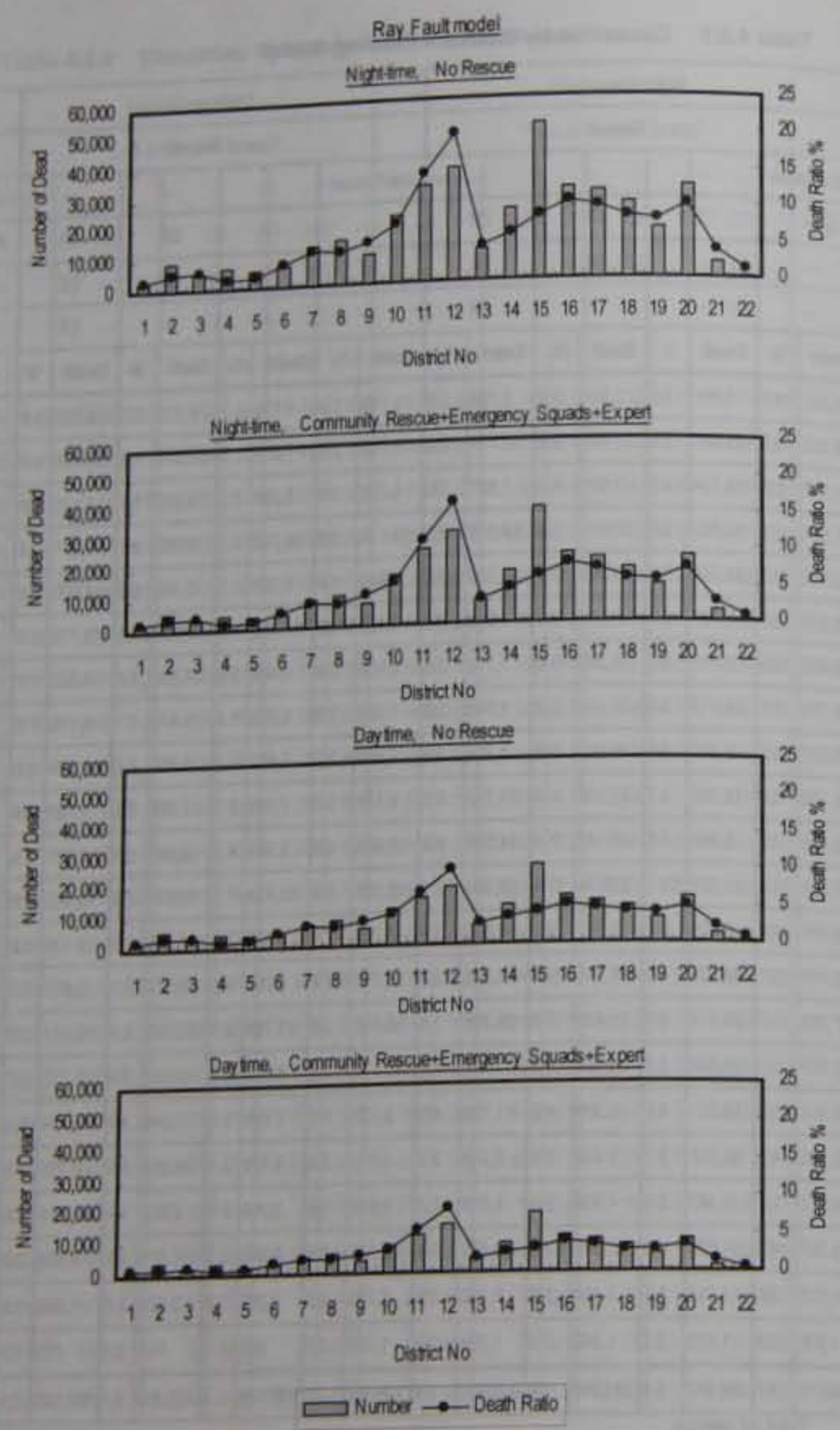

Figure 4.2.10 Distribution of Casualties by District – Ray Fault Model

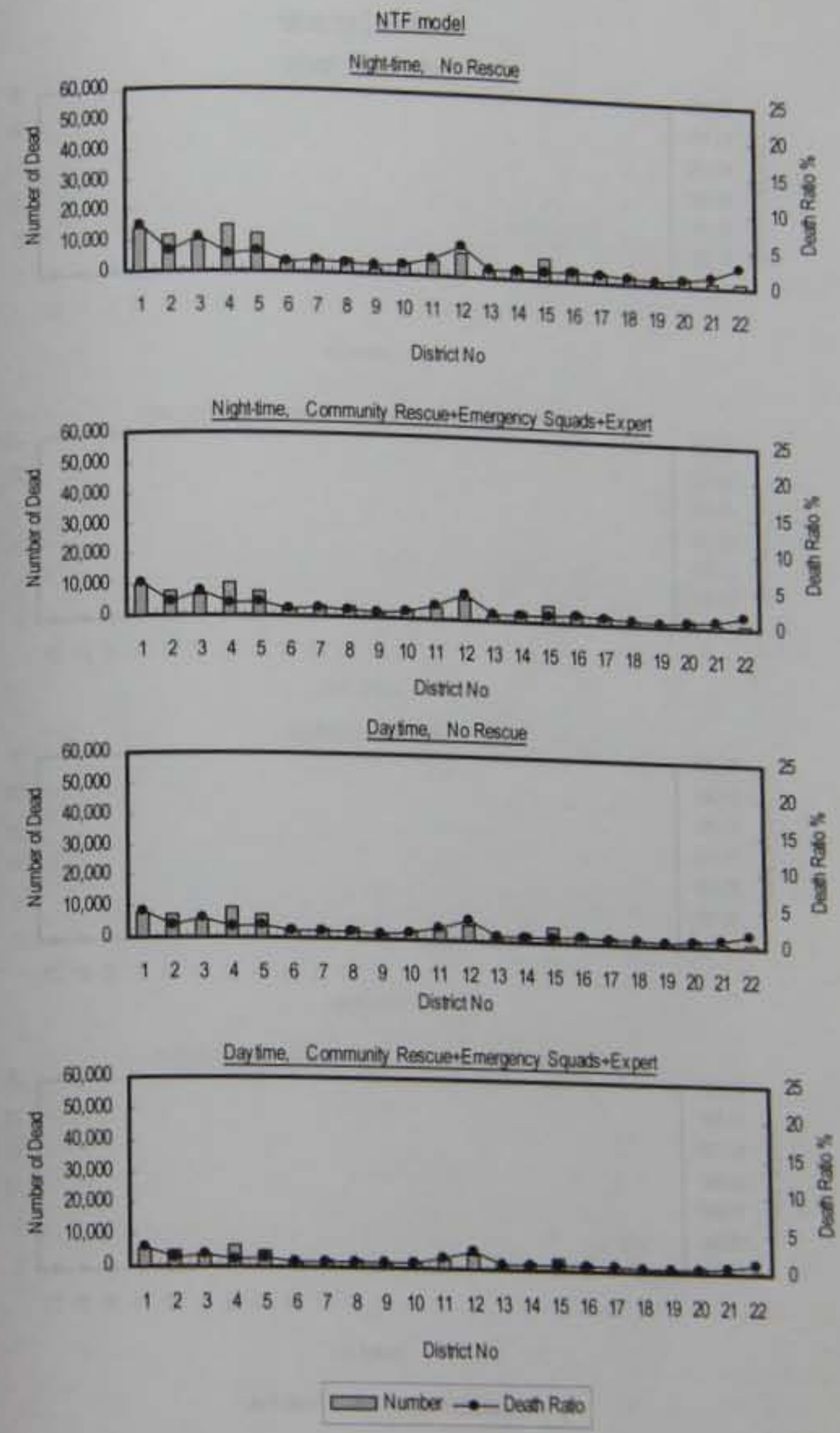

Figure 4.2.11 Distribution of Casualties by District – NTF Model

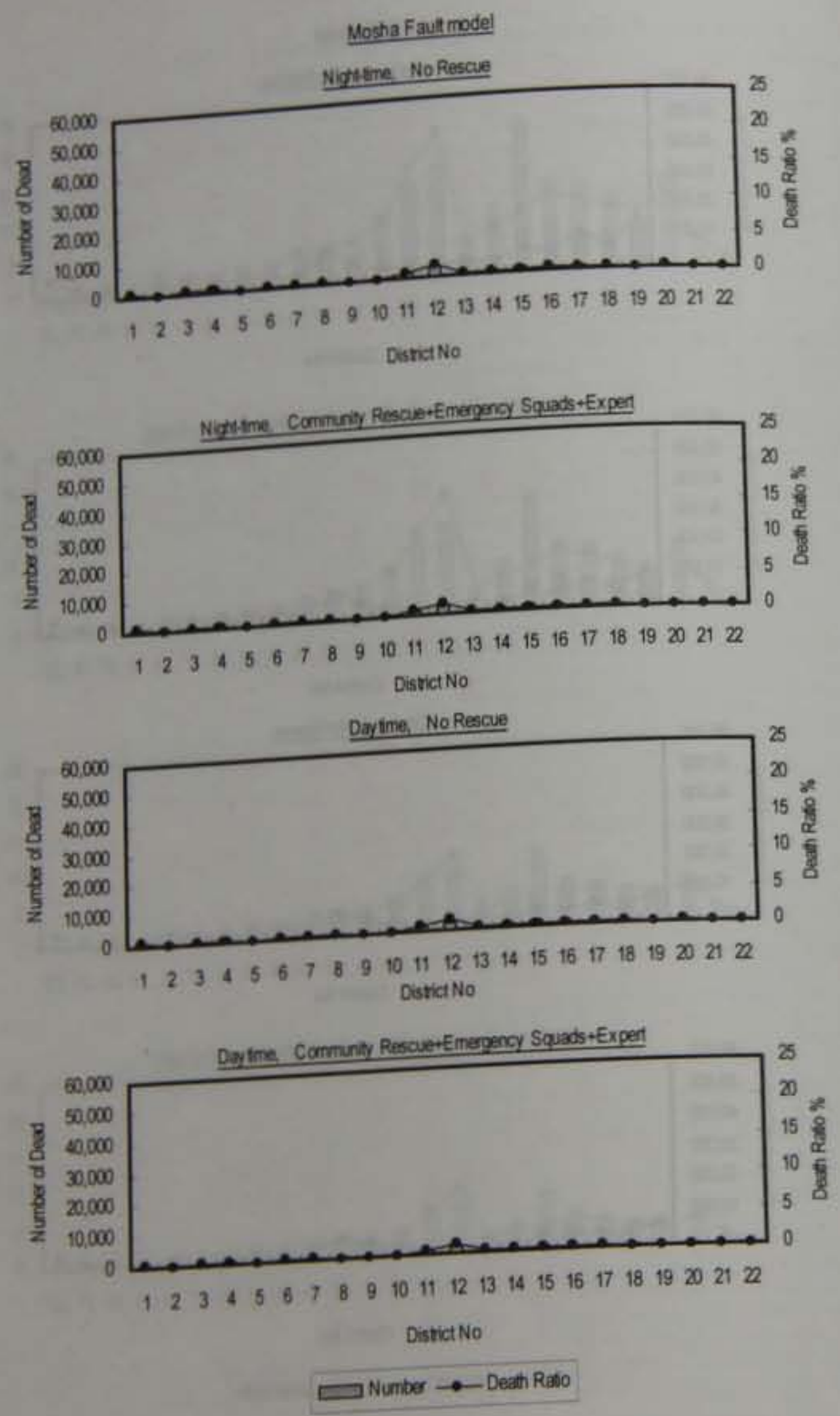

Figure 4.2.12 Distribution of Casualties by District – Mosha Fault Model

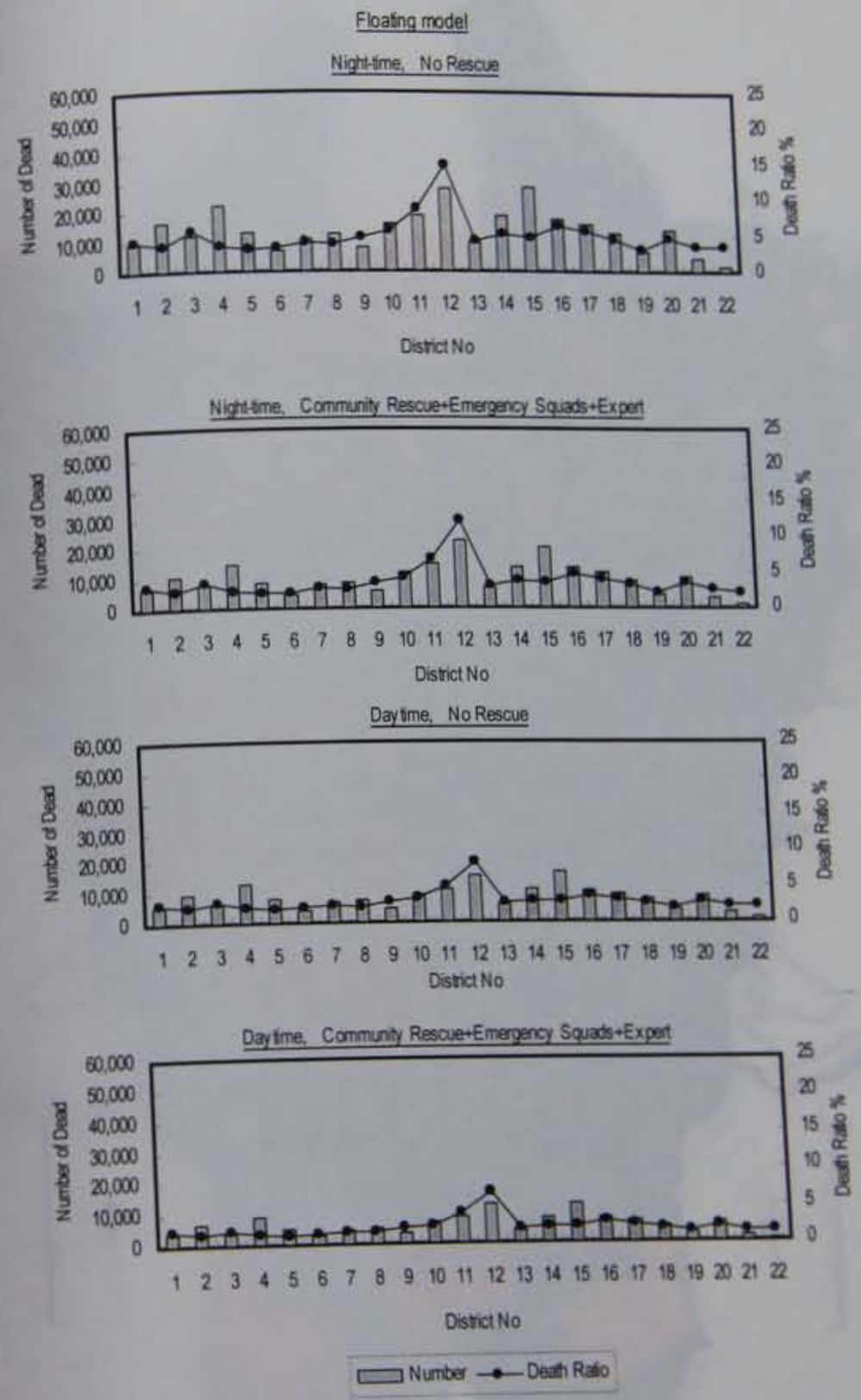

Figure 4.2.13 Distribution of Casualties by District – Floating Model

Figure 4.2.14

Casualty Distribution - Night No Rescue Work (Ray Fault model)

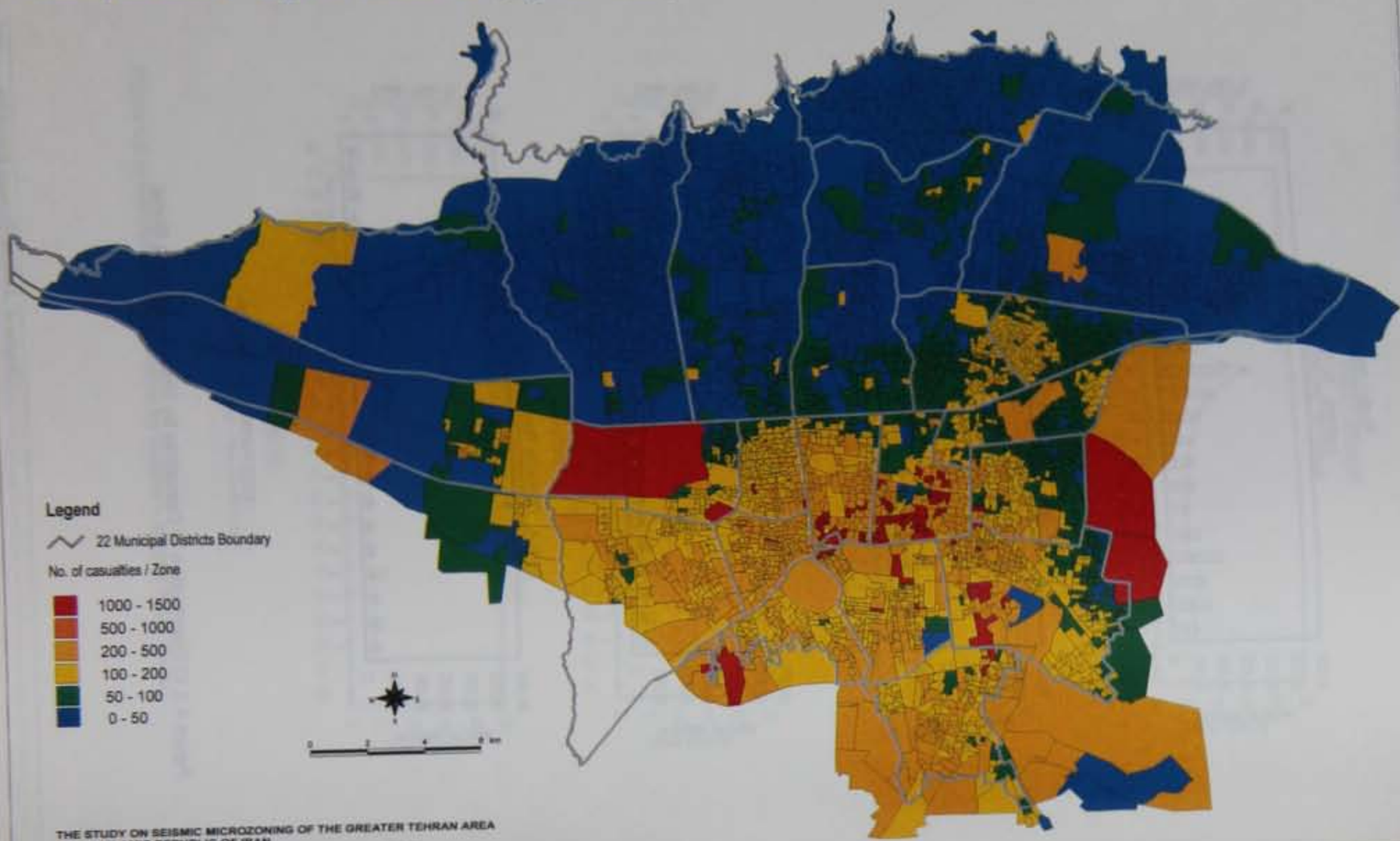

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Figure 4.2.15

Casualty Distribution - Night Full Rescue Work (Ray Fault model)

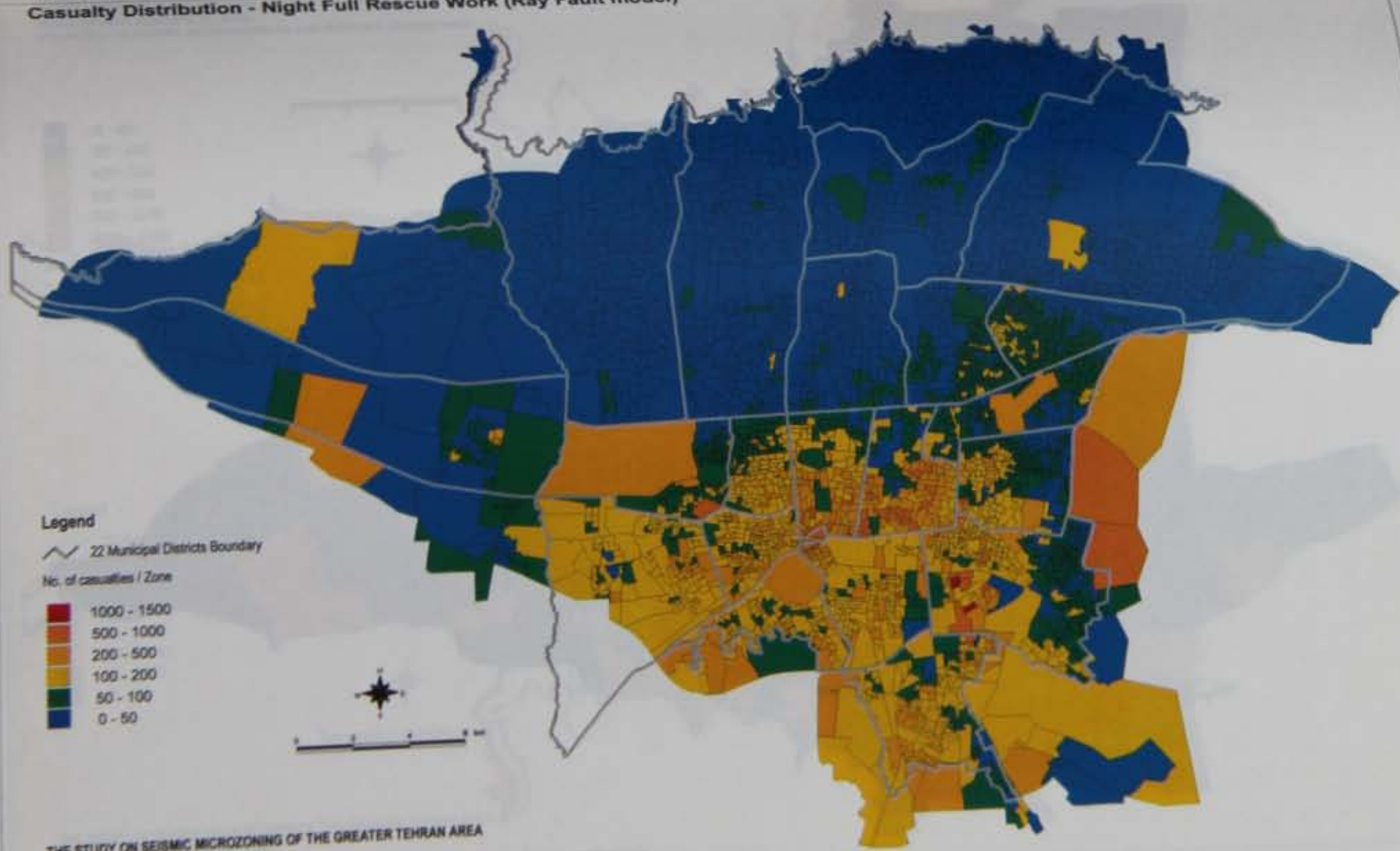

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Figure 4.2.16

Casualty Distribution - Night No Rescue Work (NTF model)

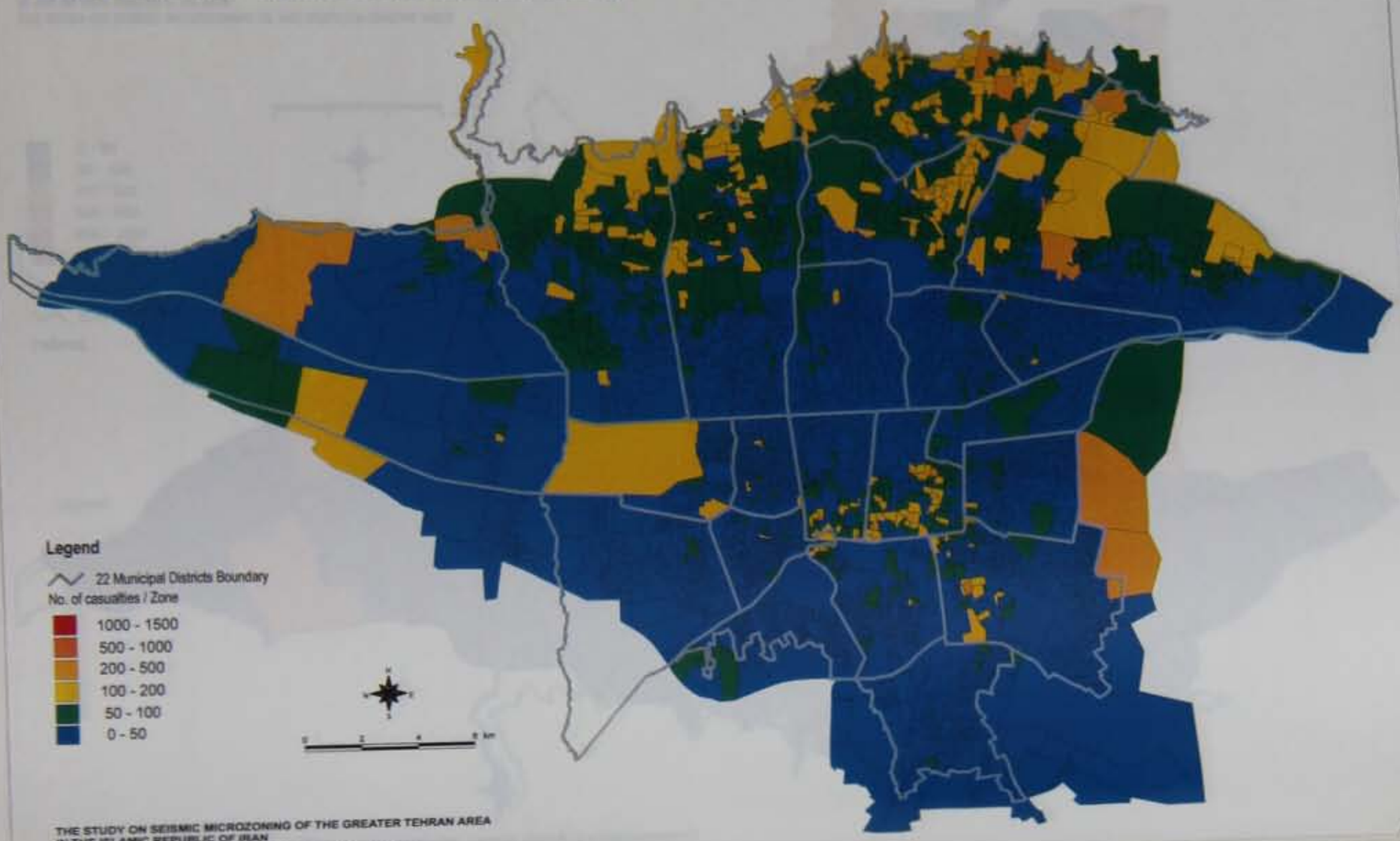

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Figure 4.2.17

Casualty Distribution - Night Full Rescue Work (NTF model)

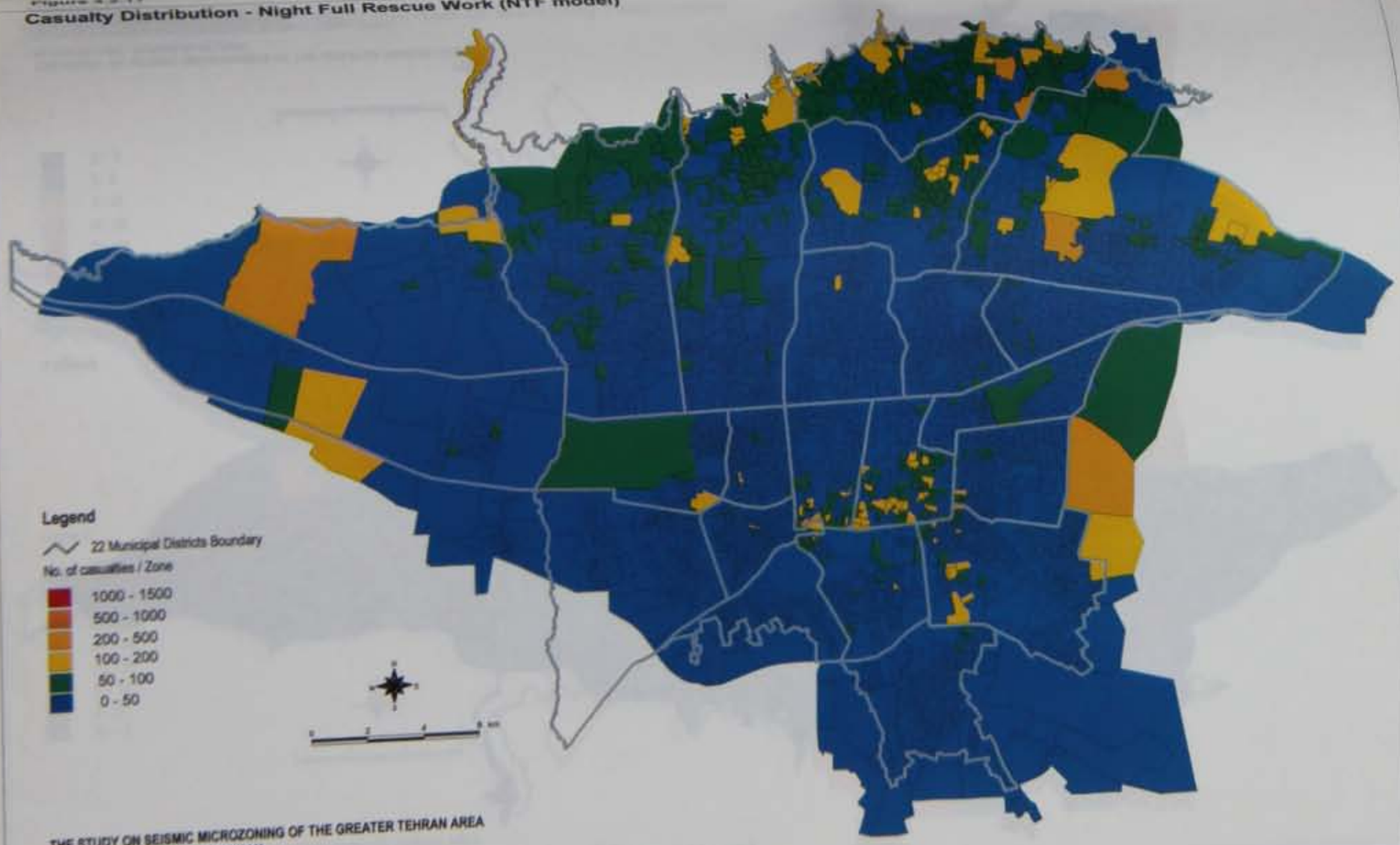

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Figure 4.2.18

Casualty Ratio Distribution - Night No Rescue Work (Ray Fault model)

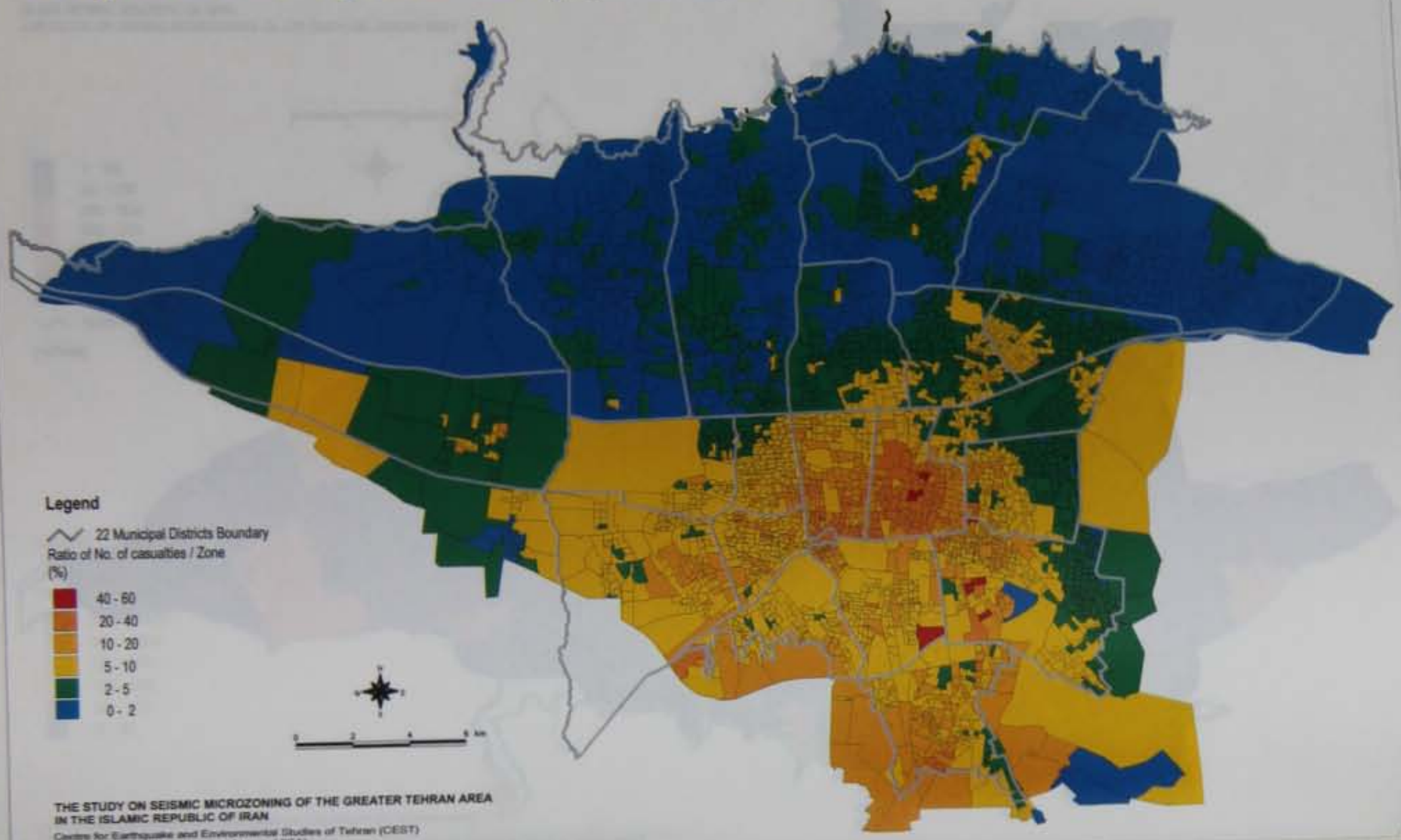

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Figure 4.2.19

Casualty Ratio Distribution - Night Full Rescue Work (Ray Fault model)

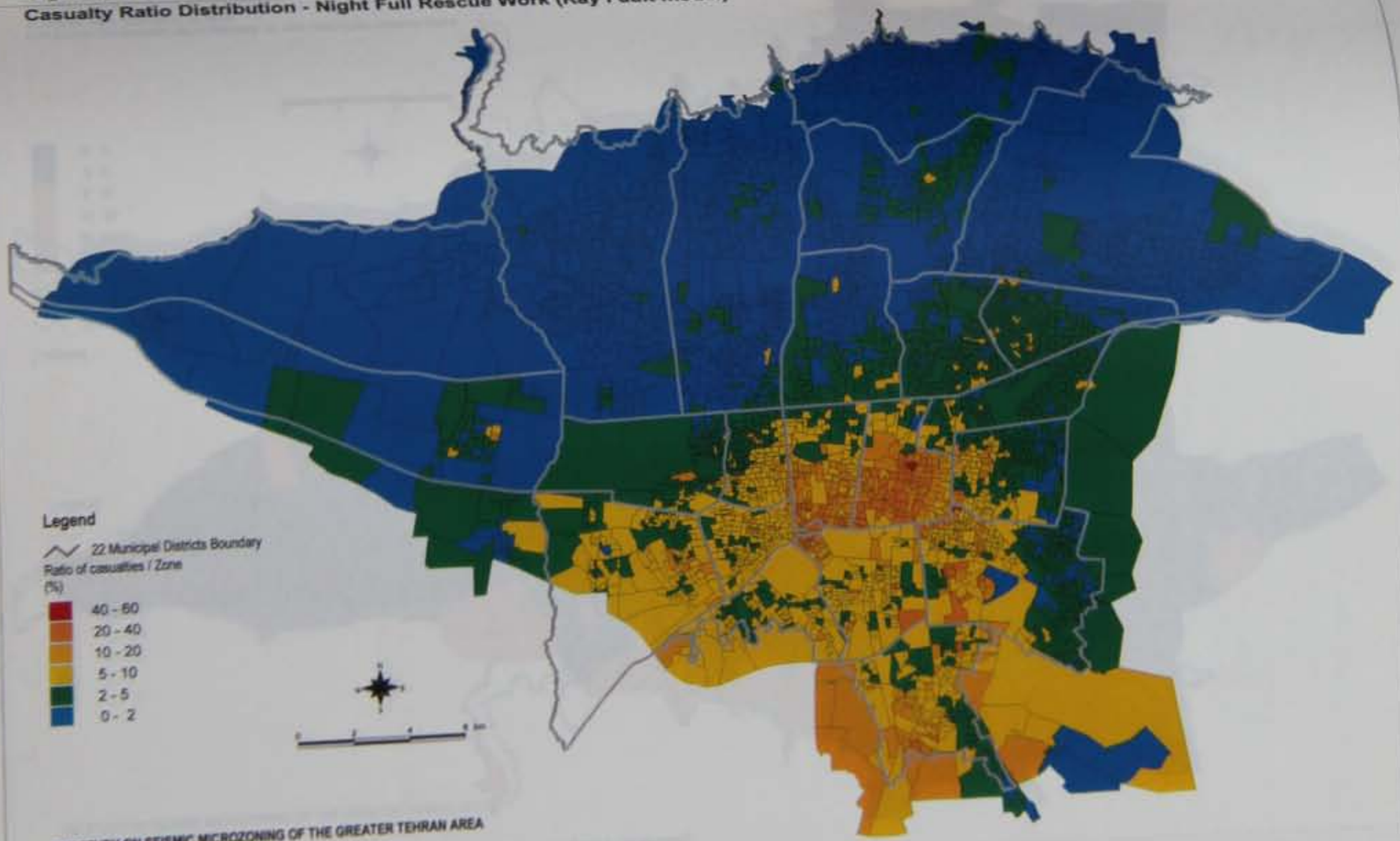

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Figure 4.2.20

Casualty Ratio Distribution - Night No Rescue Work (NTF model)

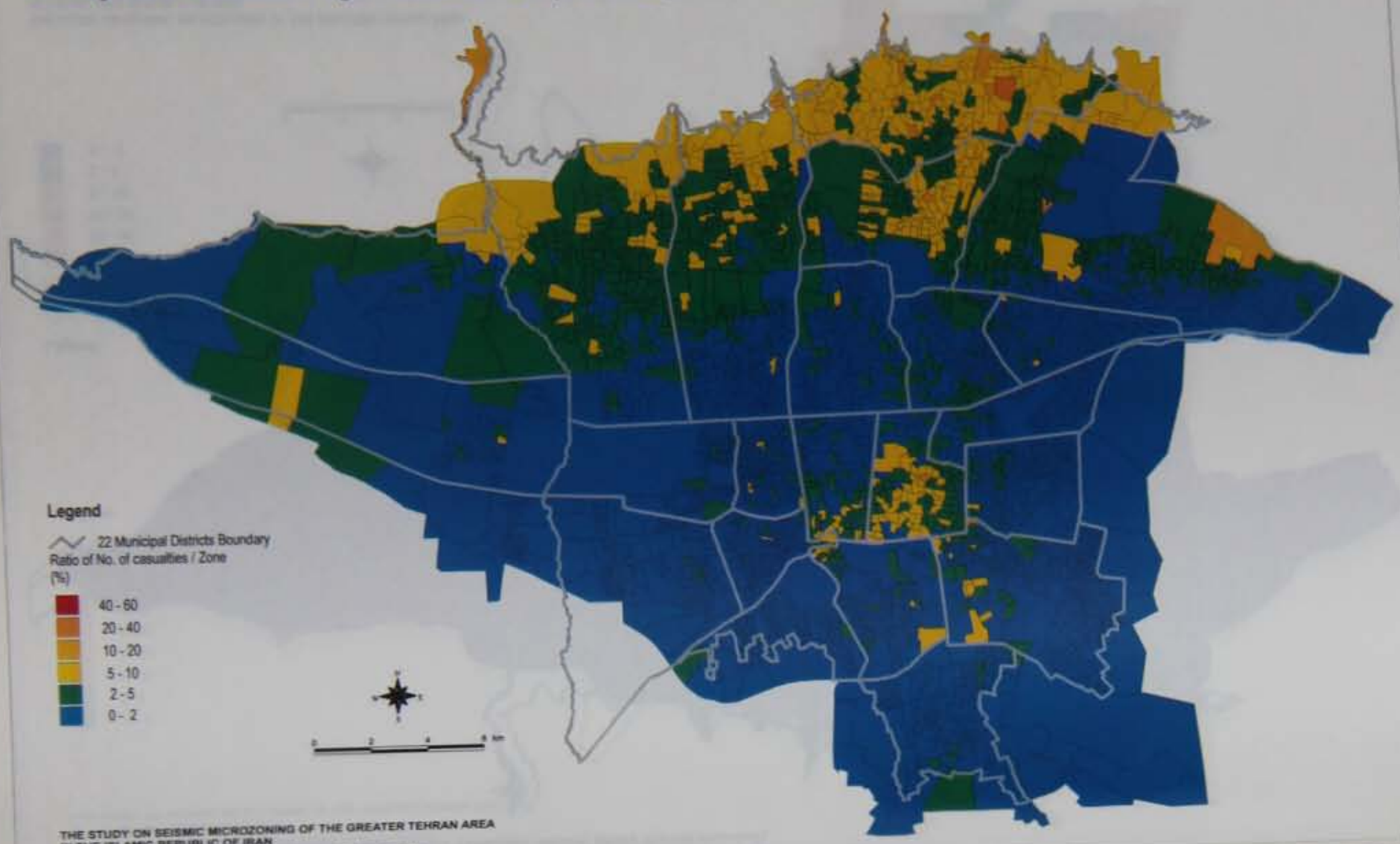

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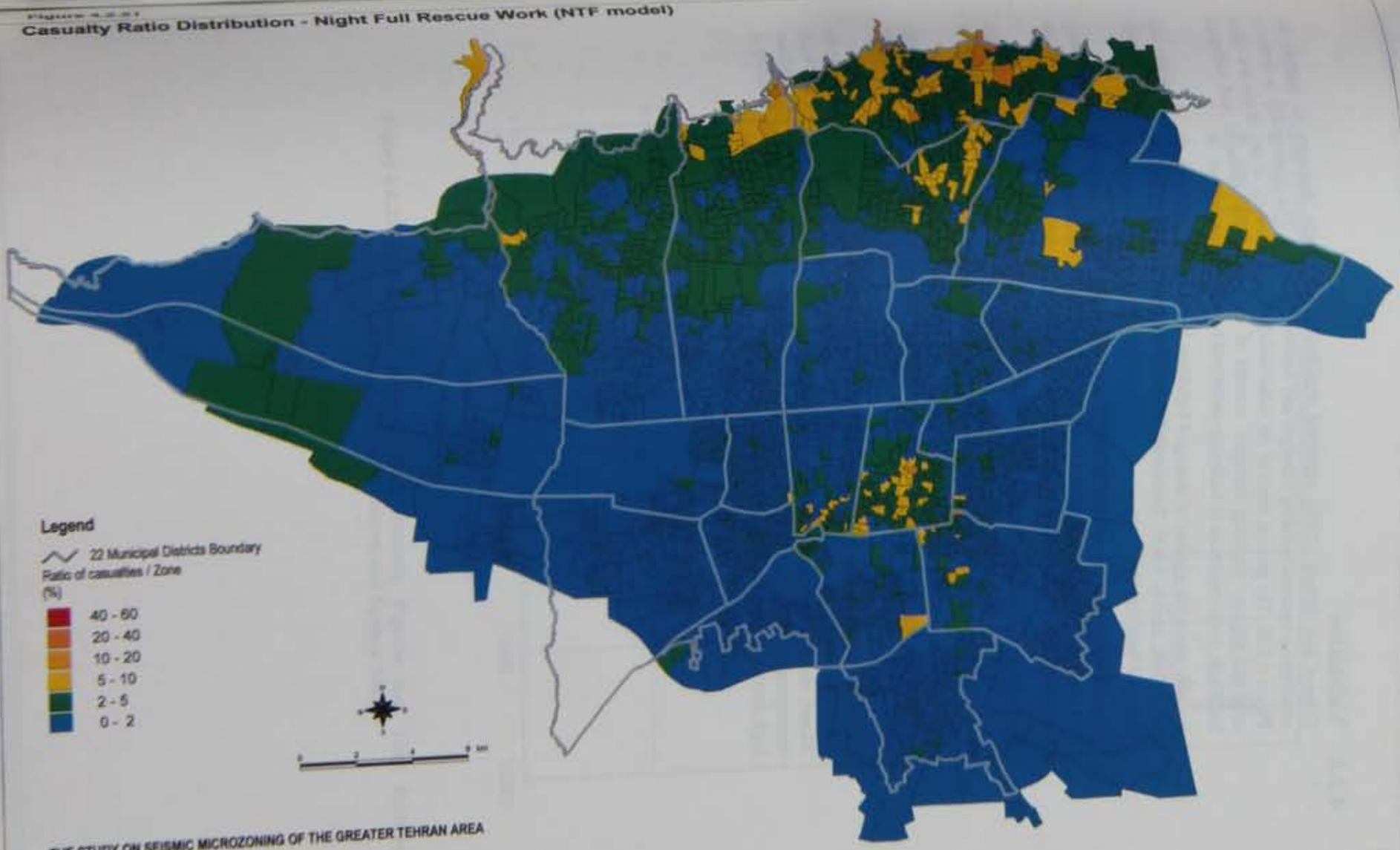
Figure 4.2.21

Casualty Ratio Distribution - Night Full Rescue Work (NTF model)



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4.2.3. Validation

Coburn and Spence (1992) surveyed worldwide earthquake damages to identify the relationship between building damages and human casualties. The relationship is shown in Figure 4.2.22. The general trend of the relationships and the results of the Study are added onto this Figure. 'Building damages' consist of only seriously damaged and collapsed buildings, to the exclusion of buildings destroyed by fire or tsunami.

In cases where the number of damaged buildings is 1,000, the distribution of fatalities will range from zero to 1,000. This range of distribution decreases as the number of heavily damaged buildings increases.

The most serious earthquake resulting in the largest number of casualties of the century was the Tang Shan Earthquake in China in 1976, killing 240 thousand people. The data are not plotted here because the number of damaged buildings is unknown.

The result of calculation in this Study will vary in terms of the night-time or daytime occurrence of the earthquake, depending on the types of emergency rescue activities available. Then the number of people killed is expressed as a range of figures.

Four types of scenario earthquakes are prepared in this Study. In all cases, the relationship between the number of damaged buildings and the number of dead people agrees with those of past earthquakes.

In the case of the Mosha Fault Model and the NTF Model, this relationship is closer to the lower limit of the general trend shown by the broken curve. In the case of the Ray Fault Model, the relationship is closer to the upper limit of the general trend. These tendencies correspond to the phenomenon of wide distribution of vulnerable buildings resulting in high death ratios per single building in the southern part of the city of Tehran.

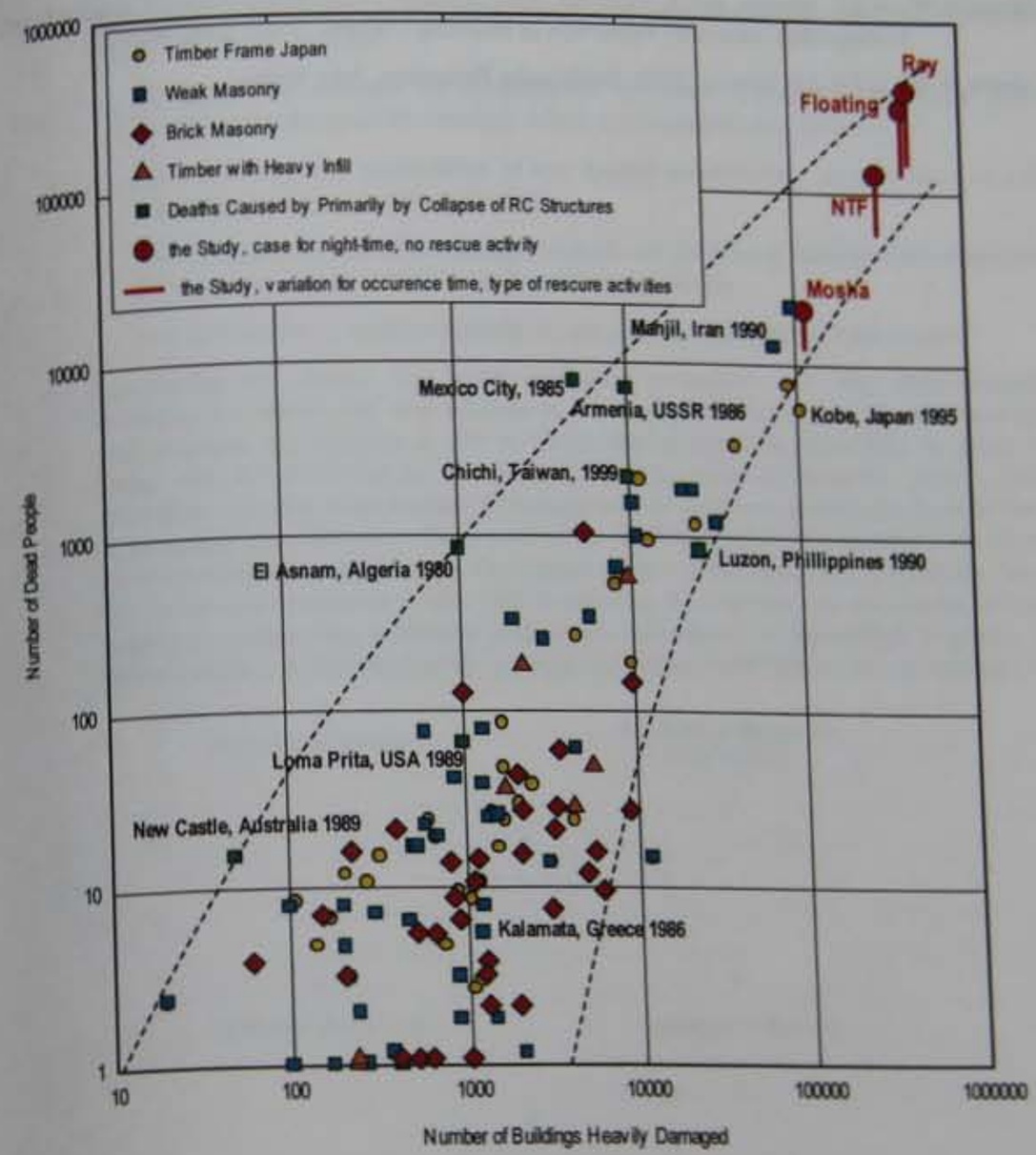


Figure 4.2.22 Relationship between Total Casualty Figures and Total Building Damage Statistics (added to Coburn and Spence 1992)

4.3.1. Method of Damage Estimation

The seismic damage possibility judgement of the bridge is based on the method proposed by Tsuneo Katayama. The method (Disaster Prevention Council of the Tokyo Metropolitan Area (1978)) is widely used in Japan for practical purpose.

Detailed procedures are explained in Appendix. The following evaluation items are taken into consideration:

- Ground type
- Liquefaction
- Girder type
- Number of individual girders
- Bearing
- Minimum bridge seat width
- Maximum height of abutment and pier
- Earthquake intensity scale
- Foundation type
- Material of abutment and pier

Result of analysis is expressed as a total score. Judgement of stability of bridges is defined as follows:

- Total score 26 and above: collapsed
- Total score below 26: stable

This criteria has some problems in the cases where relatively high total scores, but still less than 26, are obtained, because the judgement is based not upon a structural analysis, but solely on the visual inspection of bridges. Therefore, the following criteria were introduced in the Study.

- Total score 26 and over: 'collapsed'
- Total score 20 to 26: 'unstable'
- Total score below 20: 'stable'

4.3.2. Inventory Database Setup

For the analysis of bridge stability, detailed data of 160 bridges were provided by TETCO. The Study Team investigated most of the bridges and selected the bridges within the Study Area. Further, the Study Team found 79 bridges that were not listed by TETCO. These structures were investigated and integrated into the new bridge database, and 168 bridges were analysed for stability against earthquakes. Details are shown in Table 4.3.1.

Table 4.3.1 Number and Types of Bridges in Damage Analysis

Type of Bridge	Number of bridges	Within the Study Area and Location Identified (to be calculated)
Road Bridges (TETCO)	56	50
Railroad Bridges (TETCO)	51	0
Metro Bridges (TETCO)	53	39
JICA Study Team identified	79	79
Road-Road		50
Road-Metro, Railways		16
Road-River		11
Metro, Railways-River		2
Total	239	168

The following characteristics are observed when the bridges in Tehran are compared to bridges in other countries:

- Bridges that go across rivers are few. Most of the road structures are flyovers.
- Most of the road structures have been recently constructed. Therefore, they are designed with comparatively new concepts.
- Most of the bearings on piers/abutments are made of neoprene. Those are designed based upon the concept that the fixed and moving bearings are not distinguishable.

  Note: Moving bearings are bearings where the horizontal relative displacement of the bridge's axial direction is permitted, and fixed bearings are bearings where the horizontal relative displacement of the bridge's axial direction is restrained.)
- The number of spans is usually 2 to 4. A few multi-spanned continuous bridges exist.
- There are several temporary purpose bridges in the centre of the Tehran. Steel piers are used in these bridges.

The following are characteristics from the point of view of the design condition:

- It is considered that the bridges constructed after 1990 when the seismic criterion was established have a comparatively uniform earthquake resistance. However, it is considered that the earthquake resistance of the bridges that were built before 1990 is not uniform. These bridges were designed using standards of various foreign countries.
- Some bridges of uniform standard design exist also, and they may have a uniform quality.
- The construction quality of bridges is much higher compared to the construction quality of residential buildings.

4.3.3. Damage Estimation

The results of the damage estimation for the bridges are shown in Figure 4.3.2 to Figure 4.3.5. A list of bridges judged as 'collapsed' or 'unstable' is shown in Table 4.3.2.

Table 4.3.2 Results of Damage Analysis for Bridges

CODE	TETCO Crossing No	Bridge Name	Road 1	Road 2	Score				Judgment			
					Ray	North Tehran	Mosha	Floating	Ray	North Tehran	Mosha	Floating
101891	189	Nasr	Chamran	Jalal-Ale-Ahmad	23.8	23.8	14.0	23.8	U	U	s	U
102551	12/255	17 Shahrivar	Ahang	17 Shahrivar	21.2	15.0	8.8	21.2	U	s	s	U
102791	15/279	Fadaeian Eslam	Besat	Fadaeian Eslam	22.7	16.1	9.5	22.7	U	s	s	U
104731	473	Hafez	Hafez	Talaghani	33.7	23.8	14.0	23.8	C	U	s	U
104741	474	Hafez	Jomhury	Hafez	33.7	23.8	14.0	23.8	C	U	s	U
104751	475	Karim-Khan	Karim-Khan	Gharany	33.7	23.8	14.0	23.8	C	U	s	U
104761	476	Enghelab	Enghelab	Hafez	33.7	23.8	14.0	23.8	C	U	s	U
104771	477	Saadi	Saadi	Ekbatan	33.7	23.8	14.0	23.8	C	U	s	U
104781	478	Sepah	Sepah	Enghelab	23.8	23.8	14.0	23.8	U	U	s	U
202961	296	Azadegan - Tondguyan	Azadegan	Tondguyan	26.7	18.9	11.1	18.9	C	s	s	s
210081	-	Navab – Helal Ahmar	Navab	Helal Ahmar	24.9	17.7	10.4	24.9	U	s	s	U

C	Collapsed
U	Unstable
s	Stable

The results are classified into 3 types as follows:

- Score 26 and over: 'collapsed' (indicated by red mark)
- Score 20 to 26: 'unstable' (indicated by yellow mark)
- Score below 20: 'stable' (indicated by blue mark)

Compared to residential building damage, the number and damage ratio of bridges is low. Bridges are made for public purposes; therefore, detailed designs are usually applied and the construction quality is relatively high. The same kind of phenomenon is observed in other countries as well.

The instance of damage is small; however, the social influence is very high. Damaged bridges lose their function as roads after an earthquake. That leads to a very serious situation for rescue and restoration efforts as well as for the traffic system. The traffic flow is controlled more by flyovers than by signal systems at major crossings. Therefore, once flyovers collapse then the disruption in traffic is doubled, because not only is the upper road unavailable but the lower road becomes unavailable as well.

The bridges judged as 'collapsed' are almost all limited to temporary purposes. Their piers are made with steel. However, not all of the temporary bridges which have steel piers are to be rated 'collapsed'. The bridges, that are judged as 'unstable', require attention, because seismic stability is evaluated only from information obtained by the visual inspection of the bridges. Quantitative investigations are required for these bridges. This should include

detailed structural calculations and an investigation of the reinforcement and the thickness of the steel material, etc.

The characteristics of problems observed in bridges are as follows:

- In piers made with reinforced concrete, the hoop is not considered to be adequate and shear failure can easily occur.
- In piers made with steel, the density of the bulkhead is not sufficient and, therefore, the possibility of local buckling exists.

The characteristics of 'collapsed' bridges are as follows:

- 104731 Hafez - Talaghani
- 104741 Jomhury - Hafez
- 104751 Karim-Khan - Gharany
- 104761 Enghelab - Hafez
- 104771 Saadi - Ekbatan

These 5 bridges with steel piers were constructed for temporary purposes.

- 202961 Azadegan - Tondguyan

The peak ground acceleration reaches 460 gal in the case of Ray Fault Model. This bridge was constructed very recently. It was observed that the girders were not connected tightly, and it is considered that these girders are interfering with and striking against one another. Therefore, 'girder type' was categorised as '2 or more spans' and 'simple' in the damage estimation by the Study Team.

If the detailed structure is identified then there is a possibility that this judgement may change.

The characteristics of 'unstable' bridges are as follows:

- 104781 Sepah - Enghlab
- 101891 Chamron - Jalal-Ale-Ahmad
- 102551 Ahang - 17 Shahrivar

These 3 bridges with steel piers were constructed for temporary purposes.

- 102791 Besat - Fadaeian Eslam

This bridge was constructed recently. Piers are considered to be reinforced or pre-cast concrete. 'Girder type' is categorised as '2 or more spans' and 'more than 1 continuous' in the TETCO list. The bridge is long;herefore, it was considered that temperature changes would lead to serious expansion of girders and a multi-span structure was used to avoid the expansions. It is considered that these girders are interfering with and striking against one another.

Figure 4.3.2

Damage of Bridges (Ray Fault model)

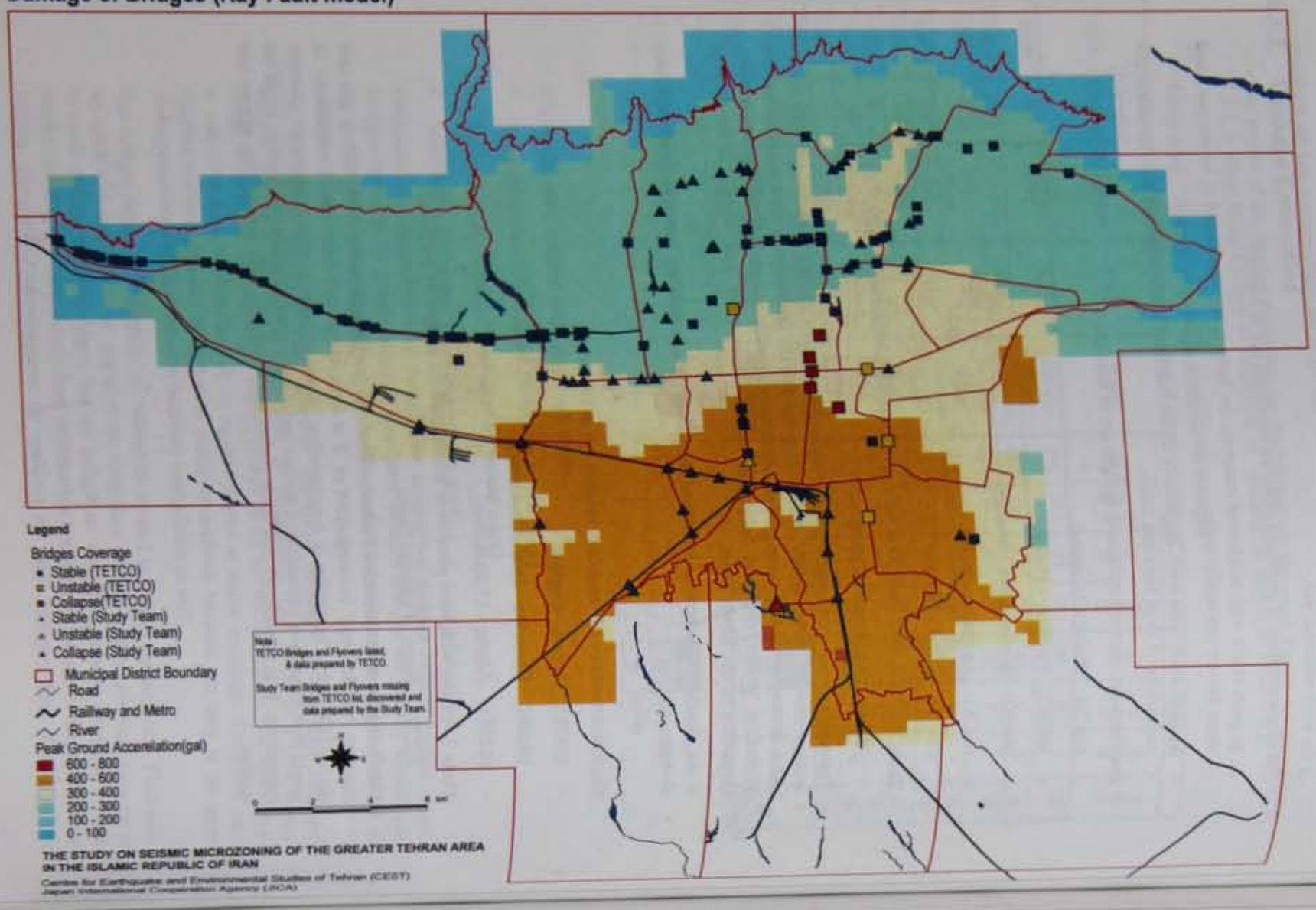


Figure 4.3.3

Damages of Bridges (NTF model)

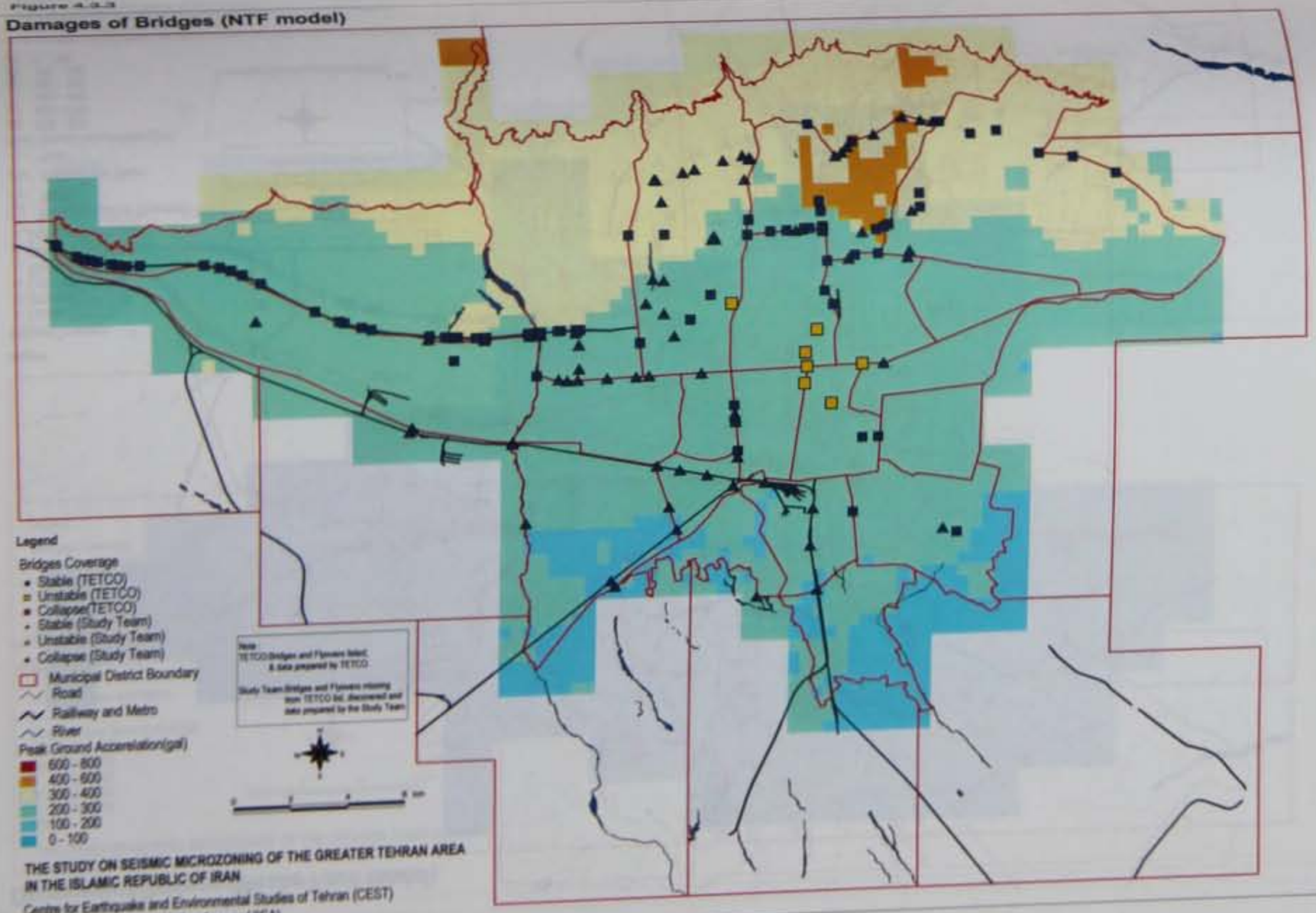
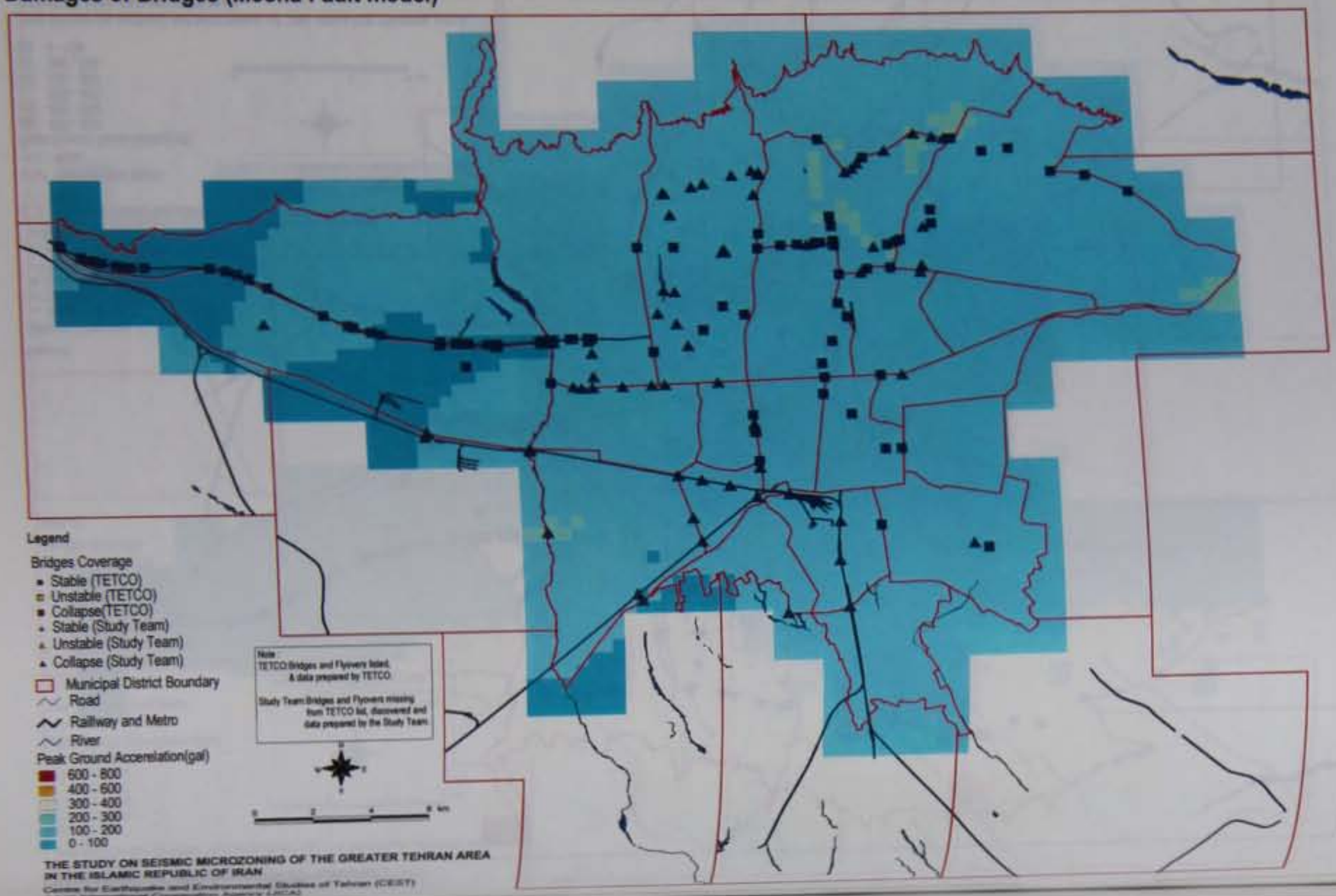


Figure 4.3.4

Damages of Bridges (Mosha Fault model)



Damages of Bridges (Floating model)

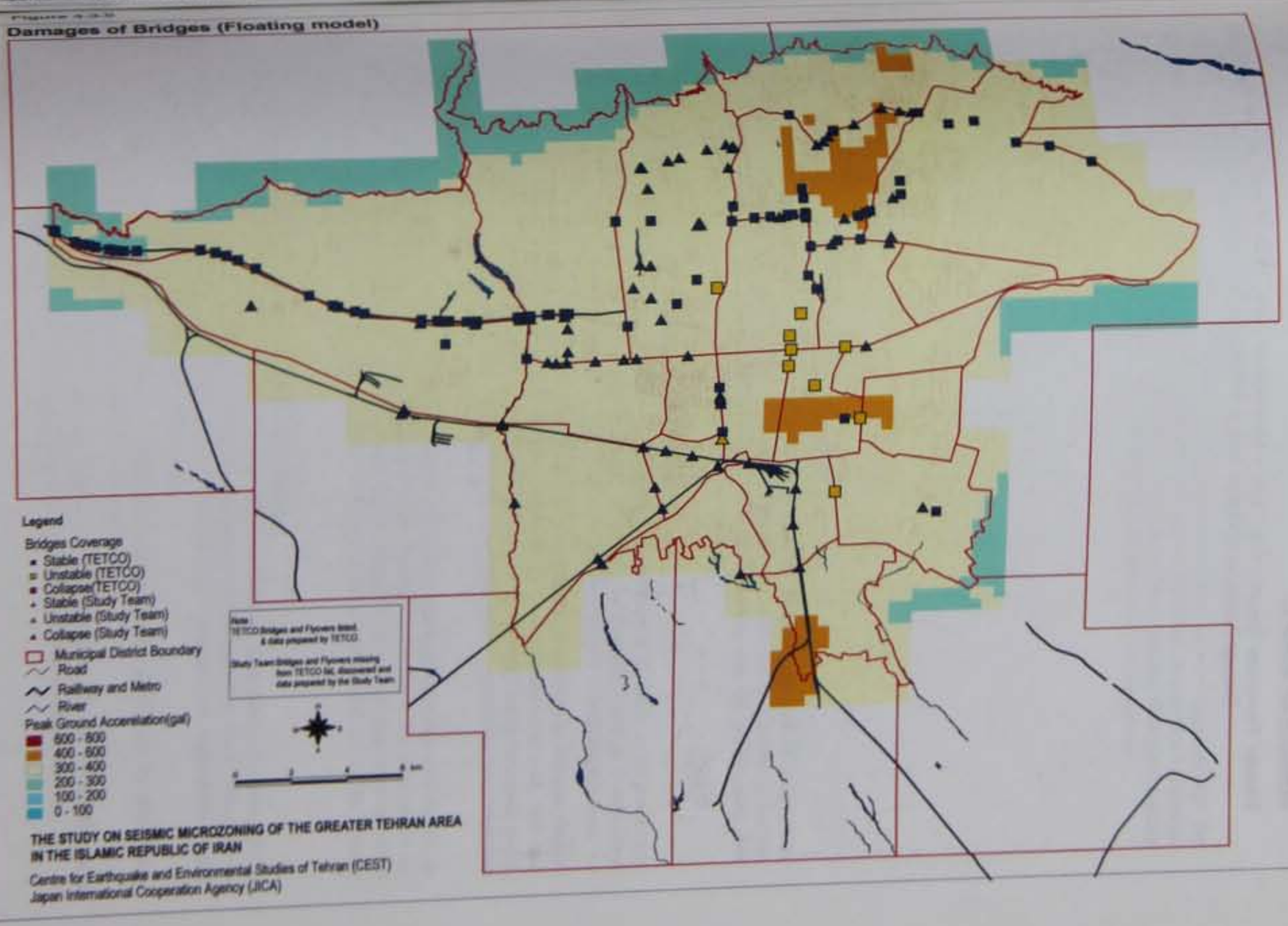


Table 4.4.1 Structure of Governmental Facility Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	1	8	0	0	0	0	0	0	1	10
2	0	0	2	0	0	0	0	0	0	0	2
3	0	0	1	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	1	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	2	0	0	0	0	0	0	7
8	2	1	2	2	0	0	0	0	0	0	2
9	0	1	0	1	0	0	0	0	0	0	3
10	1	0	2	0	0	0	0	0	0	0	2
11	0	0	0	2	0	0	0	0	0	0	1
12	0	0	0	1	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	5
15	0	0	2	3	0	0	0	0	0	0	9
16	6	1	2	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	1
18	0	0	1	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	3	3
20	0	0	0	0	0	0	0	0	0	0	2
21	1	1	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
sum	0	0	0	0	0	0	0	0	0	4	49
	10	5	21	9	0	0	0	0	0		

weak structure = 0.0 %
weakest structure = 0.0 %

Table 4.4.2 Structure of Police Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	0	0	0	0	0	0	0	12	12
2	0	0	3	0	0	0	0	0	0	1	4
3	0	0	15	0	0	0	0	0	0	0	15
4	0	0	4	0	0	0	0	0	0	1	6
5	1	0	0	2	0	0	0	0	0	0	2
6	0	0	0	0	0	0	0	0	0	4	4
7	0	0	0	0	0	0	0	0	0	1	13
8	0	5	5	2	0	0	0	0	0	0	1
9	0	0	0	1	0	0	0	0	0	0	2
10	0	0	2	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	1	1	0	1	0	0	2	0	5
13	0	0	0	0	0	0	0	0	0	5	5
14	0	0	0	1	0	0	0	0	0	0	1
15	0	0	3	1	0	0	0	0	0	0	4
16	0	0	3	0	0	0	0	0	0	0	3
17	0	0	0	0	0	0	0	0	0	4	4
18	0	0	1	1	0	0	0	0	0	0	2
19	0	0	1	0	0	0	0	0	0	0	2
20	1	0	0	0	0	0	0	0	0	1	1
21	0	0	0	5	0	0	0	0	0	0	5
22	0	0	1	0	0	0	0	0	0	0	1
Sum	0	0	0	0	0	0	0	0	0	0	0
	2	5	39	14	0	1	0	0	2	29	92

weak structure = 3.3 %
weakest structure = 2.2 %

Table 4.4.3 Structure of Traffic Police Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	2	0	0	0	0	0	0	0	2
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	1	1	0	0	0	0	0	2
6	0	0	0	0	0	0	0	0	0	1	1
7	0	0	0	1	0	0	0	0	0	1	2
8	0	0	0	1	0	0	0	0	0	1	2
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	2	0	0	0	0	0	0	2
11	0	0	1	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	1	0	1
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	1	0	0	0	0	0	0	0	1
15	0	0	2	0	0	0	0	0	0	0	2
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	6	5	1	0	0	0	1	3	16

weak structure = 12.5 %
weakest structure = 6.3 %

Table 4.4.4 Structure of Fire Fighting Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	1	0	0	0	0	0	0	0	1
2	0	0	1	2	0	1	0	0	0	0	4
3	1	0	0	2	1	0	0	0	0	0	4
4	0	0	2	1	0	1	0	0	0	0	4
5	2	0	0	1	0	1	0	0	0	0	4
6	2	0	1	1	0	0	0	0	0	0	4
7	0	0	0	1	0	0	0	0	0	0	1
8	0	0	0	1	0	1	0	0	0	0	2
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	2	0	0	1	0	0	0	0	3
11	1	0	3	1	0	1	0	0	0	0	6
12	0	0	3	0	0	0	0	0	0	0	3
13	0	0	2	1	0	0	0	0	0	0	3
14	0	0	1	1	0	0	0	0	0	0	2
15	0	0	1	1	0	1	0	0	0	0	3
16	0	0	1	0	0	0	0	0	0	0	1
17	0	0	0	0	0	1	0	0	0	0	1
18	0	0	0	0	0	1	0	0	0	0	1
19	0	0	1	0	0	0	0	0	0	0	1
20	0	0	0	1	0	1	0	0	0	0	2
21	1	0	0	0	0	1	0	0	0	0	2
22	1	0	0	1	0	0	0	0	0	0	2
Sum	8	0	19	15	1	11	0	0	0	0	54

weak structure = 22.2 %
weakest structure = 0.0 %

Table 4.4.5 Structure of Hospital Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	1	1	0	0	0	0	0	0	16	18
2	0	0	3	0	0	0	0	0	0	0	3
3	0	1	3	1	0	0	0	0	0	5	10
4	0	0	6	0	0	1	0	0	0	1	8
5	0	0	4	0	0	0	0	0	0	1	5
6	0	3	11	0	0	0	0	0	0	15	29
7	0	2	4	5	0	1	0	0	0	10	22
8	0	1	0	3	0	1	0	0	0	0	5
9	0	0	2	0	0	0	0	0	0	0	2
10	0	0	7	2	0	0	0	1	0	1	11
11	0	0	6	3	0	1	0	0	0	3	13
12	0	0	6	0	0	1	0	0	0	6	13
13	0	0	1	0	0	1	0	0	0	2	4
14	1	0	5	6	0	0	0	0	0	1	13
15	0	0	1	0	0	1	0	0	0	0	2
16	0	0	4	0	1	1	0	0	0	0	6
17	0	1	0	0	0	1	0	0	0	0	2
18	0	1	4	1	0	0	0	0	0	0	6
19	0	0	0	0	0	0	0	0	0	2	2
20	0	0	0	1	0	0	0	0	0	2	3
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
Sum	1	10	68	22	1	9	0	1	0	65	177

weak structure = 6.2 %
weakest structure = 0.6 %

Table 4.4.6 Structure of Elementary School Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	15	24	12	15	0	0	1	0	67
2	16	0	45	31	1	12	0	0	1	0	106
3	3	0	22	8	2	3	0	0	0	0	38
4	2	0	47	18	0	8	0	1	0	3	79
5	2	0	20	14	2	7	0	0	0	0	45
6	0	0	0	0	0	0	0	0	0	57	57
7	1	0	25	19	0	1	0	1	2	4	53
8	0	0	9	44	0	5	0	0	0	0	58
9	0	0	33	0	0	0	0	0	0	1	34
10	0	0	1	35	0	0	0	2	1	11	50
11	0	0	11	40	0	3	0	13	3	0	70
12	0	0	2	9	0	0	0	0	0	2	13
13	0	0	16	49	0	0	0	0	0	3	68
14	4	0	14	23	0	1	0	0	0	4	46
15	11	0	28	83	9	18	0	0	0	0	149
16	2	0	16	36	0	4	0	0	1	0	59
17	2	0	5	22	0	0	0	0	1	0	30
18	8	0	33	4	0	5	0	0	0	0	50
19	0	0	3	14	0	1	0	0	0	0	18
20	3	0	32	37	1	0	0	0	0	0	73
21	1	0	0	0	0	3	0	0	0	1	5
22	0	0	0	0	0	1	0	0	0	0	1
Sum	55	0	377	510	27	87	0	17	10	86	1,169

weak structure = 12.1 %
weakest structure = 2.3 %

District 15: Elementary School + Intermediate School + High School

Table 4.4.7 Structure of Intermediate School Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	6	22	2	6	0	0	1	0	37
2	13	0	39	33	4	11	0	1	0	0	101
3	7	0	24	7	0	1	0	0	0	0	39
4	5	0	41	1	2	14	0	0	0	0	63
5	5	0	19	8	2	14	0	0	0	1	49
6	0	0	0	0	0	0	0	0	0	47	47
7	3	0	19	8	0	2	0	0	3	5	40
8	0	0	0	29	0	3	0	0	0	0	32
9	1	0	24	0	0	1	0	0	0	0	26
10	0	0	1	19	0	0	0	0	0	13	33
11	1	0	16	32	0	0	0	3	1	2	55
12	0	0	2	9	0	0	0	0	0	1	12
13	0	0	12	33	0	0	0	0	0	0	45
14	1	0	4	12	0	2	0	0	0	1	20
15	0	0	0	0	0	0	0	0	0	0	0
16	1	0	10	19	0	9	0	0	0	0	39
17	0	0	2	8	0	1	0	0	1	14	26
18	4	0	20	4	1	8	0	0	0	2	39
19	2	0	4	16	0	0	0	0	0	0	22
20	7	0	14	19	3	0	0	0	0	2	45
21	1	0	0	0	0	2	0	0	0	0	3
22	0	0	1	3	0	0	0	0	0	0	4
Sum	51	0	258	282	14	74	0	4	6	88	777

weak structure = 12.6 %
weakest structure = 1.3 %

Table 4.4.8 Structure of High School Buildings by District

District No	Structure										sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	0	3	20	3	18	0	0	0	0	44
2	21	0	37	16	7	15	0	0	0	0	96
3	5	0	35	2	0	6	0	0	0	0	48
4	11	0	31	8	1	8	0	0	0	0	59
5	4	0	25	9	1	9	0	0	0	1	49
6	0	0	3	0	0	0	0	0	0	35	38
7	0	0	21	9	0	3	0	0	0	2	35
8	0	0	2	28	0	9	0	0	0	0	39
9	0	0	24	1	0	0	0	0	0	2	27
10	0	0	1	15	0	1	1	0	0	16	34
11	2	0	15	21	1	0	0	3	0	2	44
12	1	0	6	8	0	0	1	0	0	0	16
13	0	0	5	17	0	0	0	0	0	4	26
14	0	0	0	0	0	0	0	0	0	42	42
15	0	0	1	0	0	0	0	0	0	0	1
16	0	0	11	19	1	4	0	0	0	2	37
17	6	0	3	13	0	1	0	0	0	0	23
18	11	0	5	2	4	6	0	0	0	0	28
19	4	0	3	2	0	0	0	0	0	0	9
20	8	0	9	27	4	4	0	0	0	1	53
21	3	0	1	0	1	3	0	0	0	0	8
22	0	0	0	0	0	0	0	0	0	0	0
Sum	76	0	241	217	23	87	2	3	0	107	756

weak structure = 15.2 %
weakest structure = 0.4 %

Table 4.4.9 Structure of Higher Education Center Buildings by District

District No	Structure										Sum
	Steel-1	RC-0	Steel-2	S&B	RC-1	RC-2	Wood	B&B	Adobe	Unknown	
1	0	2	1	7	0	3	0	0	0	3	16
2	2	2	11	5	0	4	0	0	0	1	25
3	3	1	33	0	0	4	0	0	0	0	41
4	4	1	6	1	0	5	0	0	0	1	18
5	2	1	2	1	0	0	0	0	0	0	6
6	0	0	0	0	0	0	0	0	0	55	55
7	0	3	11	1	0	4	0	0	0	2	21
8	0	0	0	0	0	0	0	0	0	0	0
9	1	0	4	0	0	0	0	0	0	0	5
10	0	0	1	0	0	0	0	0	0	0	1
11	0	0	3	8	0	2	0	0	0	0	13
12	0	0	1	3	0	0	0	0	0	0	4
13	0	0	0	3	0	0	0	0	0	2	5
14	0	0	1	0	0	0	0	0	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	1	0	0	0	0	5
18	1	0	3	0	0	0	0	0	0	1	1
19	0	0	0	0	0	0	0	0	0	0	6
20	5	0	1	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	65	223
Sum	18	10	78	29	0	23	0	0	0		

Weak structure = 10.3 %
Weakest structure = 0.0 %

(3) Damage Estimation

The definition of damages is as follows:

Damage of Public Facilities	Heavily damaged or collapsed, impossible to use without reconstruction or repair
Unit	Building If the facility has several different buildings, only the main building is considered.
Cause of Damage	Seismic vibration

The results of damage estimation are listed in Table 4.4.10 to Table 4.4.13. The number of damaged buildings and the damage ratios in the case of Ray Fault Model are shown in Figure 4.4.1. The distribution of damage ratios is shown in Figure 4.4.2 to Figure 4.4.7.

The damage ratio in the southern Districts 16 and 19 is relatively high. This damage distribution is similar to that of residential buildings. The results of the damage analysis show that all public facilities will suffer damages to the same extent as residential buildings.

Public facilities are important for the seismic disaster management plan. Governmental facilities will function as headquarters for the disaster management. Police stations and traffic police function as centres for maintaining public and traffic order. Fire fighting stations function as the main bodies for fire fighting and rescue operations. Hospitals are essential facilities for the treatment of casualties and injuries. Schools will be used as refugee camps. Children who will lead the country in the future study in those schools.

Therefore, all public facilities are required to have much more aseismic resistance than the residential buildings.

However, this study shows that public facilities will suffer damages as severe as those of residential buildings. This means the public facilities in Tehran will be difficult to use for disaster management in case of an earthquake.

Table 4.4.10 Number of Damage and Damage Ratio of Facilities – Ray Fault Model

District	Number of Damage and Damage Ratio (%)																			
	Govern-mental Facility		Police		Traffic Police		Fire Fighting		Hospital		Elementary School		Intermediate school		High School		University	
1	2	(18)					0	(15)	0	(13)	24	(36)	12	(34)	18	(42)	4	(33)
2	1	(28)	1	(24)	0	(22)	2	(37)	1	(21)	37	(35)	37	(37)	35	(37)	9	(36)
3	0	(23)	3	(22)			2	(43)	2	(30)	15	(39)	13	(34)	17	(35)	13	(32)
4			1	(20)			1	(32)	2	(27)	22	(29)	20	(32)	17	(28)	5	(30)
5	0	(23)	1	(39)	1	(58)	2	(40)	1	(23)	17	(38)	21	(44)	18	(37)	2	(24)
6							2	(40)	5	(35)					1	(22)		
7	3	(37)	4	(35)	1	(45)	1	(59)	6	(47)	24	(50)	17	(49)	16	(47)	9	(48)
8	1	(41)	1	(53)	0	(43)	2	(75)	3	(55)	33	(56)	19	(61)	25	(63)		
9	1	(43)	1	(43)					1	(43)	14	(41)	11	(41)	10	(42)	2	(46)
10	1	(62)			1	(61)	2	(50)	5	(53)	29	(75)	15	(77)	13	(74)	0	(38)
11	1	(69)	5	(91)	1	(61)	4	(66)	7	(70)	59	(84)	40	(76)	30	(71)	10	(74)
12					1	(100)	2	(61)	4	(61)	8	(73)	8	(69)	10	(65)	2	(57)
13			1	(52)			1	(38)	1	(64)	33	(50)	23	(51)	11	(52)	2	(56)
14	2	(49)	2	(48)	0	(39)	1	(51)	7	(55)	24	(57)	11	(60)			1	(46)
15	4	(47)	1	(39)	1	(55)	2	(73)	2	(81)	109				(73)			
16							1	(59)	4	(70)	45	(75)	31	(79)	27	(76)		
17	1	(65)	2	(77)			1	(100)	2	(81)	25	(82)	10	(87)	18	(77)		
18			1	(68)			1	(100)	4	(65)	33	(66)	27	(72)	21	(75)	3	(69)
19							1	(63)			15	(82)	17	(77)	6	(66)		
20	1	(64)	4	(83)			2	(90)	1	(86)	55	(76)	33	(76)	43	(82)	4	(67)
21			0	(41)			1	(45)			3	(81)	2	(75)	5	(64)		
22							1	(28)			1	(64)	1	(27)				
sum	18	(40)	27	(43)	7	(52)	28	(52)	56	(50)	623	(57)	369	(54)	340	(52)	66	(42)

Note: Blank space notifies lack of facility in the area.

Table 4.4.11 Number of Damage and Damage Ratio of Facilities – NTF Model

District	Number of Damage and Damage Ratio (%)																							
	Govern-mental Facility		Police		Traffic Police		Fire Fighting		Hospital		Elementary School		Intermediate school		High School		University	
1	4	(41)					0	(42)	1	(38)	48	(72)	25	(69)	34	(78)	9	(65)
2	1	(27)	1	(23)	1	(25)	2	(57)	1	(27)	41	(38)	41	(40)	38	(40)	9	(37)
3	0	(29)	5	(32)			2	(57)	2	(45)	21	(56)	19	(50)	24	(51)	18	(44)
4			1	(22)			2	(49)	3	(38)	27	(36)	25	(40)	22	(37)	8	(45)
5	0	(31)	1	(40)	1	(44)	2	(44)	1	(27)	19	(43)	23	(48)	20	(42)	2	(29)
6							1	(24)	3	(22)					1	(22)		
7	2	(27)	3	(24)	0	(39)	0	(35)	4	(32)	16	(33)	12	(35)	10	(31)	7	(34)
8	1	(29)	0	(38)	0	(38)	1	(55)	2	(41)	22	(38)	13	(41)	18	(45)		
9	1	(16)	0	(17)					0	(16)	5	(17)	5	(18)	4	(17)	1	(16)
10	1	(30)			1	(32)	1	(34)	3	(28)	14	(35)	6	(30)	6	(35)	0	(19)
11	0	(34)	3	(64)	0	(17)	2	(29)	3	(28)	32	(46)	17	(33)	13	(31)	5	(35)
12					1	(100)	1	(19)	2	(26)	3	(30)	3	(30)	5	(29)	1	(31)
13			0	(29)			1	(25)	1	(44)	18	(27)	12	(27)	6	(27)	1	(31)
14	1	(22)	1	(18)	0	(17)	0	(20)	3	(21)	10	(23)	5	(27)			0	(15)
15	1	(14)	0	(13)	0	(14)	1	(29)	1	(48)	43				(29)			
16							0	(18)	2	(30)	16	(27)	13	(33)	10	(28)		
17	0	(19)	1	(24)			1	(65)	1	(42)	9	(30)	5	(38)	6	(25)		
18			0	(18)			1	(68)	1	(18)	11	(23)	10	(26)	9	(30)	1	(28)
19							0	(13)			4	(24)	4	(20)	1	(16)		
20	0	(11)	1	(22)			1	(42)	0	(18)	13	(18)	8	(19)	12	(22)	1	(13)
21			0	(18)			1	(49)			2	(53)	2	(50)	3	(41)		
22							1	(34)			1	(87)	2	(42)				
sum	11	(25)	18	(28)	5	(35)	21	(38)	33	(29)	376	(35)	250	(36)	242	(37)	61	(39)

Note: Blank space notifies lack of facility in the area.

Table 4.4.12 Number of Damage and Damage Ratio of Facilities – Mosha Fault Model

District	Number of Damage and Damage Ratio (%)																	
	Govern-mental Facility		Police		Traffic Police		Fire Fighting		Hospital		Elementary School		Intermediate school		High School		University	
1	1	(10)					0	(9)	0	(7)	14	(21)	8	(20)	10	(24)	3	(20)
2	0	(6)	0	(6)	0	(5)	1	(13)	0	(6)	10	(9)	9	(9)	9	(10)	2	(9)
3	0	(8)	1	(8)			1	(15)	1	(10)	6	(15)	5	(12)	6	(13)	5	(13)
4			0	(8)			1	(16)	1	(11)	10	(13)	9	(14)	7	(12)	3	(16)
5	0	(4)	0	(9)	0	(13)	0	(9)	0	(5)	4	(8)	5	(10)	4	(8)	0	(5)
6							0	(7)	1	(7)					0	(7)		
7	1	(9)	1	(8)	0	(16)	0	(13)	1	(10)	7	(14)	6	(17)	4	(11)	2	(12)
8	0	(9)	0	(12)	0	(10)	0	(21)	1	(13)	7	(12)	4	(13)	6	(15)		
9	0	(5)	0	(5)					0	(4)	2	(5)	2	(6)	1	(5)	0	(5)
10	0	(9)			0	(8)	0	(12)	1	(9)	5	(12)	2	(9)	2	(11)	0	(5)
11	0	(8)	2	(48)	0	(6)	1	(9)	1	(9)	14	(21)	7	(13)	5	(12)	1	(11)
12					1	(93)	0	(9)	1	(10)	1	(13)	1	(11)	2	(12)	0	(9)
13			0	(12)			0	(8)	0	(17)	7	(10)	5	(11)	2	(11)	0	(11)
14	1	(9)	0	(8)	0	(7)	0	(9)	1	(9)	4	(10)	2	(12)			0	(7)
15	1	(6)	0	(6)	0	(5)	0	(13)	0	(22)	18				(12)			
16							0	(7)	1	(13)	7	(12)	6	(14)	4	(11)		
17	0	(8)	0	(9)			0	(35)	0	(18)	4	(14)	2	(19)	2	(10)		
18			0	(7)			0	(25)	0	(7)	5	(10)	4	(10)	3	(12)	1	(10)
19							0	(4)			1	(8)	2	(7)	1	(5)		
20	0	(6)	0	(9)			0	(22)	0	(7)	6	(8)	4	(8)	5	(10)	0	(7)
21			0	(6)			0	(9)			1	(20)	1	(18)	1	(13)		
22							0	(5)			0	(14)	0	(5)				
sum	4	(8)	7	(11)	2	(16)	7	(12)	11	(9)	133	(12)	81	(12)	75	(12)	18	(12)

Note: Blank space notifies lack of facility in the area.

Table 4.4.13 Number of Damage and Damage Ratio of Facilities – Floating Model

District	Number of Damage and Damage Ratio (%)																	
	Govern-mental Facility		Police		Traffic Police		Fire Fighting		Hospital		Elementary School		Intermediate school		High School		University	
1	3	(32)					0	(32)	1	(30)	41	(62)	22	(58)	31	(69)	7	(55)
2	1	(33)	1	(31)	1	(30)	2	(56)	1	(31)	47	(44)	47	(46)	45	(47)	11	(45)
3	0	(35)	6	(37)			3	(67)	3	(55)	24	(62)	22	(56)	27	(56)	21	(51)
4			2	(32)			2	(51)	3	(40)	33	(43)	29	(46)	25	(43)	8	(49)
5	0	(32)	1	(51)	1	(66)	2	(49)	1	(32)	22	(49)	26	(54)	23	(47)	2	(33)
6							1	(36)	4	(31)					1	(30)		
7	2	(35)	4	(34)	1	(48)	1	(50)	5	(45)	22	(45)	16	(46)	14	(43)	9	(45)
8	1	(41)	1	(53)	1	(54)	1	(71)	3	(55)	31	(53)	18	(56)	24	(60)		
9	1	(34)	1	(34)					1	(33)	12	(35)	9	(36)	9	(36)	2	(36)
10	1	(57)			1	(53)	2	(52)	5	(46)	24	(61)	12	(59)	11	(61)	0	(33)
11	1	(53)	4	(80)	0	(35)	3	(47)	5	(48)	47	(67)	29	(55)	22	(52)	7	(57)
12					1	(100)	1	(45)	3	(46)	7	(59)	6	(53)	8	(50)	2	(48)
13			1	(53)			1	(39)	1	(62)	31	(48)	21	(47)	11	(48)	2	(53)
14	2	(45)	2	(39)	0	(33)	1	(43)	6	(46)	20	(48)	10	(52)			0	(34)
15	3	(30)	1	(32)	1	(33)	2	(58)	1	(64)	81				(54)			
16							0	(38)	3	(54)	32	(54)	23	(60)	19	(56)		
17	0	(39)	1	(50)			1	(96)	1	(65)	17	(56)	8	(63)	12	(51)		
18			1	(38)			1	(96)	2	(40)	22	(44)	19	(52)	16	(56)	3	(50)
19							0	(30)			9	(49)	10	(43)	3	(34)		
20	1	(35)	3	(52)			2	(76)	1	(51)	33	(45)	20	(47)	28	(54)	2	(38)
21			0	(31)			1	(58)			3	(73)	2	(68)	5	(57)		
22							1	(38)			1	(89)	2	(45)				
sum	16	(36)	26	(41)	6	(48)	28	(53)	50	(44)	558	(51)	350	(51)	331	(51)	76	(48)

Note: Blank space notifies lack of facility in the area.

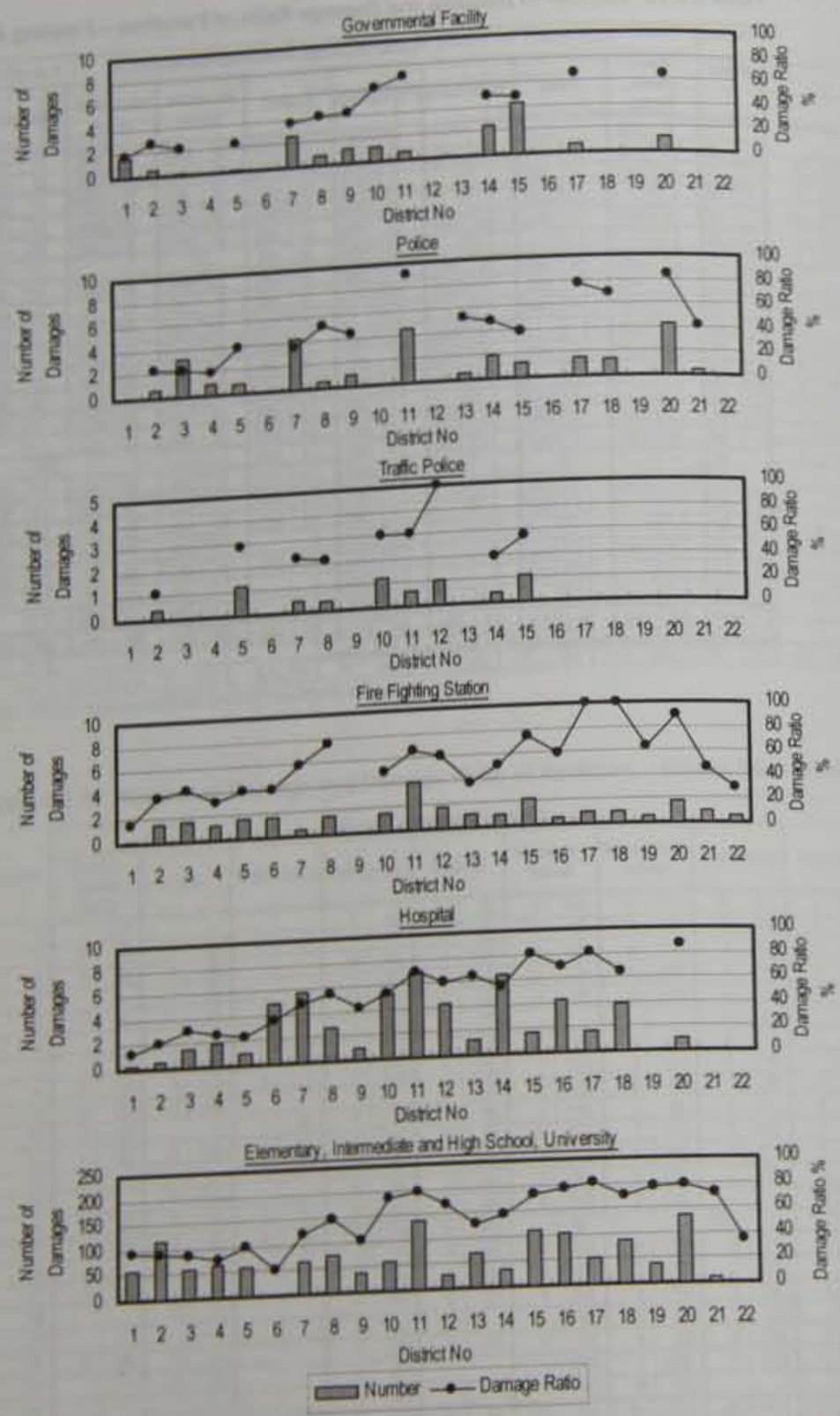


Figure 4.4.1 Damage and Damage Raito of Major Public Facilities by District Ray Fault Model

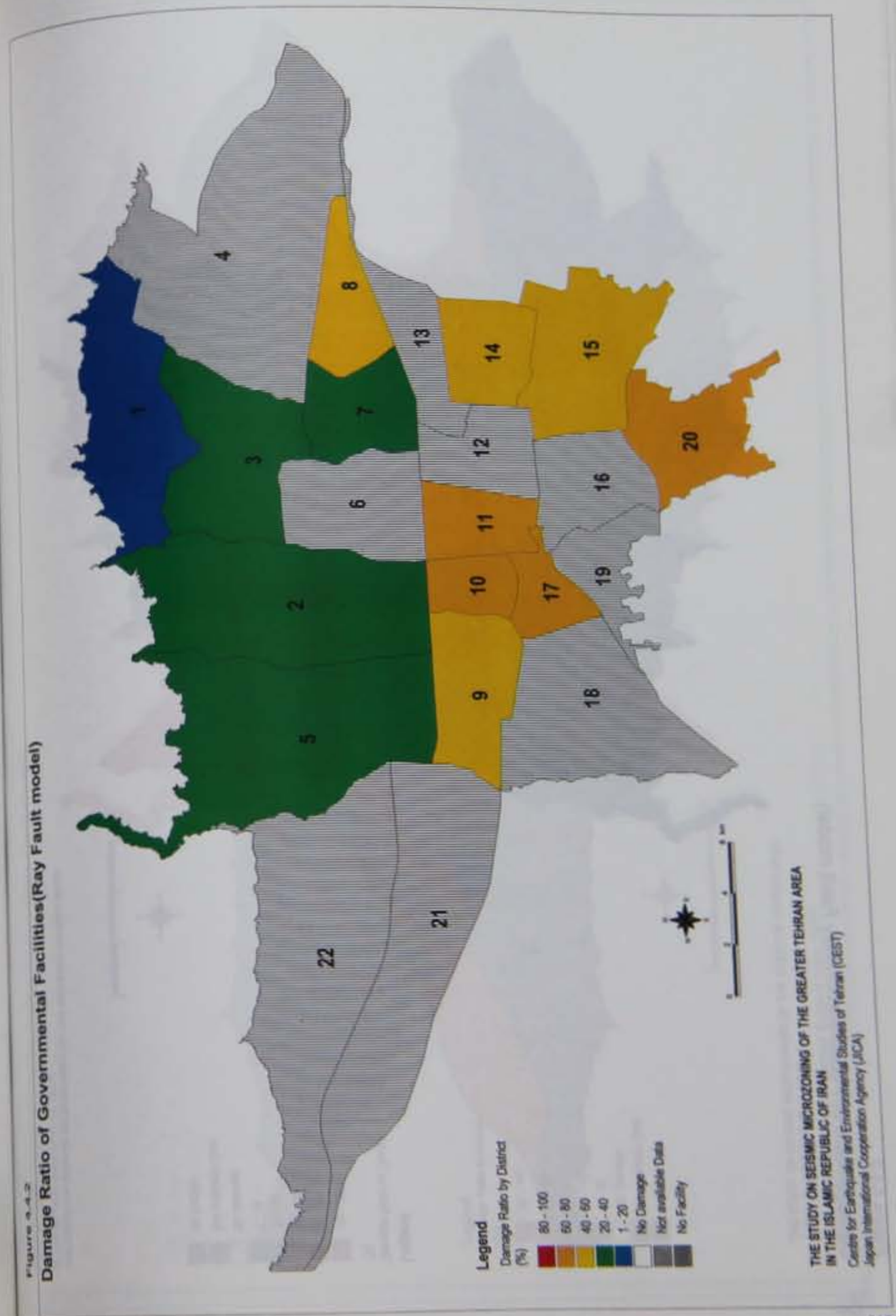


Figure 4.4.3

Damage Ratio of Police Station(Ray Fault model)

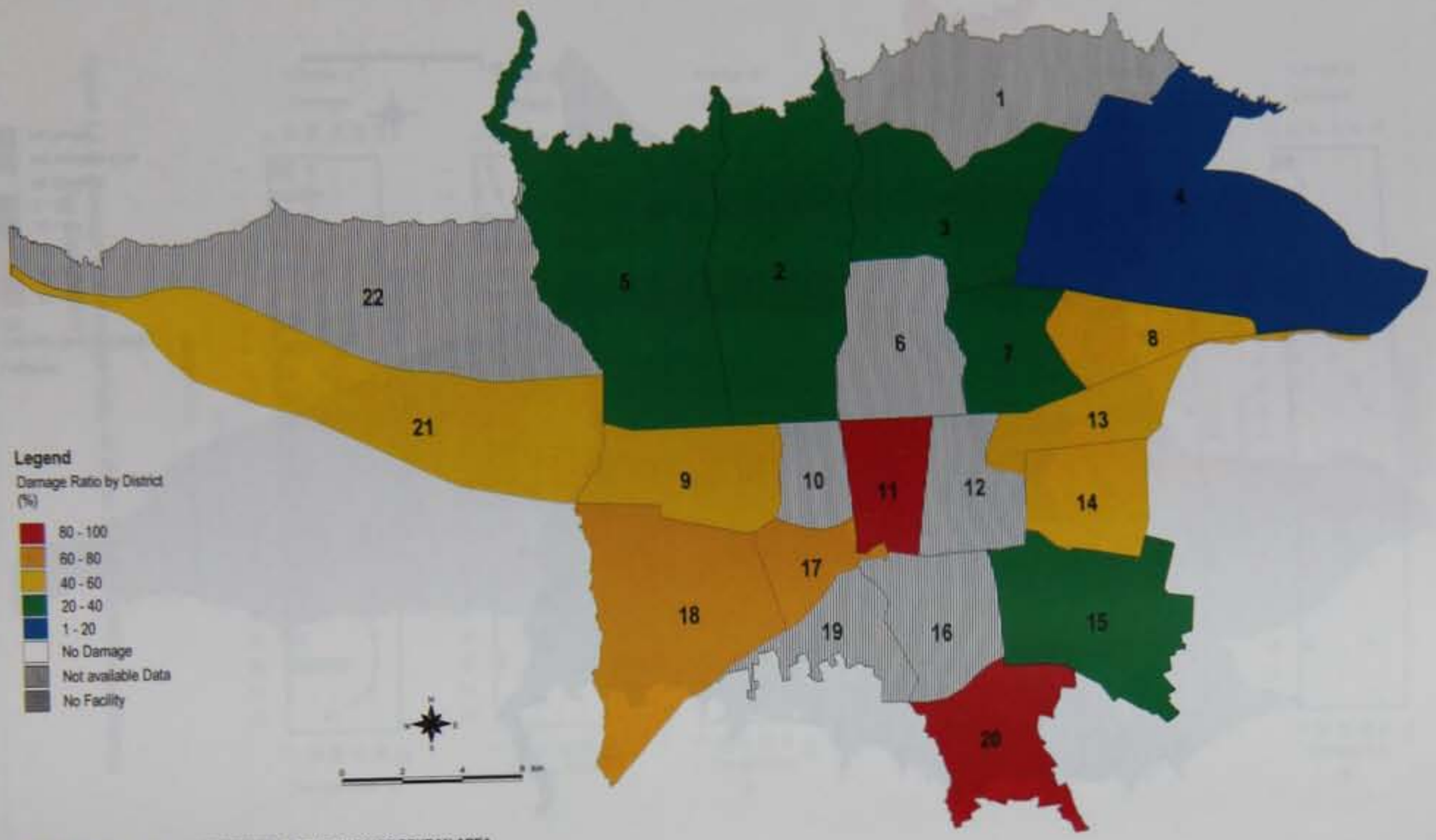


Figure 4.4.4

Damage Ratio of Traffic Police Station(Ray Fault model)

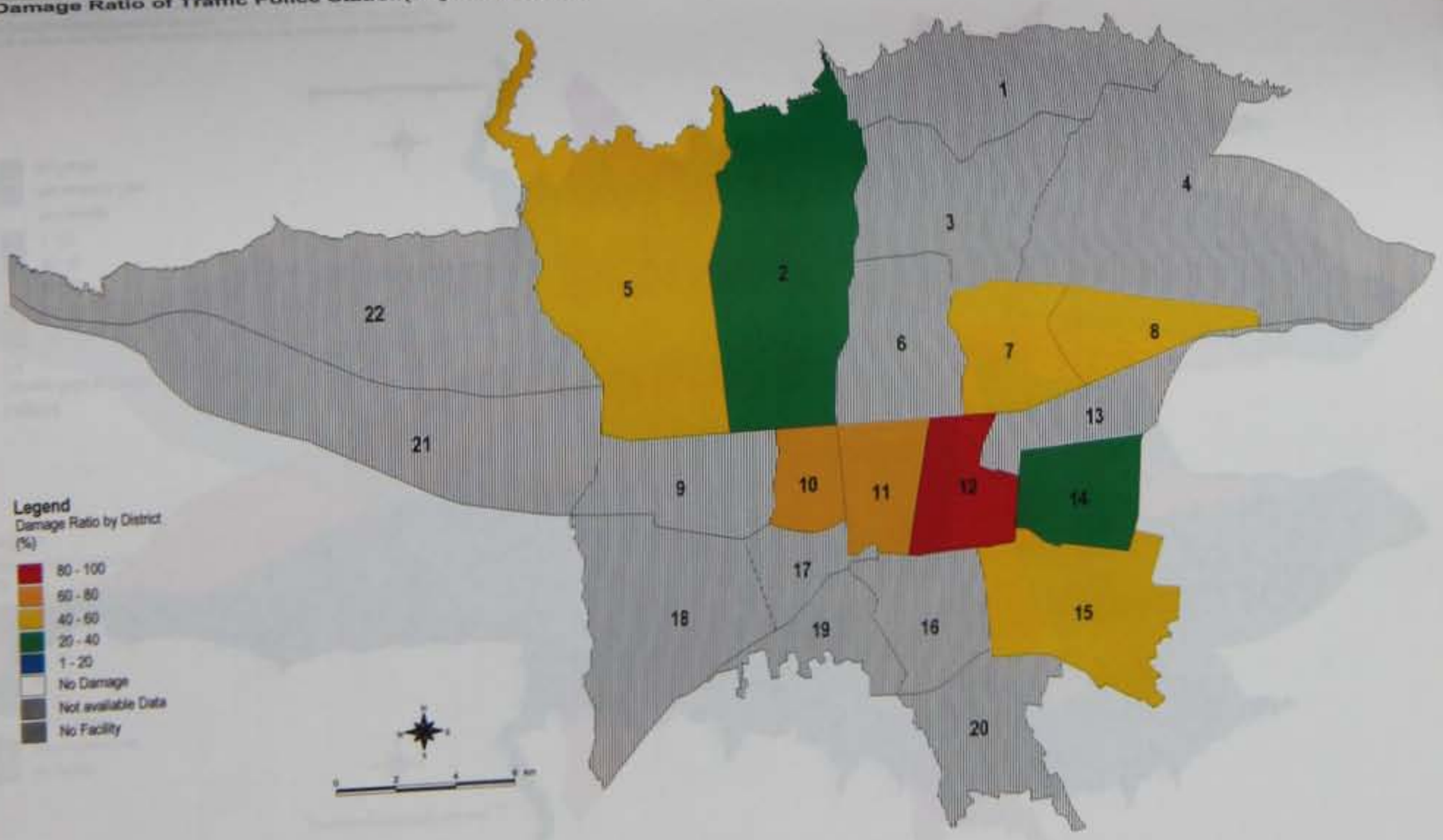


Figure 4.4.5

Damage Ratio of Fire Fighting Office(Ray Fault model)

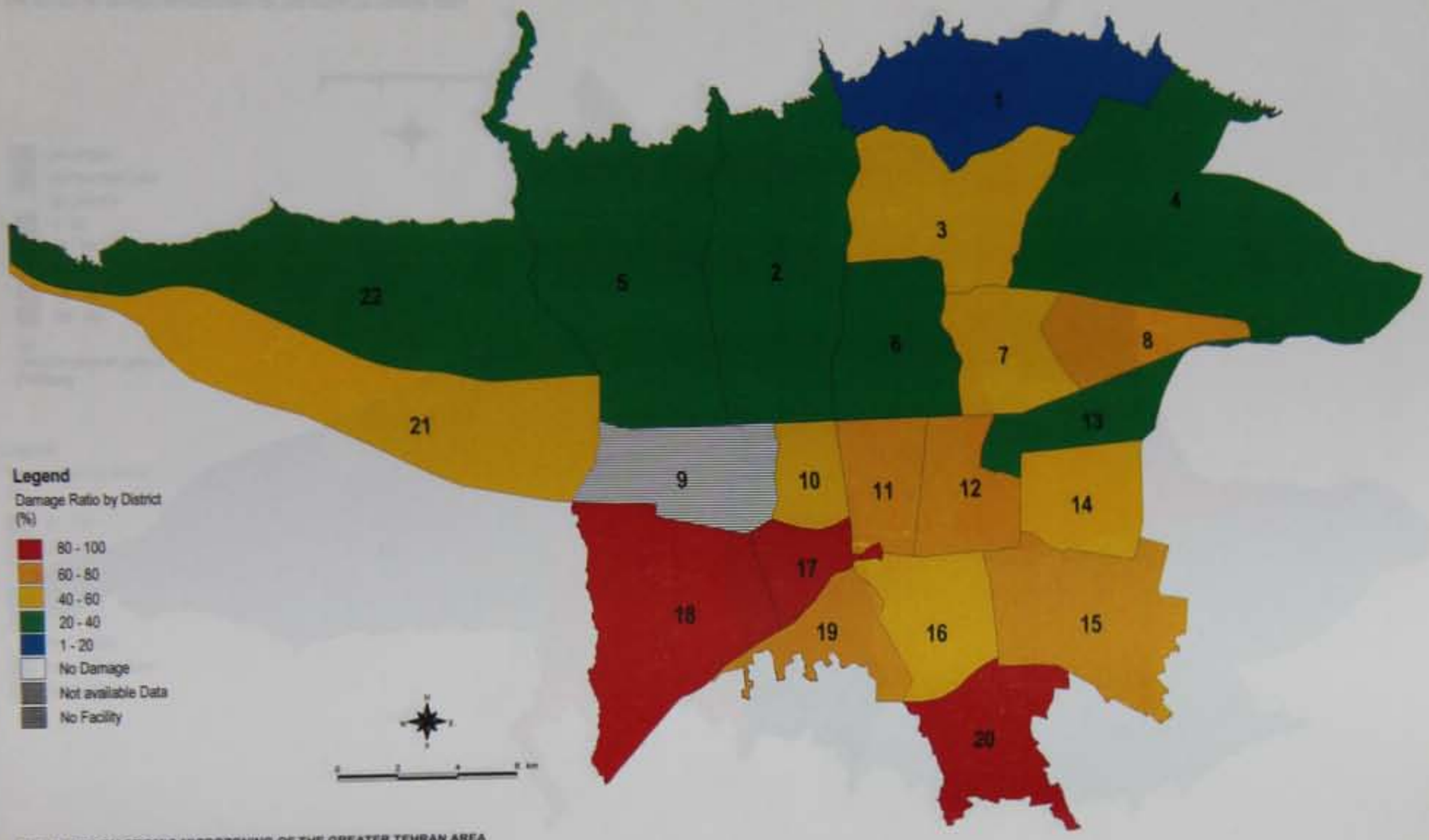


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Figure 4.4.6

Damage Ratio of Hospital(Ray Fault model)

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Figure 4.4.7

Damage Ratio of School(Ray Fault model)

4.4.2. Lifelines

Information on seismic damage to lifelines is very important for the preparation of a seismic disaster management plan. In this section, damages of lifelines are estimated. The following 4 types of lifelines are considered:

(1) Water supply pipelines

(2) Gas pipelines

(3) Electric power supply cables

(4) Telecommunications cables

Lifeline facilities are to be classified into two major categories, nodes and links. Nodes include facilities such as purification plants and substations. Links include facilities such as pipes or lines for supply and distribution purposes.

A statistical approach for damage estimation of links, i.e. distribution pipes and lines, is applicable only when information on their structures and lengths is available in any given area. This approach was used in the Study

Damages for the node facilities were not estimated in the Study, because such structures are different with respect to purpose and location and a statistical approach is not applicable for the analysis. Separate detailed surveys are required for the damage estimation of the node facilities.

(1) Method of damage estimation

The basic concepts for lifeline damage estimation are as follows:

- Except for a few qualitative studies, no quantitative studies on seismic damage for lifelines in Iran were available.
- Structural characteristics of buildings in Iran are different from those in Japan. However, network characteristics, pipeline structures and cable structures are considered similar to those of Japan.
- Although the strength of the pipeline materials is not much different from that of the pipeline materials in Japan, it is considered that the construction quality of the joints always leads to problems.
- Therefore, an analysis method for the damage estimation of water and gas pipelines proposed by Kubo and Katayama (1975), which is widely used in Japan, was applied to the Study. However, it is considered that the damages will be more serious than those estimated.
- Details of the strength of electric power supply and telecommunications cables were not available for the Study. Furthermore, details of the structure and strength of electricity posts, which are significant damage factors for aerial cables, were not available in the Study.
- Therefore, the damages to those cables are estimated using empirical methods based upon the damages that occurred during the 1995 Kobe Earthquake, Japan.
- Consequently, the damages of lifelines estimated here indicate only a relative damage distribution rather than an absolute one.

- The length of each lifeline facility in each census zone is assumed to be proportional to the number of residential buildings in that zone.
- The lifeline service districts and the census zones are correlated and the distribution is subdivided based upon the above proportions.
- In cases where census zones overlap with the service districts, the lifeline distribution area is subdivided into census zones with the weighted average of the number of residential buildings in each census zone.

(3) Damage Estimation

The definition of damage is as follows:

Water Supply Pipelines Gas Pipelines	Content of damage	Break of pipelines or joints
	Amount of damage	Number of damaged points
Electric Power Supply Cables Telecommunications Cable	Content of damage	Rupture of cables
	Amount of damage	Length of cables to be replaced

The results of the damage estimations are shown in Figure 4.4.9 to Figure 4.4.12 for each earthquake model. The damage distributions for the Ray Fault Model are shown in Figure 4.4.13 to Figure 4.4.16 for each type of lifeline. In general, the damages are huge in the southern districts in response to the seismic intensity.

The damage figures are conservative, considering the limitations of the damage estimation procedure.

It is clear that, if gas supplies do not shut off immediately, gas leakage will occur everywhere, resulting in explosions and fire outbreaks under the current manual valve shut-off manipulation system.

Almost all of the water supply lines will be out of service, and electricity and telecommunications will not be available in the southern part of the city. If independent power generators are not adequately available, the electric power failure may seriously affect the function of other lifelines.

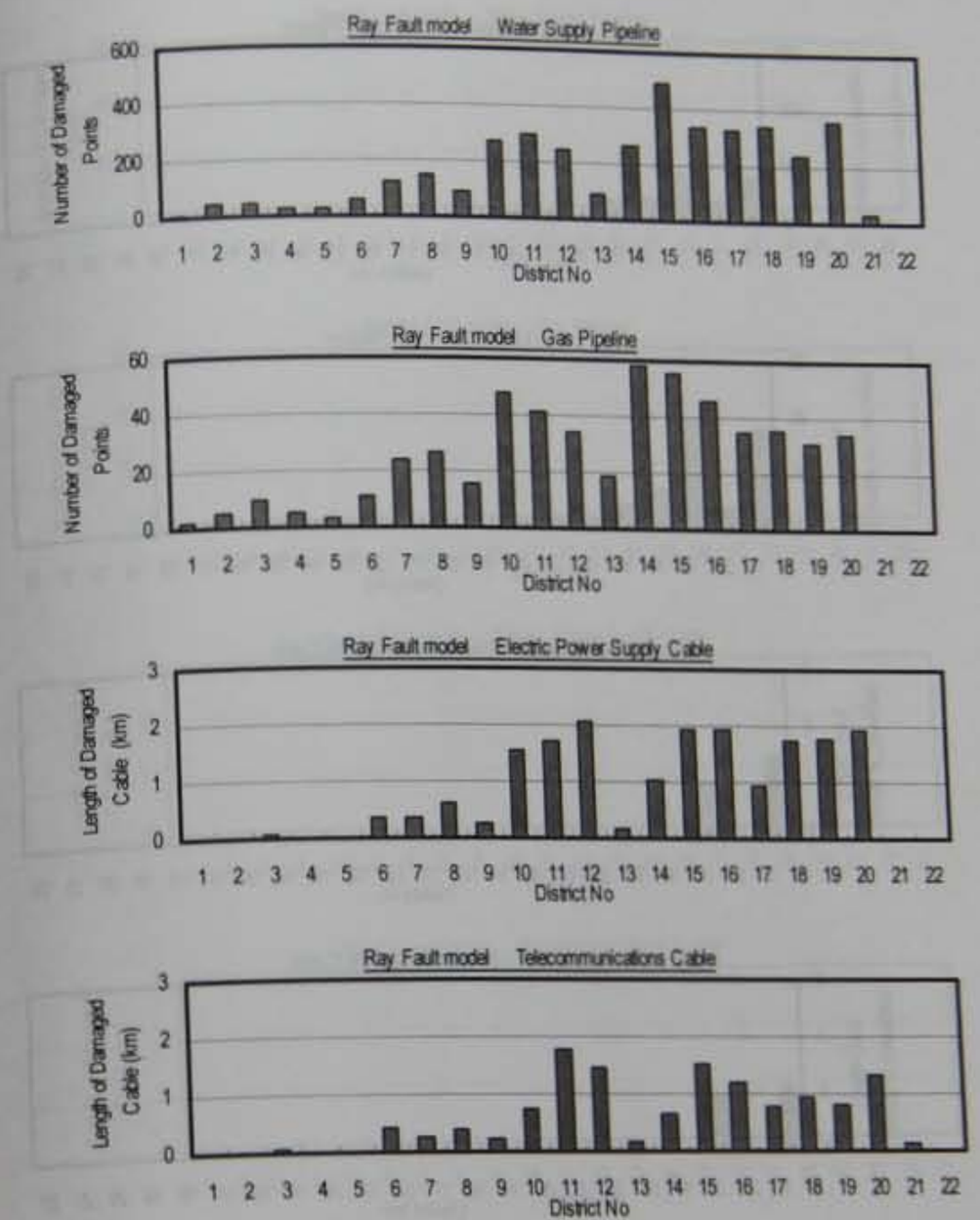

Figure 4.4.9 Damage of Lifelines by District – Ray Fault Model

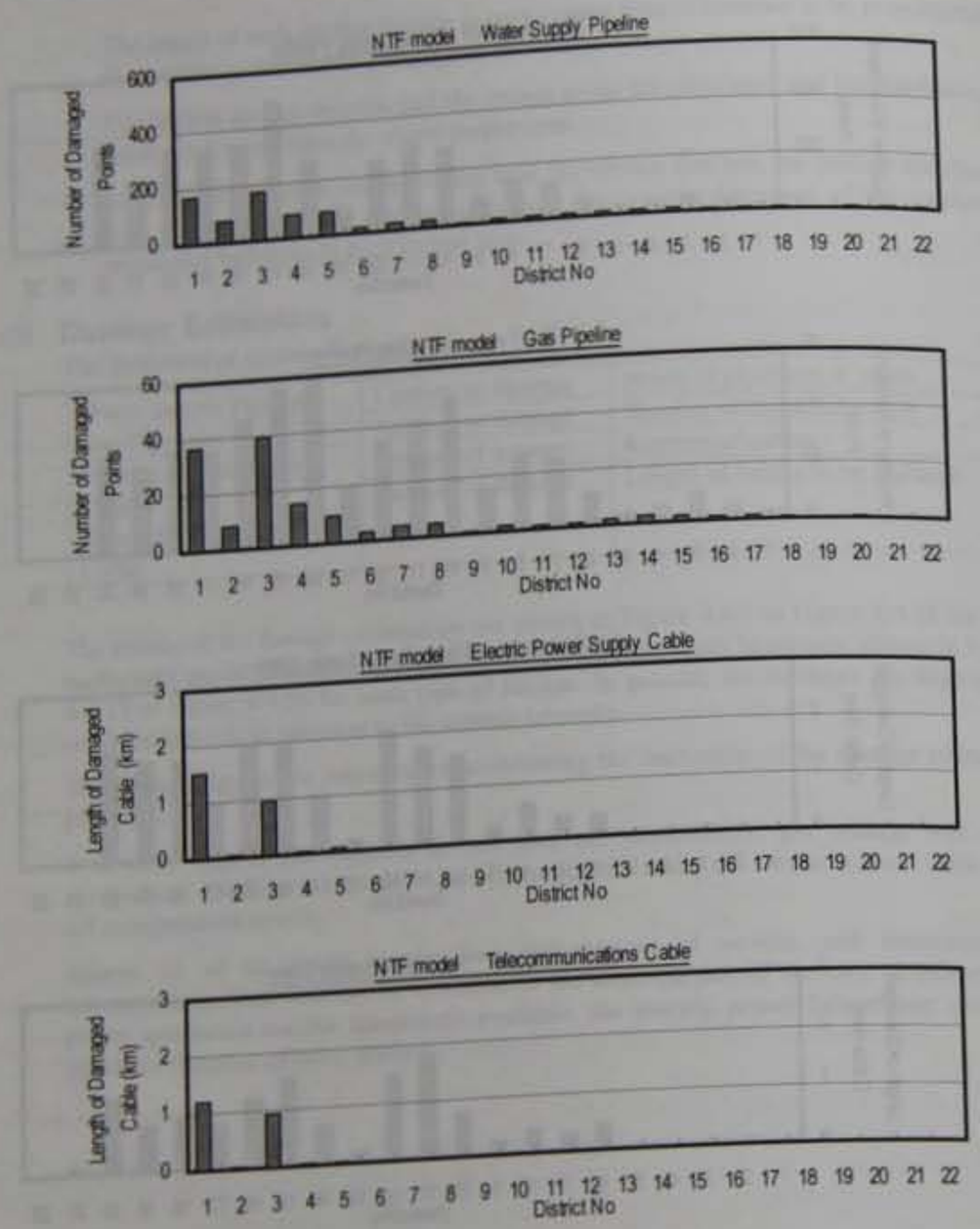

Figure 4.4.10 Damage of Lifelines by District – NTF Model

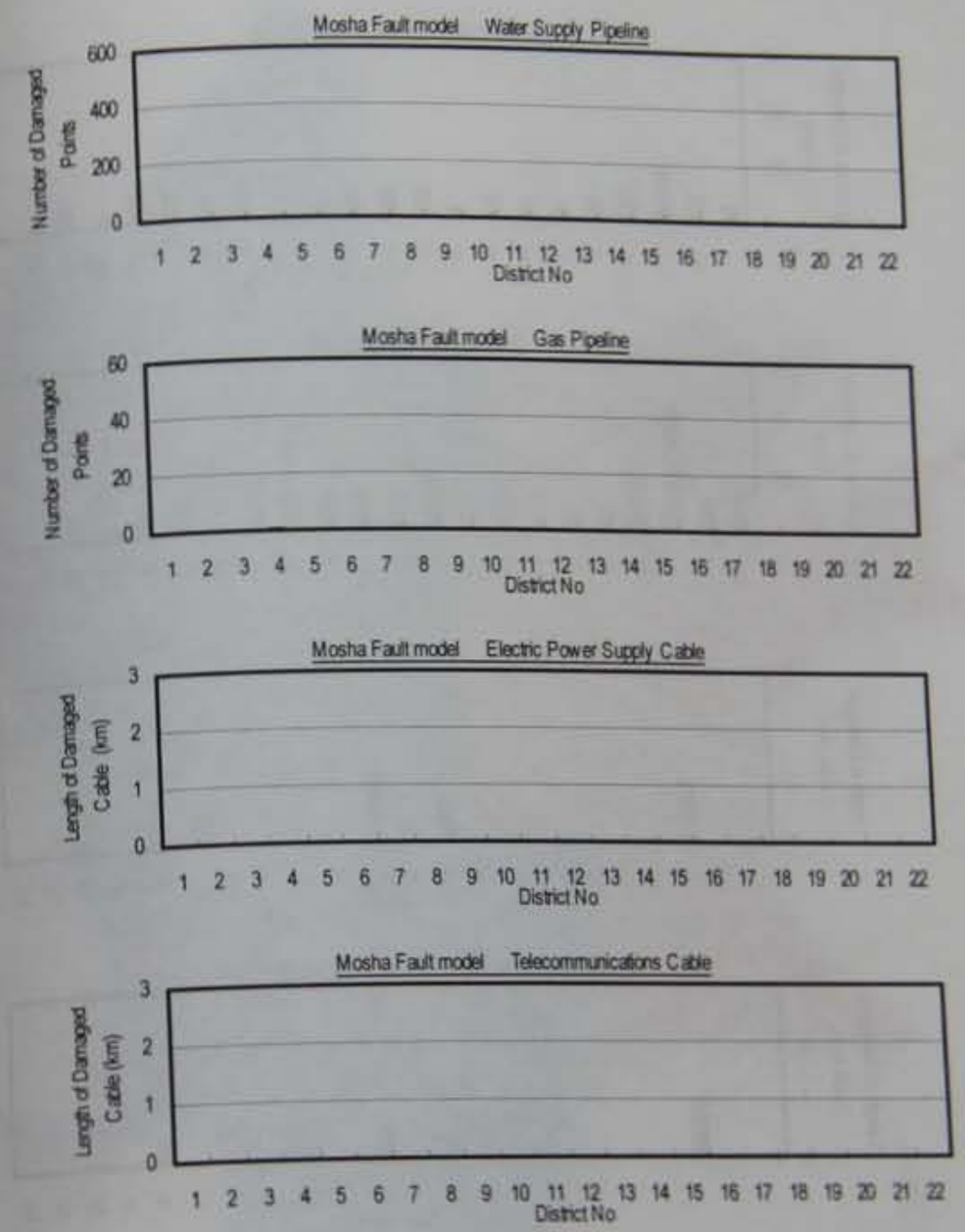

Figure 4.4.11 Damage of Lifelines by District – Mosha Fault Model

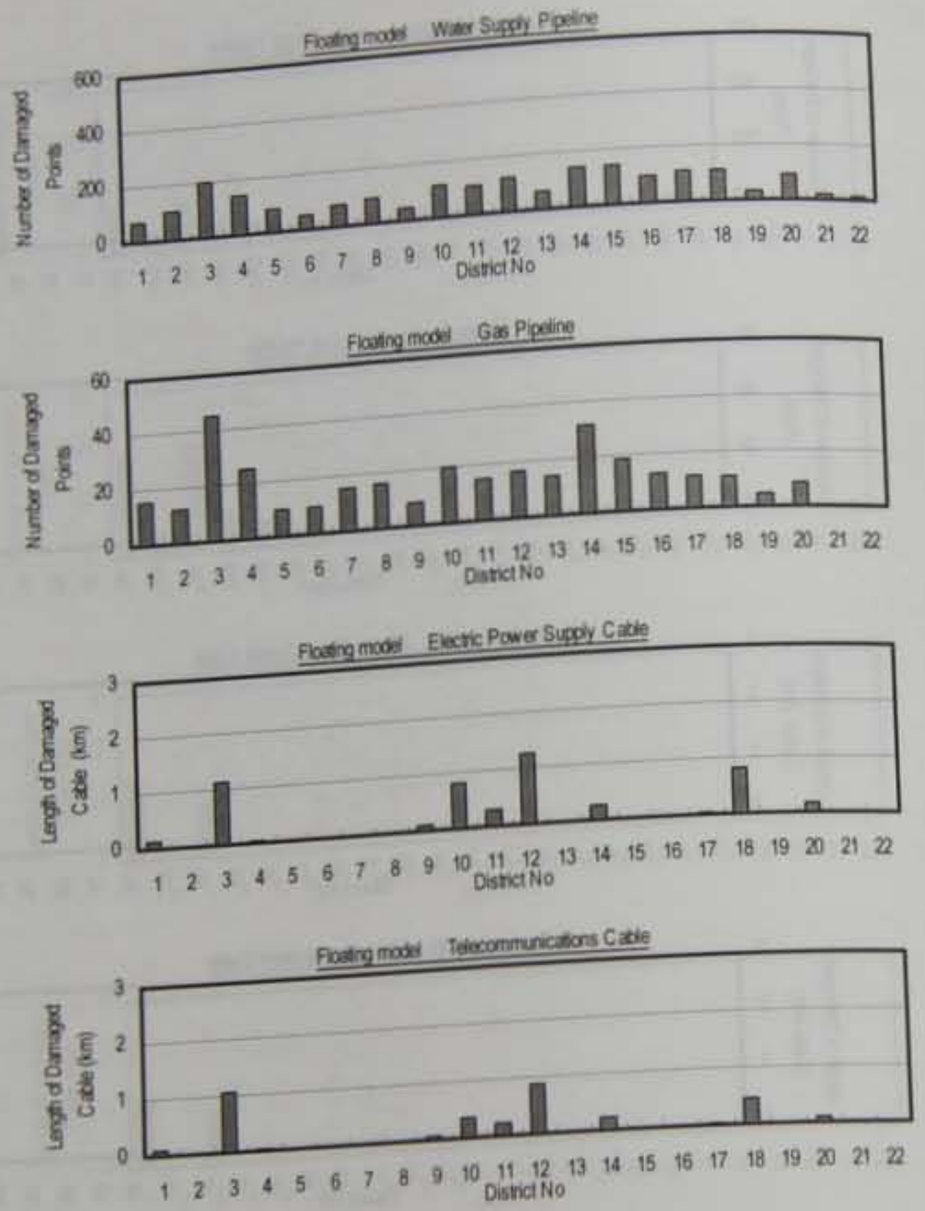

Figure 4.4.12 Damage of Lifelines by District – Floating Model

Figure 4.4.14

Damage of Gas Pipeline(Ray Fault model)

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Damage of Electric Power Supply Cable(Ray Fault model)

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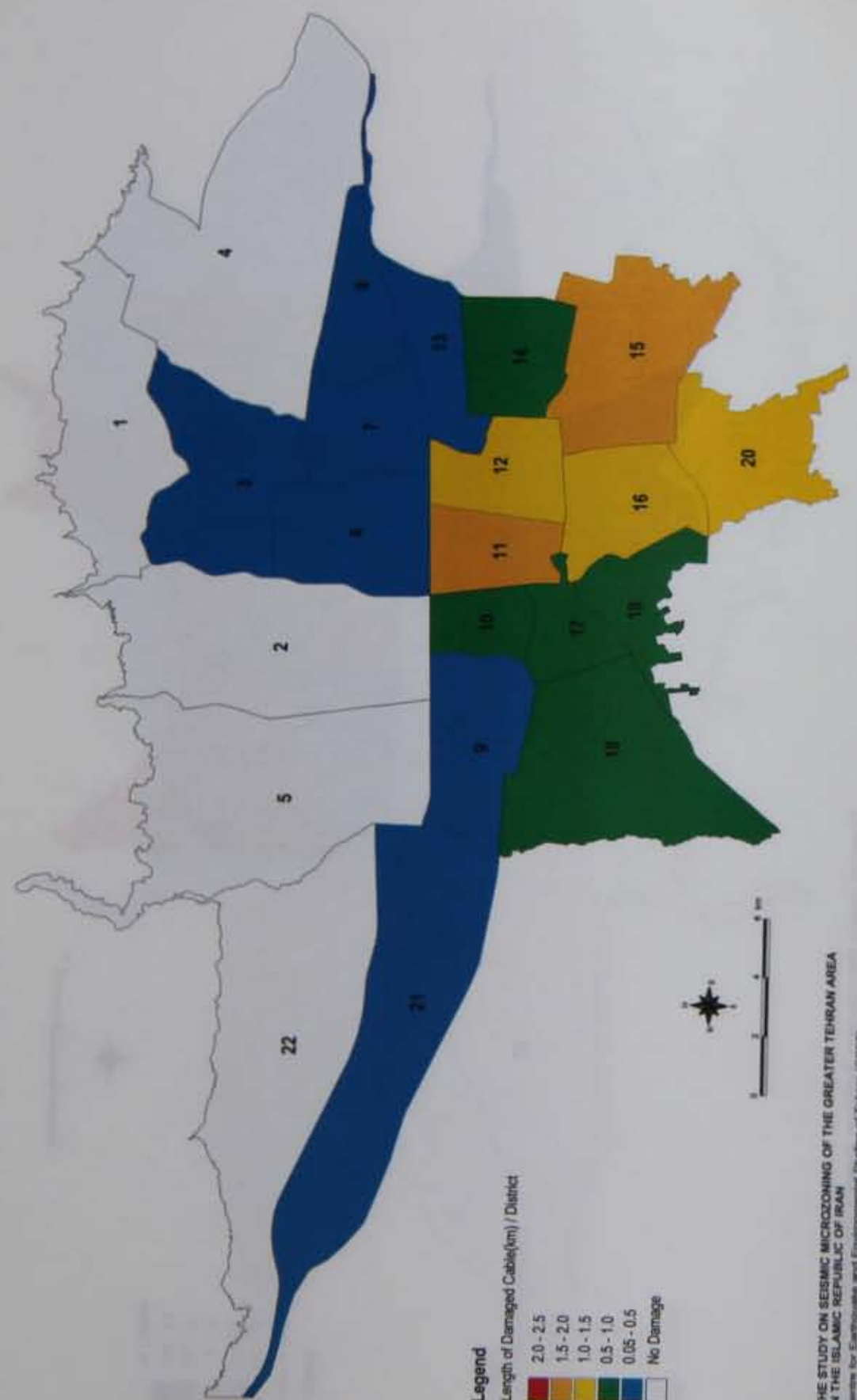
Figure 4.4.16

Damage of Telecommunications Cable(Ray Fault model)



4.4.3. Hazardous Facilities

A possibility of fire outbreaks from facilities where inflammable liquids or gases materials are handled was estimated. The facilities are classified as follows:

(1) Petrol stations

(2) Refuelling stations

(3) Gas refilling workshops

(4) Kerosene distributors

(5) Oil distributors

The concepts of the estimation are as follows:

- The offices of the facilities will suffer damages caused by earthquake motion, and the damage functions for residential buildings were applied in the estimation of damages to office buildings.
- At facilities that are seriously damaged or collapsed, inflammable liquids or gases will leak from the storage tanks.
- The leaking liquids or gases ignite to fire according to the following probability:

Petrol stations, refuelling stations: 2.55%

Others: 3.66%.

(Kanagawa Prefecture 1986)

- The above values are estimated based on Japanese experience. No case information on fire occurrences in Iran was available. Consequently, the results show only a relative possibility of fire occurrence.
- The number of fire outbreaks is summed up in each district and then expressed as rating of fire hazard.

The distribution for the hazardous facilities is not uniform in the Study Area and it is considered that the database was not prepared based upon a uniform criterion. Therefore, fire outbreak was calculated for the municipal districts in which more than 5 hazardous facilities were located within the district. There are only 11 such districts among the 22 districts considered in the Study.

Results of the analysis are shown in Table 4.4.14. Distribution of the vulnerability rating for districts under the Ray Fault Model are shown in Figure 4.4.17.

Table 4.4.14 Vulnerability Rating of Fire Outbreaks from Hazardous Facilities

District	Petrol Station	Other Types of Stores	Vulnerability Rating			
			Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
1	2	0				
2	3	0				
3	8	0	C	C	D	C
4	1	0				
5	1	0				
6	6	0	D	D	D	D
7	10	8	B	C	D	B
8	4	7	B	B	C	B
9	3	0				
10	2	0				
11	4	0				
12	7	1	C	D	D	C
13	10	8	B	C	D	B
14	3	0				
15	2	17	A	C	D	B
16	2	0				
17	3	6	B	C	D	B
18	2	32	A	B	C	A
19	0	9	B	D	D	C
20	5	8	B	D	D	B
21	0	0				
22	0	0				
Sum	78	96				

Vulnerability Rating	Possibility of Fire Outbreak
A:	High
B:	↑
C:	↓
D:	Low
Blank:	Inadequate Data

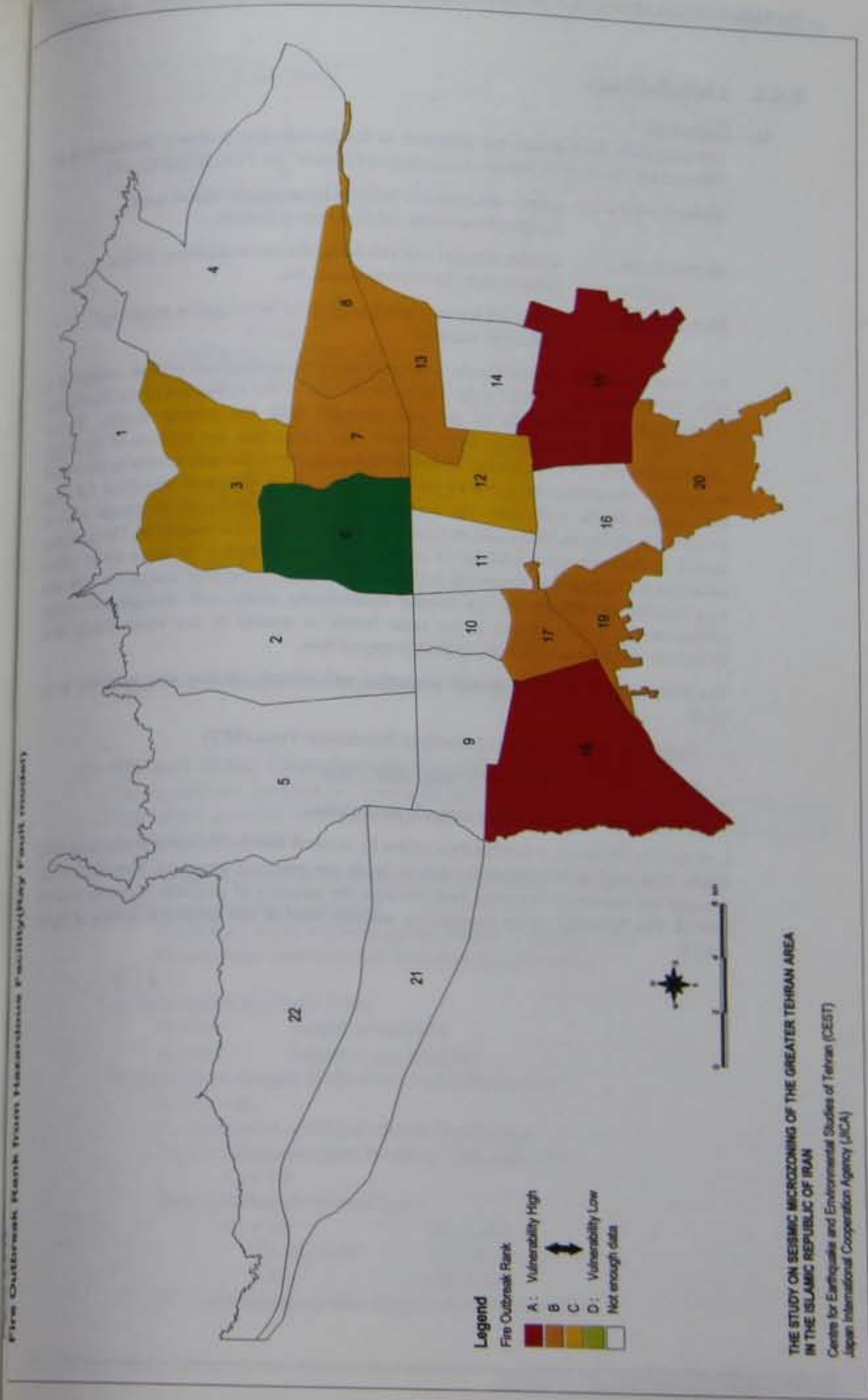
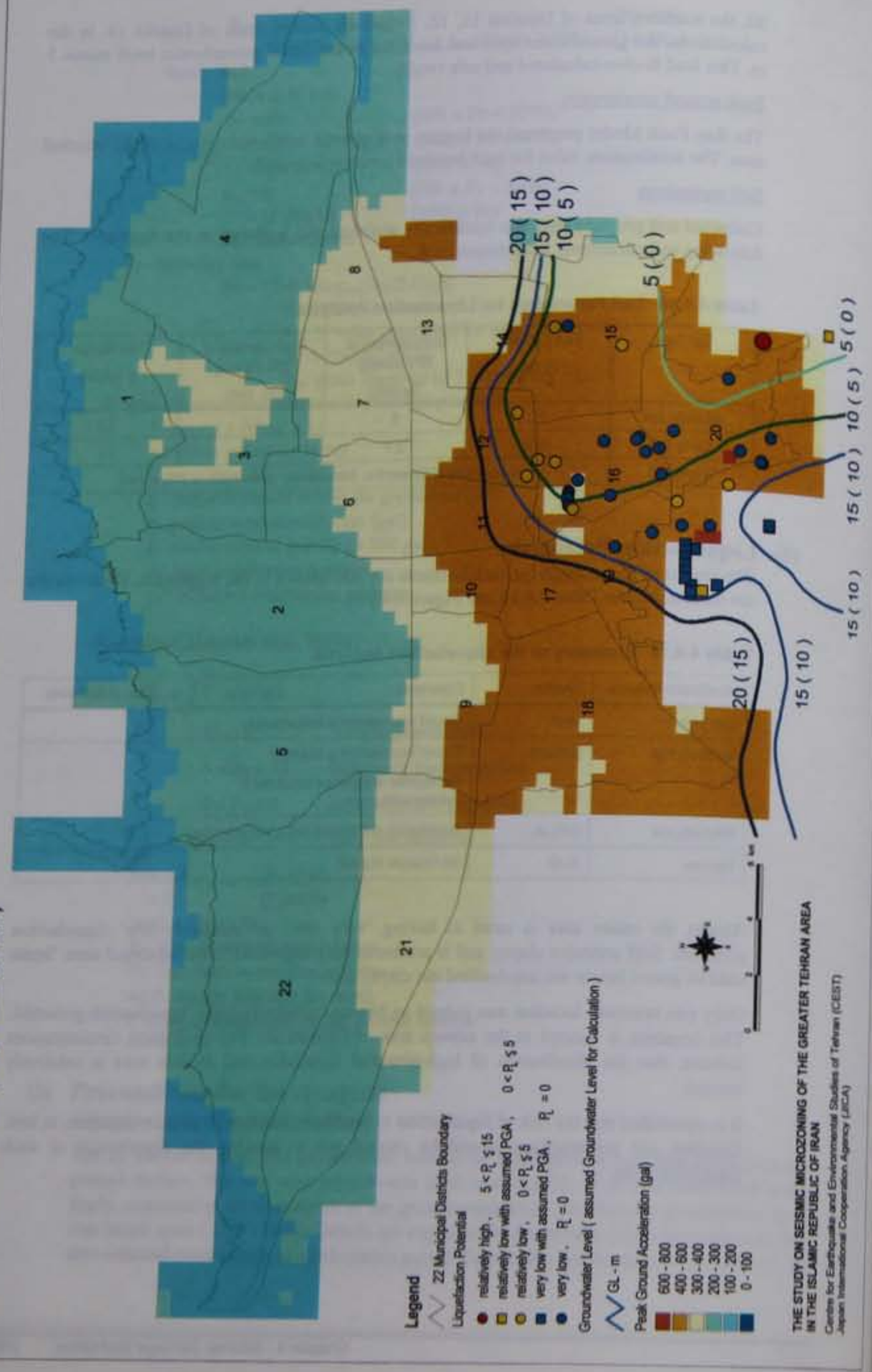


Figure 4.4.19

Liquefaction Potential (Ray Fault model)



4.4.5. Slope Stability

The following three methods are indicated as the slope stability estimation methods in the "Manual for Zonation on Seismic Geotechnical Hazards" by TC4, ISSMFE (1993).

1) Method Grade 1: simple and synthetic analysis by using seismic intensity or magnitude without information of geological condition

2) Method Grade 2: rather detail analysis with geological information by using site reconnaissance result or existing geological information

3) Method Grade 3: detail analysis by using geological investigation result and numerical analysis

It is considered that Method Grade 3 is appropriate in quality and content, compared to the other estimation items of the Study. This method requires information on detailed shape of slope, load conditions and strength of soils. Slopes in the Study Area are categorised as follows:

Large-scale slope

- The northern edge of the Study Area is at the foot of the Alborz Mountains and steep slopes are distributed throughout.
- The northern half of the Study Area consists of alluvial fans. A gentle slope with the same gradient is prevalent in the area.
- A deep valley is distributed alongside a major river in the northern part of the Study Area.
- Elevation data from the Beautification Organisation is available. It is possible to determine the slope gradient within every 50-mesh unit. Statistical treatment is applicable.

Small-scale slope

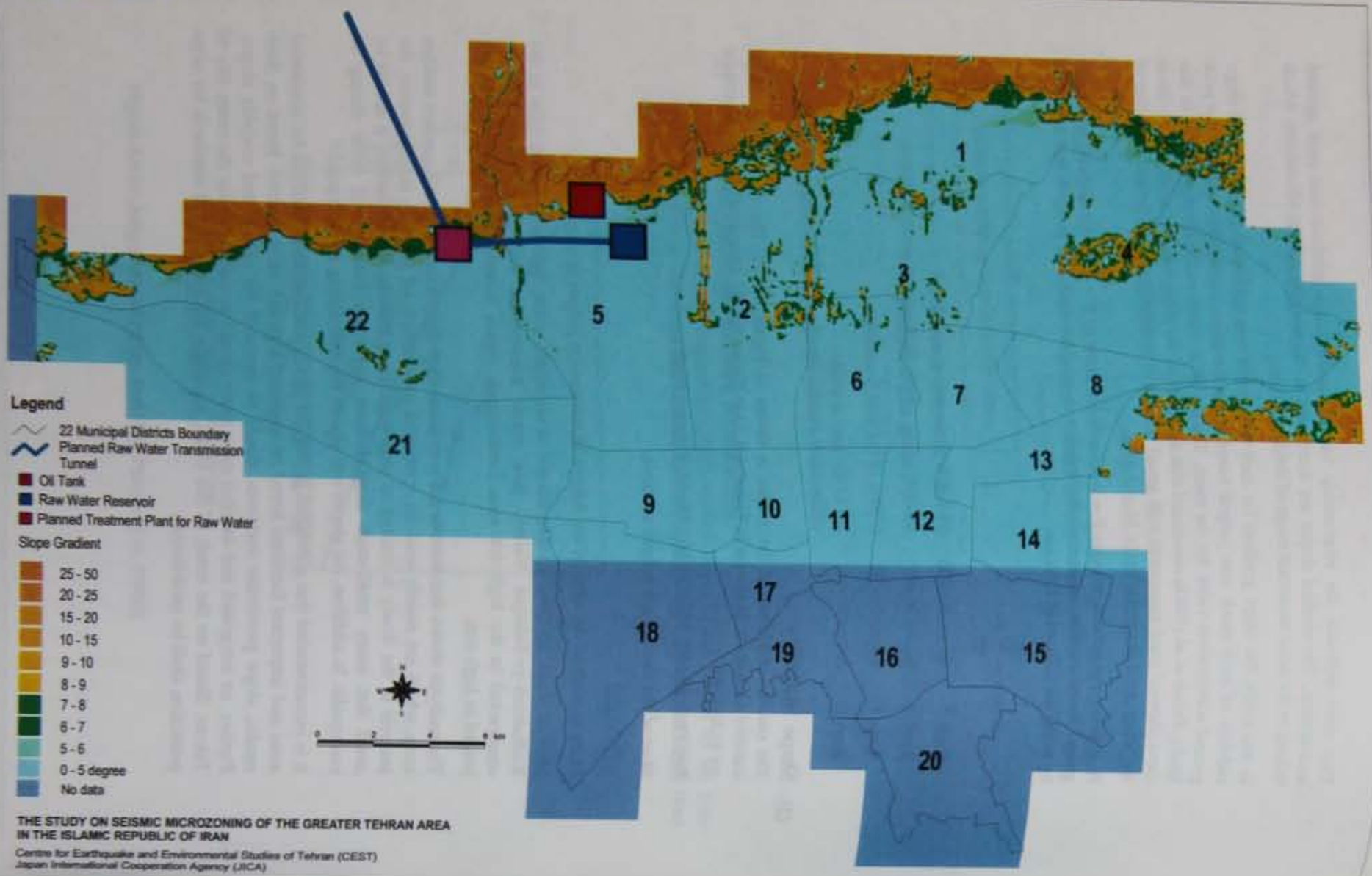
- Cut slopes are distributed alongside major highways in the northern part of the Study Area. Most of these have no slope protection and tall buildings are constructed on top of the slopes.
- Information on location of slope, shape of slope and soil strength is not available.

Considering the above condition, only large-scale slopes were examined in the Study. For cases of small-scale slopes, it is recommended that the stability of each slope be analysed.

The outline of the evaluation method is described below and shown in Figure 4.4.20.

Figure 4.4.22

Slope Gradient



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Slope Stability (Ray Fault model)

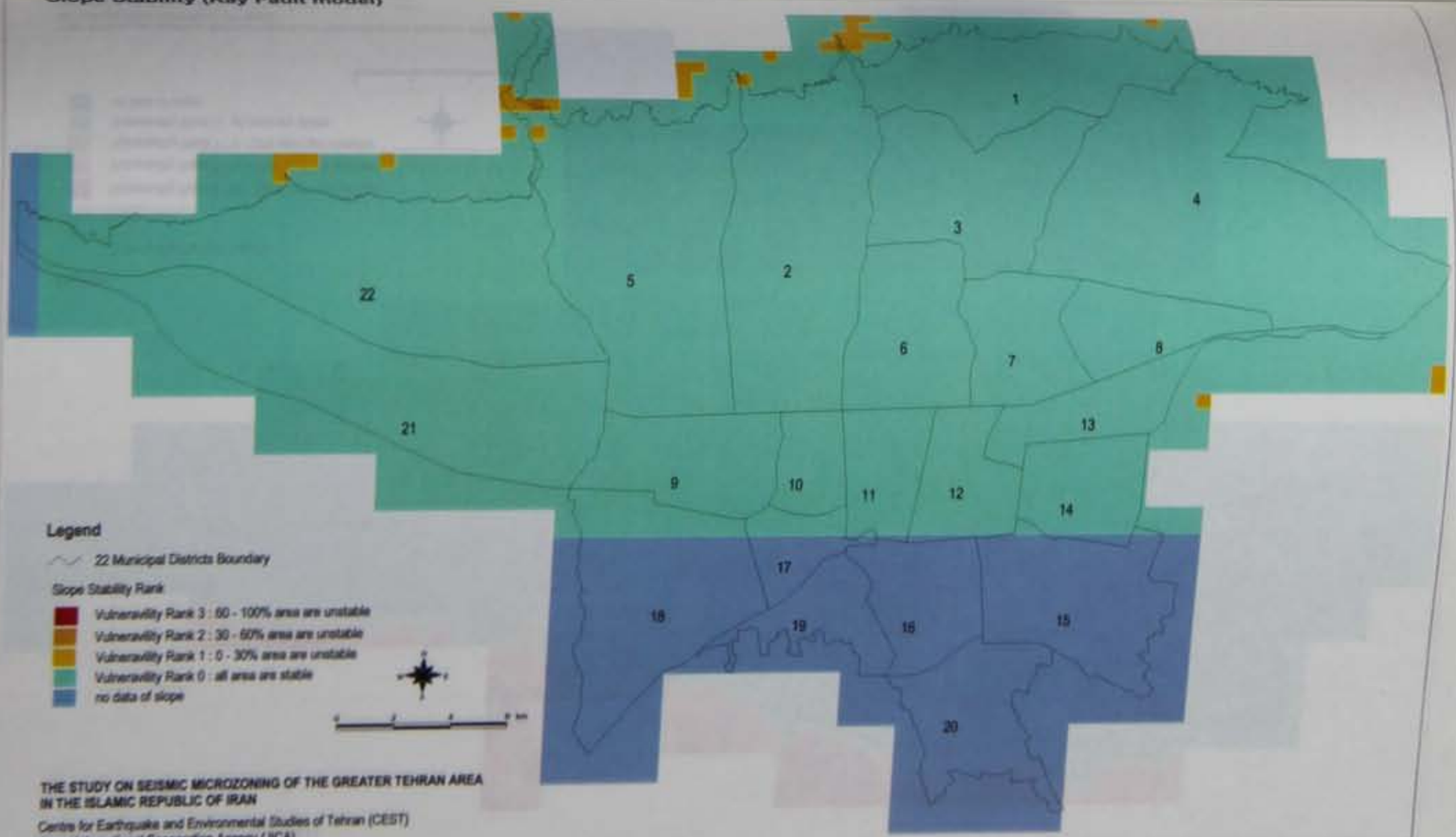

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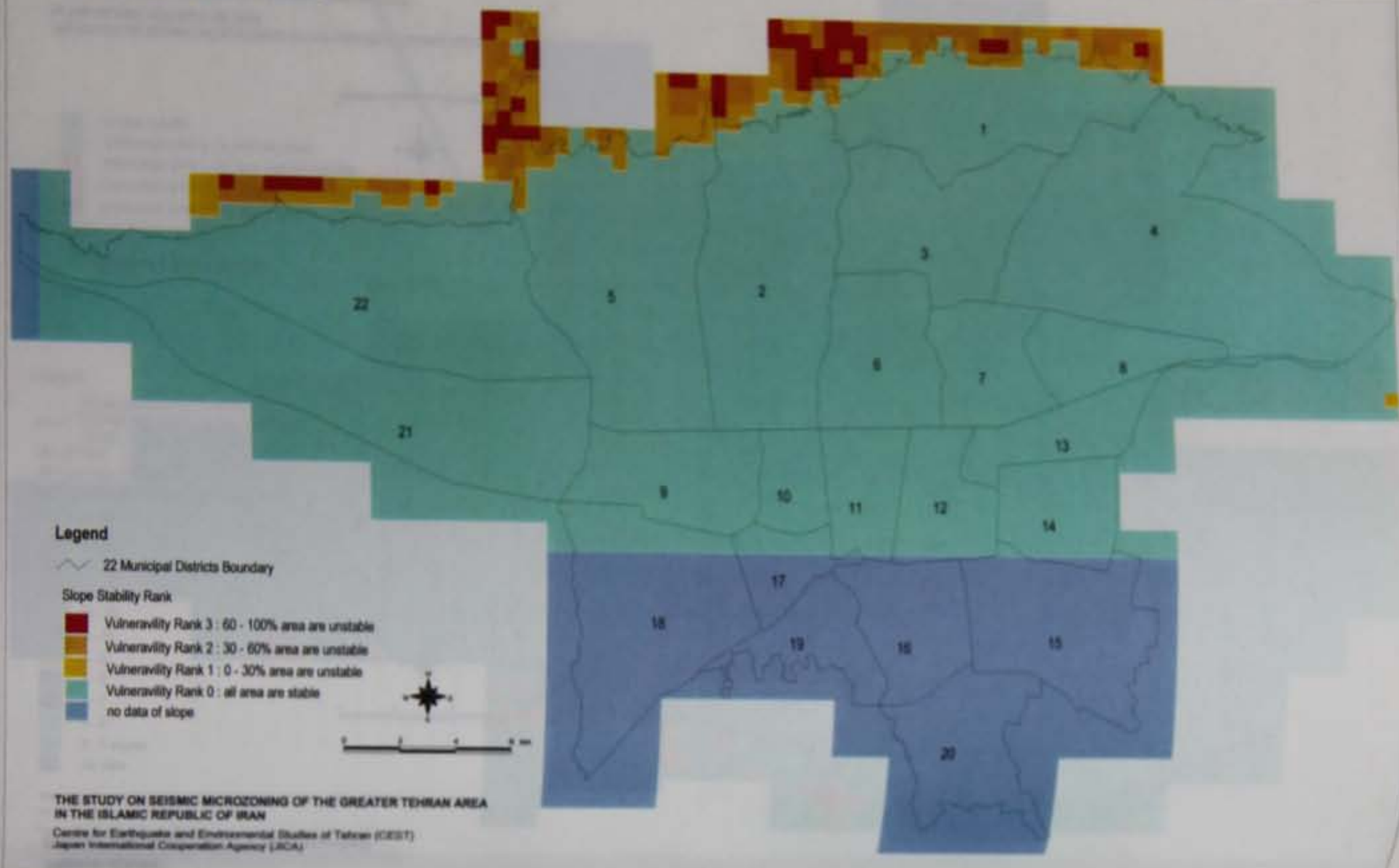
Figure 4.4.24

Slope Stability (NTF model)



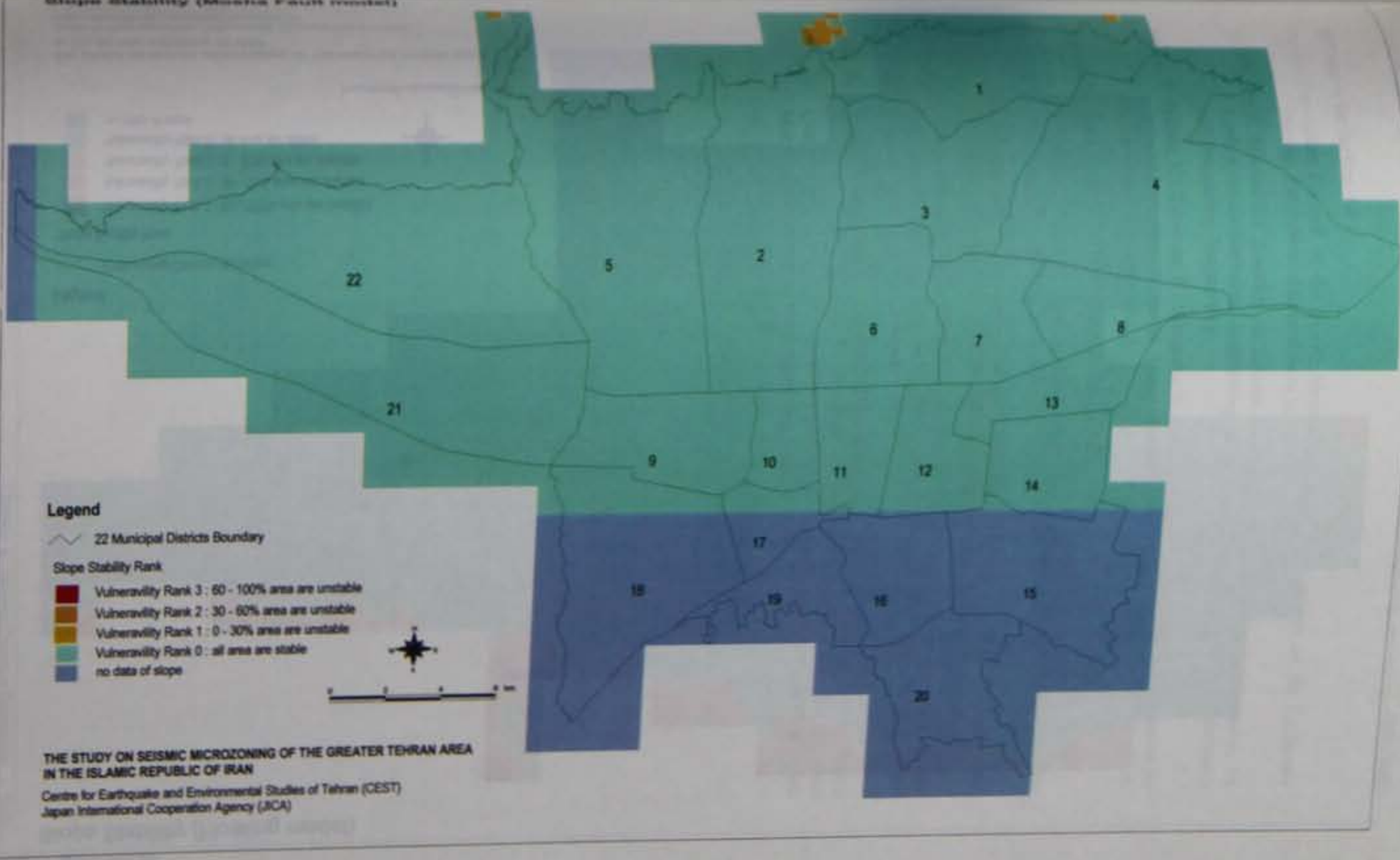


Figure 4.4.26

Slope Stability (Floating model)

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Chapter 5:

Evaluation of Risks in Each district for seismic Hazard

Chapter 5. Evaluation of Risks in Each District for Seismic Hazard

As evidenced by the result of the quantitative hazard analysis that explained in Chapter 4, each district in Tehran has a different earthquake hazard. In this chapter, the result of the analysis was evaluated comprehensively. Further, the disaster feature of each district was evaluated considering its respective social condition.

The following items are considered in the comprehensive analysis:

a) Seismic hazard and damage

- Average seismic intensity
- Residential building damage ratio
- Death ratio

b) Social condition

- Population density
- Open space per person
- Narrow road ratio

5.1. Method of Evaluation

Each seismic hazard and damage item indicates direct damage caused by earthquakes. Each social condition item indicates difficulty of rescue operations, evacuation, recovery operations and living conditions after an earthquake disaster. Evaluation criteria of risk items are shown in Table 5.1.1. The rankings are derived by calculating the average value for each. Common seismic hazard and damage ranking criteria are employed for three models (Ray Fault Model, NTF Model and Floating Model). Therefore, the hazard and damage ranking can be used in the comparison of not only districts but also earthquakes. Meanwhile, the social condition ranking can be used as the unique parameter for each model. The ranking of each item is depicted by radar charts shown in Figure 5.2.1 to Figure 5.2.3

Table 5.1.1 Evaluation Criteria of Risk Items

Item / Rank	Seismic Hazards and Damage			Social Condition		
	Average Seismic Intensity (MMI)	Residential Buildings Damage Ratio(%)	Death Ratio (%)	Population Density (persons / hectare)	Open Space (m^2/person)	Narrow Roads Ratio (%) *)
5	8.67 – 8.93	69.68 - 82.20	16.22 - 20.10	291.73 - 362.43	0.00 - 0.49	55.12 - 66.85
4	8.41 - 8.66	57.16 - 69.67	12.34 - 16.21	221.05 - 291.72	0.50 - 1.99	43.39 - 55.11
3	8.15 - 8.40	44.64 - 57.15	8.46 - 12.33	150.37 - 221.04	2.00 - 9.99	31.66 - 43.38
2	7.89 - 8.14	32.11 - 44.63	4.58 - 8.45	79.68 - 150.36	10.00 - 14.99	19.93 - 31.65
1	7.63 - 7.88	19.60 - 32.11	0.70 - 4.57	9.00 - 79.67	15.00 – 182.73	8.20 - 19.93

*) Narrow Road Ratio is calculated by combining roads with 3 m and 6 m width and dividing by total length of road within each district.
(Length of 3 m, 6 m / Total Length of Road) X 100

5.2. Evaluation by Each Fault Model in the Districts

Each model of the scenario earthquake was evaluated based on the six parameters mentioned above. However, since the Mosha Fault Model produced only minimal seismic hazard, it was not included in the following discussion.

5.2.1. Ray Fault Model

A summary of the evaluation results is shown in Table 5.2.1 and Figure 5.2.1. District 17 has the highest disaster risk, not only for the Ray Fault Model, but also for every other model. The district experiences a high seismic intensity, a high building damage ratio because of weak structures, and a high death ratio. Evacuation will prove difficult because the district has narrow roads. Following District 17 as having a high disaster risk are Districts 10, 11 and 12. The population density of Districts 11 and 12 are smaller than that of District 17, but each parameter of seismic hazard and damage for Districts 11 and 12 has a rank of almost 5. The death ratio of District 10 is relatively low but each item of social condition has a rank of 5. This shows there may be great difficulty in the evacuation and restoration efforts carried out in District 10. Meanwhile, Districts 9, 14 and 16 have 3 as their average rank for all items, indicating a relatively higher disaster risk.

As a whole, the southern area of the city has relatively high disaster risk. However, it is considered that in the suburban area, including Districts 18 and 20, rescue, evacuation and recovery operations will be relatively less difficult to carry out.

Table 5.2.1 Score for Ray Fault Model

District	Seismic Intensity	Building Damage	Casualties	Population Density	Open Space	Narrow Road	Total Score (Max Score = 30)
1	1	1	1	1	2	2	8
2	2	2	1	2	3	1	11
3	2	2	1	1	3	1	10
4	1	1	1	1	1	1	6
5	2	2	1	1	2	1	9
6	3	3	1	2	3	1	13
7	3	3	2	3	5	3	19
8	3	3	1	4	4	2	17
9	4	4	2	2	4	3	19
10	5	4	2	5	5	5	26
11	5	5	4	3	4	4	25
12	5	5	5	2	4	5	26
13	3	3	2	2	5	2	17
14	4	4	2	3	4	3	20
15	5	4	3	2	3	2	19
16	5	5	3	3	3	3	22
17	5	5	3	5	5	4	27
18	5	5	2	2	1	3	18
19	5	5	2	2	3	2	19
20	5	5	3	1	1	2	17
21	3	3	1	1	1	1	10
22	1	1	1	1	1	2	7

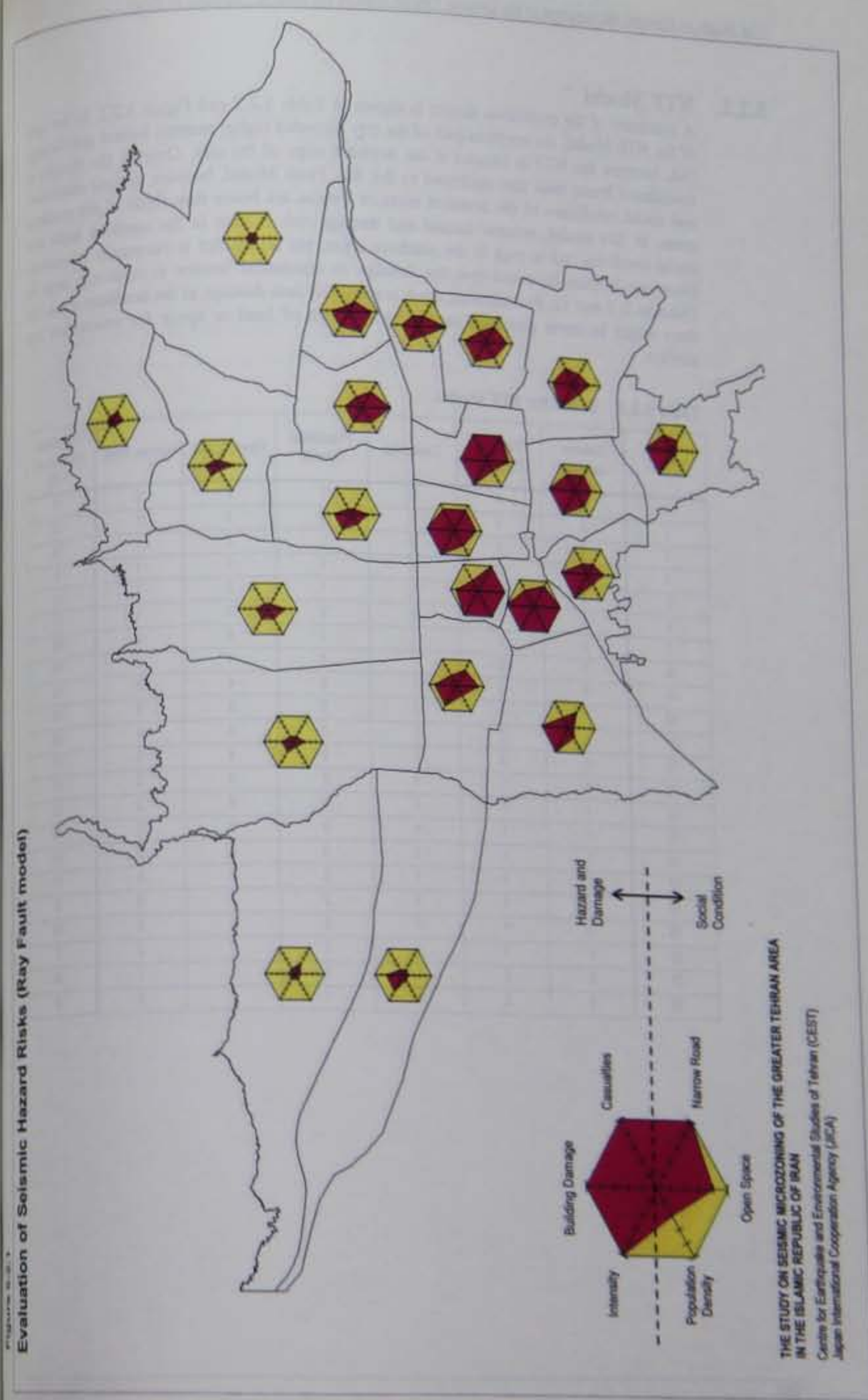


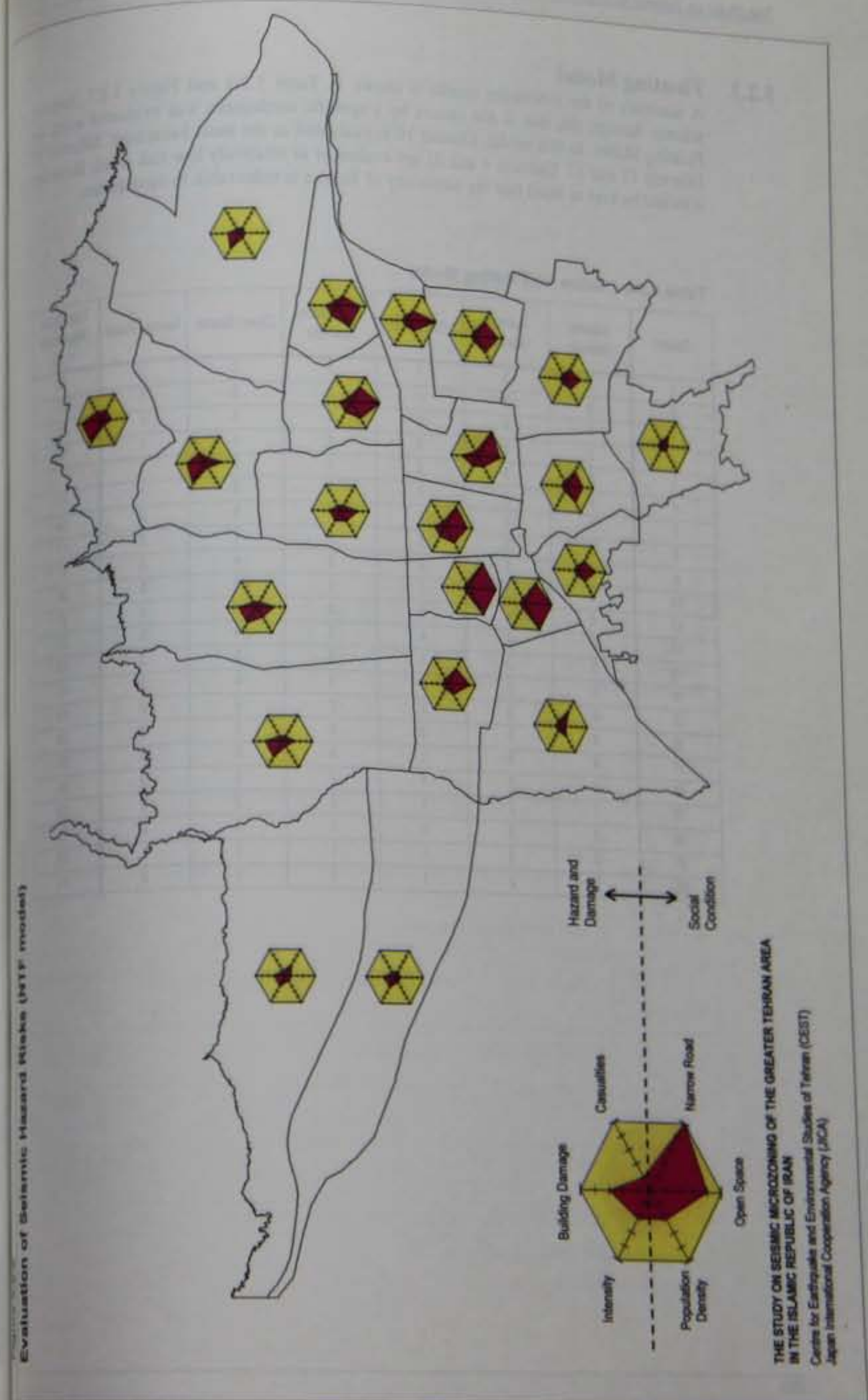
Figure 5.2.1 Evaluation of Seismic Hazard Risks (Ray Fault model)

5.2.2. NTF Model

A summary of the evaluation results is shown in Table 5.2.2 and Figure 5.2.2. In the case of the NTF Model, the northern part of the city recorded higher seismic hazard and damage risk, because the NTF is located at the northern edge of the city. Overall, the disaster is considered lesser than that attributed to the Ray Fault Model, because ground conditions and social conditions of the northern areas of Tehran are better than those of the southern areas. In this model, seismic hazard and damage risk is high in the northern areas and social condition risk is high in the southern areas, but no district is extremely vulnerable. However, it must be noted that the damage to residential houses is relatively large in Districts 2, 3 and 12. Furthermore, there is relatively less damage in the southern areas, but there might be some problems caused by shortage of land or space for evacuation and shelters.

Table 5.2.2 Score for NTF Model

District	Seismic Intensity	Building Damage	Casualties	Population Density	Open Space	Narrow Road	Total Score (Max Score = 30)
1	4	4	2	1	2	2	15
2	3	3	1	2	3	1	13
3	4	3	2	1	3	1	14
4	3	2	1	1	1	1	9
5	3	3	1	1	2	1	11
6	2	2	1	2	3	1	11
7	2	2	1	3	5	3	16
8	2	2	1	4	4	2	15
9	1	1	1	2	4	3	12
10	1	1	1	5	5	5	18
11	2	2	1	3	4	4	16
12	2	3	1	2	4	5	17
13	1	1	1	2	5	2	12
14	1	1	1	3	4	3	13
15	1	1	1	2	3	2	10
16	1	1	1	3	3	3	12
17	1	1	1	5	5	4	17
18	1	1	1	2	1	3	9
19	1	1	1	2	3	2	10
20	1	1	1	1	1	2	7
21	2	2	1	1	1	1	8
22	2	2	1	1	1	2	9

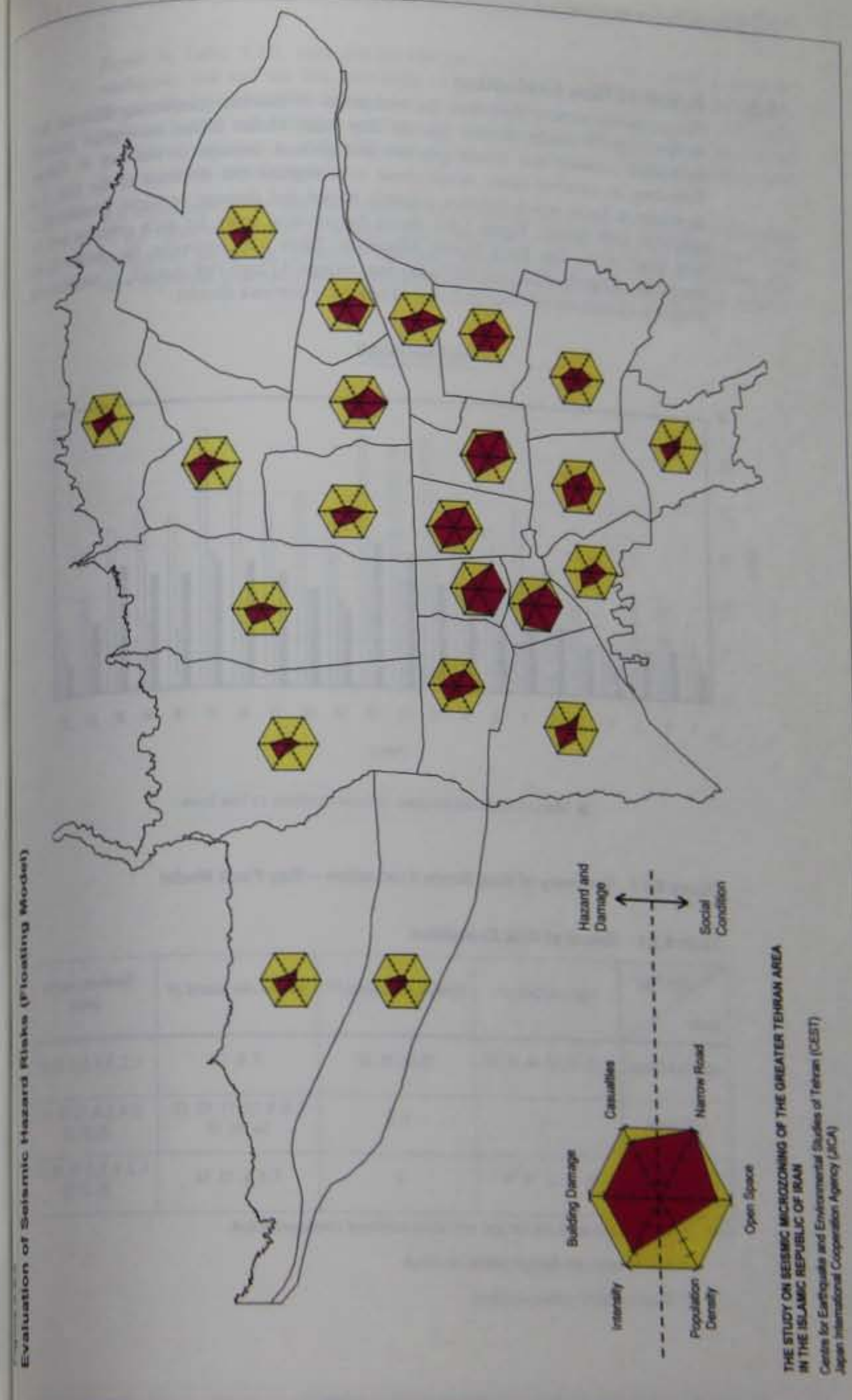


5.2.3. Floating Model

A summary of the evaluation results is shown in Table 5.2.3 and Figure 5.2.3. Relative seismic damage risk that is not caused by a specific earthquake was evaluated using the Floating Model. In this model, District 10 is evaluated as the most hazardous, followed by Districts 12 and 17. Districts 4 and 21 are evaluated as relatively low risk areas. However, it should be kept in mind that the entire city of Tehran is vulnerable to earthquakes.

Table 5.2.3 Score for Floating Model

District	Seismic Intensity	Building Damage	Casualties	Population Density	Open Space	Narrow Road	Total Score (Max Score = 30)
1	3	3	1	1	2	2	12
2	3	3	1	2	3	1	13
3	4	4	2	1	3	1	15
4	3	3	1	1	1	1	10
5	3	3	1	1	2	1	11
6	3	3	1	2	3	1	13
7	3	3	1	3	5	3	18
8	3	3	1	4	4	2	17
9	3	3	2	2	4	3	17
10	4	3	2	5	5	5	24
11	4	4	3	3	4	4	22
12	4	4	4	2	4	5	23
13	3	3	1	2	5	2	16
14	3	3	2	3	4	3	18
15	3	3	2	2	3	2	15
16	4	3	2	3	3	3	18
17	4	3	2	5	5	4	23
18	4	3	1	2	1	3	14
19	3	2	1	2	3	2	13
20	3	3	1	1	1	2	11
21	3	3	1	1	1	1	10
22	3	3	1	1	1	2	11



Evaluation of Seismic Hazard Risks (Floating Model)

THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)

5.3. Result of Risk Evaluation

The preceding sections described the evaluation of districts considering different fault models, and the results showed that the Ray Fault Model offers the highest potential earthquake scenario that would generate the greatest damage to the city of Tehran. Therefore, to consider future development to strengthen the structure of the city, it is important to know which criterion (seismic hazard and damage or social conditions) is critical in each district. Figure 5.3.1 shows the sub-total score for each criterion and the total score of the Ray Fault Model. Moreover, Table 5.3.1 provides the results of the evaluation categorised into the following four ratings: 1) high-risk district, 2) medium-risk district 1, 3) medium-risk district 2, and 4) relatively low-risk district.

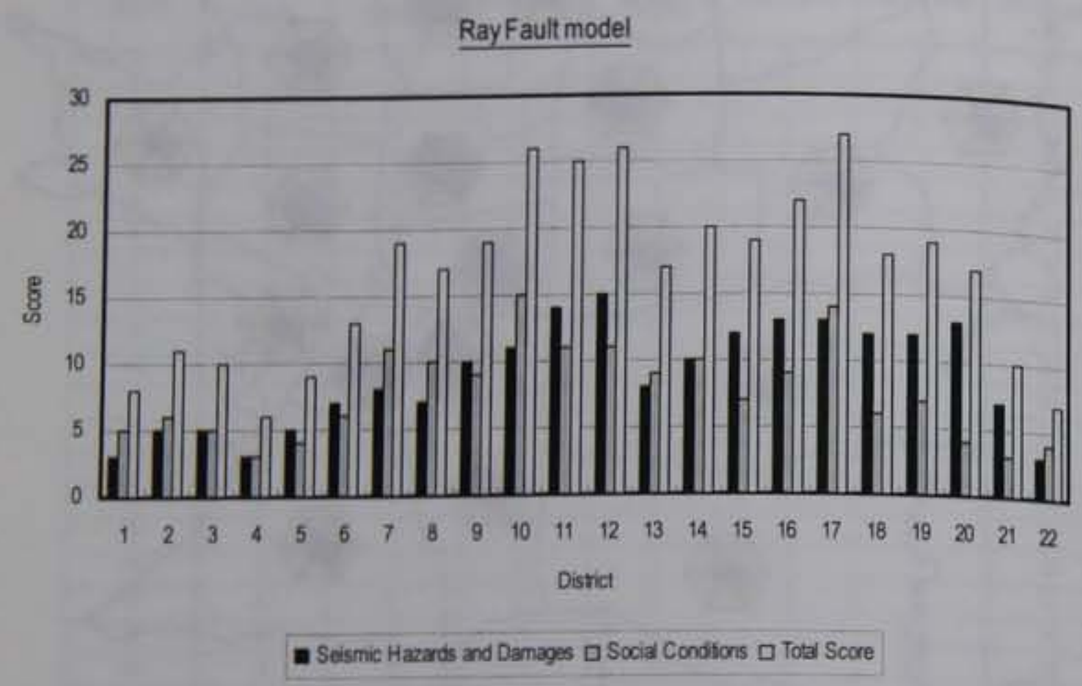


Figure 5.3.1 Summary of Risk Score Evaluation -- Ray Fault Model

Table 5.3.1 Result of Risk Evaluation

Risk Type / Model	High-risk District[1]	Medium-risk District 1[2]	Medium-risk District 2[3]	Relatively Low-risk District
Ray Fault Model	9, 10, 11,12, 14, 16, 17	15,18, 19, 20	7, 8, 13	1, 2, 3, 4, 5, 6, 21, 22
NTF Model	—	1, 3	7, 8, 9, 10, 11, 12, 13, 14, 16, 17	2, 4, 5, 6, 15, 18, 19, 20, 21, 22
Floating Model	10, 11, 12, 16, 17	3,	7, 8, 9, 13, 14	1, 2, 4, 5, 6, 15, 18, 19, 20, 21, 22

Note: [1] Both 'Seismic hazard and damage' and 'social conditions' criteria are critical.

[2] 'Seismic hazard and damage' criteria are critical.

[3] 'Social conditions' criteria are critical.

Based on Table 5.3.1, each district can get a sense of where they stand in terms of earthquake risk and use this knowledge to plan for future development corresponding to the priority by each model. For instance, in case of districts categorised as 'high-risk', both 'seismic hazard and damage' criteria, e.g., strengthening building structures, and 'social conditions' criteria, e.g., redevelopment of area and maintaining adequate open space, need to be carefully investigated.

It is important to note that the results of the evaluation show only an index or an indication of the relative potential of seismic risk. Therefore, even the districts, which have been categorised as having 'relatively low risk', cannot afford to be complacent. In fact, it is very important to keep in mind that the entire Tehran area is vulnerable to seismic hazard.

Chapter 6:

Conduct of Pilot Study

Table 6.1.1 Social Conditions Of The Pilot Study Area (1)

Zone Number	Block Number	No of Buildings	Parcels Area (ha)	Population	Density (person / ha)	Building Structure			Building Usage					
						Steel	Steel and Brick	Others	Residential	School	Workshop	Medical	Public Usage	Others
17084	1	28	0.245	224	914	3	24	1	27	0	0	0	1	1
	2	29	0.285	215	753	0	29	0	29	0	0	0	0	0
	3	31	0.350	239	682	2	29	0	29	0	0	2	0	2
	4	33	0.380	270	711	1	31	1	32	0	0	0	1	1
	5	36	0.348	275	789	5	31	0	36	0	0	0	0	0
	6	147	1.473	1,331	904	26	120	1	146	0	0	1	0	1
	7	37	0.343	326	949	11	25	1	37	0	0	0	0	0
17085	1	31	0.314	336	1,072	6	25	0	30	0	0	1	0	1
	2	17	0.163	176	1,080	2	15	0	17	0	0	0	0	0
	3	1	0.017	12	698	0	1	0	1	0	0	0	0	0
	4	16	0.128	142	1,111	1	15	0	16	0	0	0	0	0
	5	6	0.048	49	1,028	3	3	0	6	0	0	0	0	0
	6	315	2.990	2,975	995	13	294	8	311	0	0	0	0	0
	7	5	0.046	33	711	5	0	0	5	0	0	0	0	0
17086	0	1	0.006		-	0	0	1	0	0	0	0	0	0
	1	21	0.199	171	858	13	7	1	18	0	0	1	1	2
	2	21	0.164	179	1,090	16	4	1	21	0	0	0	0	0
	3	21	0.157	165	1,049	11	10	0	21	0	0	0	0	0
	4	20	0.156	155	994	15	5	0	20	0	0	0	0	0
	5	16	0.214	138	646	8	8	0	15	0	0	0	1	1
	6	23	0.174	197	1,129	2	21	0	19	0	4	0	0	4
	7	22	0.192	188	979	0	22	0	21	0	1	0	0	1
	8	18	0.151	158	1,045	0	17	1	17	0	0	0	0	0
	9	18	0.146	140	956	0	17	1	17	0	0	0	0	0
	10	19	0.147	109	741	0	18	1	16	0	1	1	0	2
	11	12	0.138	99	718	2	10	0	12	0	0	0	0	0
	12	14	0.300	105	351	0	13	1	13	0	0	0	0	0
	13	34	0.840	322	384	16	18	0	33	0	0	0	0	0
	14	15	0.358	161	450	8	7	0	14	0	0	0	0	0
	15	12	0.302	152	503	6	6	0	12	0	0	0	0	0
	16	14	0.337	119	353	7	7	0	13	0	0	0	0	0

Table 6.1.1 Social Conditions Of The Pilot Study Area (2)

Zone Number	Block Number	No of Buildings	Parcels Area (ha)	Population	Density (person / ha)	Building Structure			Building Usage					
						Steel	Steel and Brick	Others	Residential	School	Workshop	Medical	Public Usage	Others
17086	17	4	0.149	27	181	3	1	0	2	0	1	0	0	1
	18	16	0.200	129	644	4	12	0	15	0	0	0	1	1
17087	0	1	0.121		-	0	0	1	0	0	0	0	0	0
	1	25	0.176	188	1,069	25	0	0	25	0	0	0	0	0
	2	27	0.177	213	1,201	27	0	0	27	0	0	0	0	0
	3	28	0.184	223	1,210	28	0	0	27	0	1	0	0	1
	4	28	0.187	216	1,154	28	0	0	28	0	0	0	0	0
	5	30	0.194	254	1,311	30	0	0	30	0	0	0	0	0
	6	32	0.206	255	1,240	32	0	0	32	0	0	0	0	0
	7	31	0.206	235	1,143	31	0	0	31	0	0	0	0	0
	8	2	0.221	11	50	1	1	0	1	1	0	0	0	1
	9	16	0.107	143	1,339	16	0	0	16	0	0	0	0	0
	10	14	0.138	118	856	14	0	0	13	0	0	0	0	0
	11	15	0.320	166	519	15	0	0	15	0	0	0	0	0
	12	11	0.335	102	305	10	0	1	9	0	1	0	0	1
	13	31	1.066	337	316	29	0	2	28	0	1	0	0	1
	14	17	0.353	137	388	17	0	0	17	0	0	0	0	0
	15	19	0.403	188	466	19	0	0	19	0	0	0	0	0
	16	39	0.994	361	363	36	1	2	36	0	1	0	1	2
17088	1	34	0.484	278	575	10	22	2	31	0	0	0	1	1
	2	40	0.251	367	1,460	33	7	0	40	0	0	0	0	0
	3	37	0.250	257	1,027	20	17	0	36	0	0	1	0	1
	4	25	0.348	359	1,031	15	9	1	23	0	0	0	1	1
	5	27	0.282	251	890	15	12	0	26	0	1	0	0	1
	6	29	0.179	213	1,188	21	8	0	29	0	0	0	0	0
	7	15	0.174	87	499	14	1	0	14	1	0	0	0	1
	8	13	0.523	80	153	9	0	4	8	3	1	0	0	4
	9	13	0.180	112	622	13	0	0	12	0	0	0	1	1
	10	30	0.298	258	866	28	2	0	30	0	0	0	0	0
	11	28	0.300	238	793	25	3	0	25	0	0	1	0	1
	12	19	0.187	175	937	17	2	0	18	0	1	0	0	1
	13	17	0.173	148	856	16	1	0	16	0	1	0	0	1

Table 6.1.1 Social Conditions Of The Pilot Study Area (3)

Zone Number	Block Number	No of Buildings	Parcels Area (ha)	Population	Density (person / ha)	Building Structure			Building Usage					
						Steel	Steel and Brick	Others	Residential	School	Workshop	Medical	Public Usage	Others
17089	1	31	0.310	303	978	20	11	0	30	0	1	0	0	1
	2	32	0.322	272	844	4	28	0	32	0	0	0	0	0
	3	32	0.331	306	923	1	31	0	32	0	0	0	0	0
	4	32	0.373	278	746	1	30	1	31	0	0	0	0	0
	5	52	0.599	535	893	0	52	0	52	0	0	0	0	0
	6	47	0.471	421	894	0	47	0	46	0	1	0	0	1
	7	40	0.395	395	1,001	1	39	0	39	0	1	0	0	1
	8	32	0.319	327	1,025	0	32	0	32	0	0	0	0	0
	9	24	0.238	247	1,038	0	24	0	24	0	0	0	0	0
17090	1	20	0.181	182	1,007	8	12	0	20	0	0	0	0	0
	2	23	0.153	178	1,163	3	20	0	23	0	0	0	0	0
	3	27	0.181	226	1,247	4	23	0	27	0	0	0	0	0
	4	31	0.209	255	1,218	4	27	0	31	0	0	0	0	0
	5	30	0.193	213	1,106	3	27	0	30	0	0	0	0	0
	6	11	0.092	72	787	1	10	0	11	0	0	0	0	0
	7	14	0.330	123	373	1	13	0	14	0	0	0	0	0
	8	14	0.331	103	312	1	12	1	13	0	0	0	1	1
	9	14	0.353	137	388	4	10	0	12	0	2	0	0	2
	10	16	0.370	145	392	3	13	0	16	0	0	0	0	0
	11	16	0.382	182	476	4	11	1	16	0	0	0	0	0
	12	28	0.219	249	1,136	2	26	0	27	0	0	0	1	1
	13	80	0.685	570	832	20	57	3	78	0	0	1	1	2
	14	17	0.390	147	377	5	12	0	16	0	1	0	0	1
	15	16	0.384	179	466	3	12	1	15	0	0	0	1	1
	16	1	0.212	7	33	0	1	0	0	1	0	0	0	1
17091	1	28	0.299	284	949	28	0	0	28	0	0	0	0	0
	2	26	0.284	235	828	26	0	0	26	0	0	0	0	0
	3	24	0.263	162	615	23	1	0	23	0	1	0	0	1
	4	24	0.245	231	942	23	1	0	24	0	0	0	0	0
	5	40	0.407	352	866	40	0	0	40	0	0	0	0	0

Table 6.1.1 Social Conditions Of The Pilot Study Area (4)

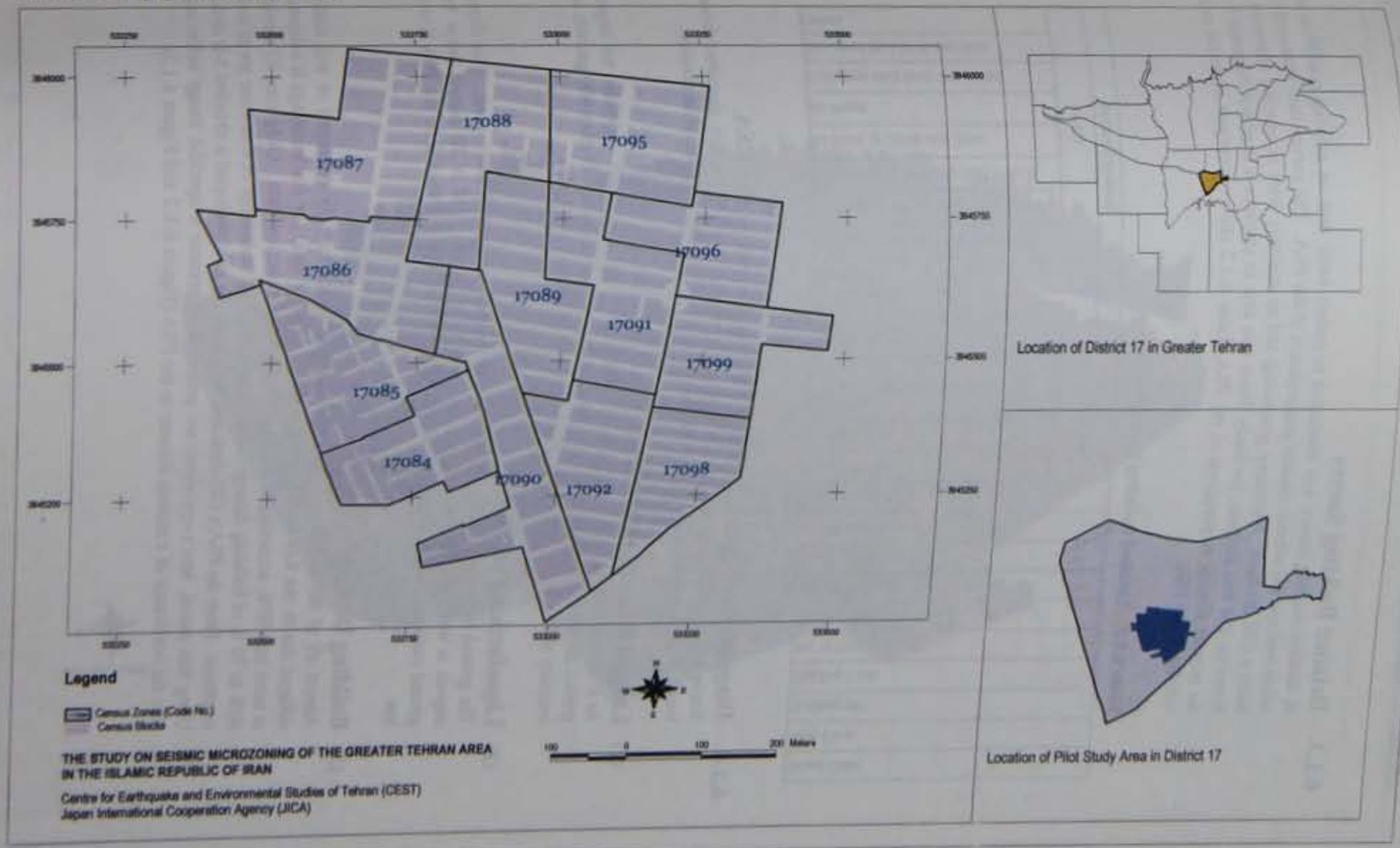
Zone Number	Block Number	No of Buildings	Parcels Area (ha)	Population	Density (person / ha)	Building Structure			Building Usage					
						Steel	Steel and Brick	Others	Residential	School	Workshop	Medical	Public Usage	Others
17091	6	27	0.336	219	652	26	0	1	25	1	0	0	1	2
	7	2	0.316	-	-	2	0	0	0	2	0	0	0	2
	8	11	0.195	80	410	10	0	1	8	0	0	1	1	2
	9	41	0.414	403	973	41	0	0	41	0	0	0	0	0
	10	43	0.417	381	914	35	8	0	43	0	0	0	0	0
	11	42	0.423	364	860	39	3	0	40	0	1	0	1	2
17092	1	44	0.425	409	962	31	11	2	42	0	2	0	0	2
	2	43	0.417	399	958	16	27	0	43	0	0	0	0	0
	3	16	0.167	155	927	7	9	0	16	0	0	0	0	0
	4	7	0.090	71	787	3	2	2	6	0	1	0	0	1
	5	44	0.439	419	954	10	33	1	43	0	1	0	0	1
	6	42	0.434	320	737	3	39	0	39	0	1	0	1	2
	7	1	0.004		-	0	0	1	0	0	0	0	0	0
	8	41	0.426	362	850	8	33	0	41	0	0	0	0	0
	9	34	0.355	263	742	6	28	0	34	0	0	0	0	0
	10	27	0.277	257	929	2	25	0	27	0	0	0	0	0
	11	20	0.208	206	992	5	15	0	20	0	0	0	0	0
	12	1	0.078	6	77	0	1	0	0	1	0	0	0	1
17095	1	40	0.421	375	891	12	28	0	40	0	0	0	0	0
	2	40	0.410	382	932	3	37	0	40	0	0	0	0	0
	3	39	0.410	340	829	2	37	0	38	0	1	0	0	1
	4	41	0.432	336	778	1	40	0	39	1	2	0	0	3
	5	30	0.385	221	574	7	23	0	25	0	3	2	0	5
	6	30	0.326	192	589	11	18	1	25	1	0	3	1	5
	7	36	0.377	359	951	5	31	0	36	0	0	0	0	0
	8	34	0.357	322	903	8	26	0	33	0	1	0	0	1
	9	21	0.231	199	860	5	16	0	21	0	0	0	0	0
	10	22	0.234	189	806	7	15	0	22	0	0	0	0	0
	11	1	0.040		-	1	0	0	0	0	0	0	1	1
17096	1	40	0.416	354	852	37	3	0	40	0	0	0	0	0
	2	40	0.413	347	840	30	9	1	40	0	0	0	0	0

Table 6.1.1 Social Conditions Of The Pilot Study Area (5)

Zone Number	Block Number	No of Buildings	Parcels Area (ha)	Population	Density (person / ha)	Building Structure			Building Usage					
						Steel	Steel and Brick	Others	Residential	School	Workshop	Medical	Public Usage	Others
17096	3	45	0.326	353	1,084	29	16	0	45	0	0	0	0	0
	4	40	0.336	283	841	38	1	1	38	0	0	0	2	2
	5	43	0.349	373	1,070	37	6	0	43	0	0	0	0	0
	6	47	0.347	350	1,010	28	19	0	47	0	0	0	0	0
	7	42	0.363	318	875	3	39	0	41	1	0	0	0	1
	8	44	0.334	391	1,170	1	42	1	43	0	0	1	0	1
17098	1	3	0.017	26	1,504	0	3	0	3	0	0	0	0	0
	2	14	0.099	116	1,175	3	11	0	14	0	0	0	0	0
	3	23	0.164	166	1,014	3	20	0	22	0	1	0	0	1
	4	31	0.216	248	1,148	1	30	0	31	0	0	0	0	0
	5	38	0.288	299	1,038	2	36	0	37	0	1	0	0	1
	6	50	0.344	371	1,078	0	50	0	50	0	0	0	0	0
	7	50	0.372	383	1,029	1	48	1	48	0	2	0	0	2
	8	49	0.370	402	1,087	3	46	0	49	0	0	0	0	0
	9	53	0.368	399	1,086	1	52	0	52	0	1	0	0	1
	10	48	0.362	345	954	3	45	0	45	0	3	0	0	3
17099	1	48	0.356	349	979	3	45	0	47	0	1	0	0	1
	2	40	0.355	272	766	2	37	1	39	0	0	0	1	1
	3	49	0.343	360	1,050	2	47	0	49	0	0	0	0	0
	4	46	0.332	306	921	4	42	0	44	0	2	0	0	2
	5	45	0.343	313	914	6	39	0	44	0	0	0	0	0
	6	44	0.338	330	977	6	38	0	42	0	1	1	0	2
	7	40	0.358	330	921	3	37	0	38	0	0	0	2	2
	8	31	0.307	260	846	5	26	0	30	0	0	0	0	0
	9	33	0.223	254	1,140	0	33	0	33	0	0	0	0	0
Total	149	4,464	47	38,130	803	1,573	2,838	53	4,332	13	47	17	24	101

Figure 6.1.1

Location Map (Pilot Study Area)



6.1.3. Detailed Building Survey

A detailed building survey was conducted to collect basic data on existing conditions of urban land use and seismic disaster preparedness of the PSA. The survey data were used to build a GIS database. Necessary processing and an analysis were conducted afterwards. Based on this data analysis, the Study Team was able to produce a regional diagnosis for the seismic disaster preparedness of the PSA. Table 6.1.2 shows surveyed items for each building in the PSA.

Table 6.1.2 Detailed Building Survey Items

										Accessible Lifelines					Building Structure										
																	Others								
Street Code	Alley Code	Building No.	Building Code	No. of Floors	No. of Dwelling Units	Type of Building Use	No. of Households	No. of Residents	Construction Year	Service Water	Sewage	Electricity	Gas	Telephone	RC	Steel	Brick and Steel, or Stone and Steel	Brick and Wood, or Stone and Wood	Cement Block [with any kind of roof]	All Brick, or Stone and Brick	All Wood	Sun-dried Mud Brick and Wood	Sun-dried Mud Brick and Mud	Others	

6.1.4. Diagnosis for Seismic Disaster Preparedness of the PSA

Issues and problems for seismic disaster preparedness in the PSA are described below based on the diagnosis of the PSA from the viewpoint of mitigating a seismic disaster.

(1) Largest Estimated Seismic Ground Motion

As a basic condition of seismic disaster mitigation, the Study Team estimated the largest ground motion that could occur in the PSA. It was calculated at more than 400 gal with an intensity of 9 in MMI scale. This category covers the entire PSA area.

(2) Liquefaction Potential

The ground condition of the PSA is mainly composed of alluvial clayey soil. This clayey deposit is well consolidated and ground water level in the area is 20 meters below the ground surface. Due to these ground conditions, liquefaction potential of the PSA is very low.

(3) Building Damage

Almost all of the buildings in the PSA will be either heavily damaged or will totally collapse due to the Ray Fault Earthquake. The damage ratio for the buildings is estimated at more than 80%, according to the available damage function data. Only zone 87 showed 60% to 70 % of building damage ratio because 97% of buildings in this zone are of steel structures. From the PSA's GIS database, the Study Team developed a detailed 3-D model. Using this model, bird's-eye views are prepared to present a specific image before and after the occurrence of a seismic disaster in the PSA (Figure 6.1.2 and Figure 6.1.3).

Figure 6.1.2 3D View - Existing

Figure 6.1.3
3D View - After Damage

(4) Human Casualties

In the PSA, not only will building damage be high, but also the number of human casualties. Although the damage ratio of human casualties is different according to the type of building structure, it is estimated that 3,048 people could die out of the total 32,239 night-time population (1996 Census) of the area. If a community rescue function and related rescue operation by another organisation arrive timely and work effectively, the total number of deaths will be reduced to 2,151.

(5) Disaster Prevention Base

For quick and effective response to emergencies such as a seismic disaster, it is essential to properly equip facilities that will serve as bases that provide countermeasures for disasters. Presently, in District 17, there is nothing being done to prepare for a seismic disaster or to take necessary countermeasures. Although the Red Crescent Society of Iran can start rescue operations immediately after a seismic disaster occurs, the estimated damage for Tehran would be simply too huge for them to manage alone. Therefore, district- or regional-based disaster prevention bases should be prepared independently. At the very least, emergency response supplies such as food, water, medicine, and tools for rescue operation and self-sustaining generators should be stocked in these disaster prevention bases. The district office building should be partly used for this purpose.

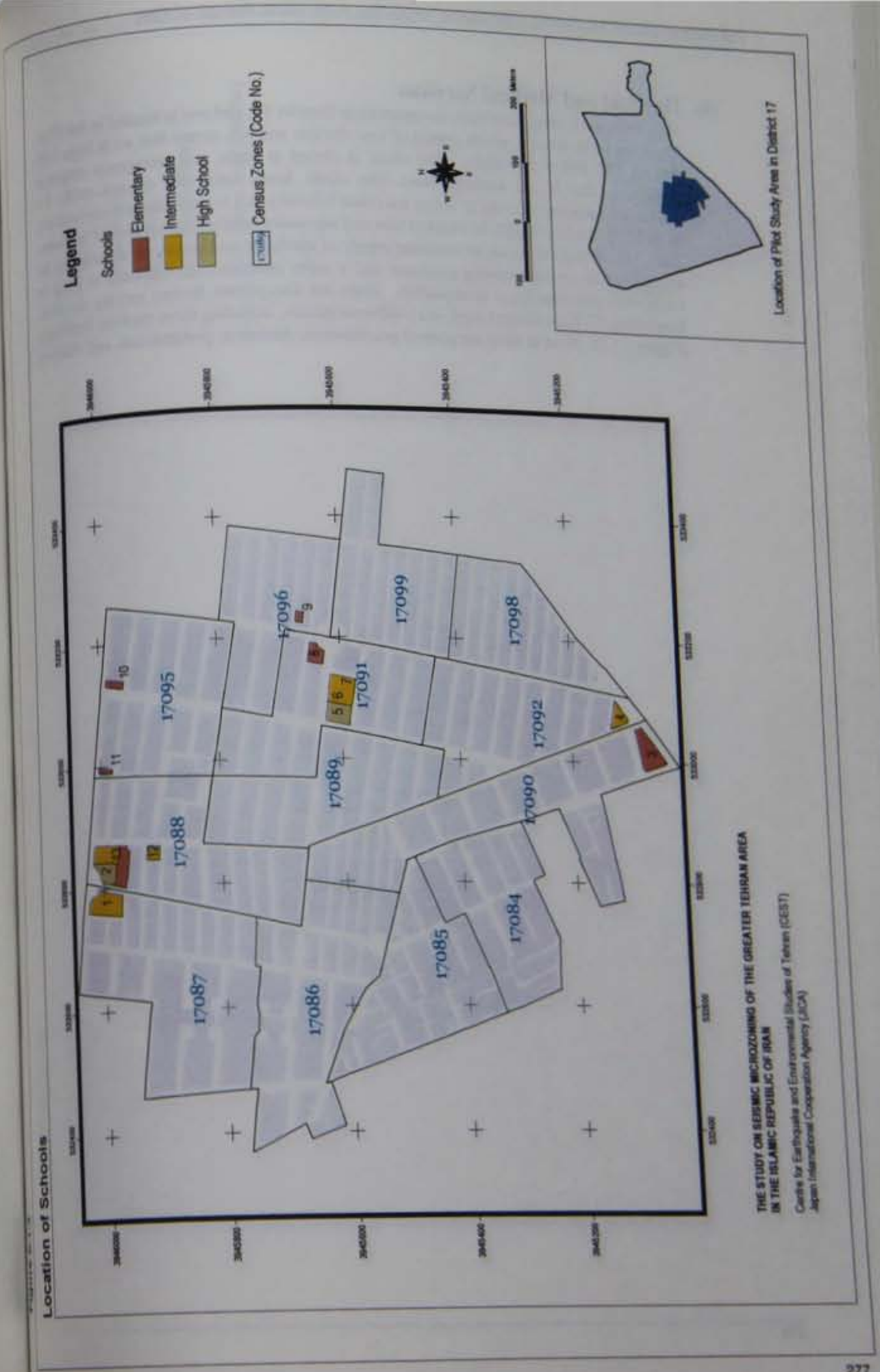
(6) School Buildings

Most schools usually have two shifts to accommodate the rapidly increasing younger population in Tehran. There are 13 schools in the PSA, including elementary through high schools. The distribution and other details of the schools are shown in Table 6.1.3 and Figure 6.1.4 respectively. These school buildings are made of steel and brick. There is one reinforced concrete building in the area. Resistance of the building structures against a strong earthquake is not enough. Besides, the school grounds are rather narrow in general; they would not be easy to use as a temporary evacuation site for students when a seismic disaster occurs. Resistance of school buildings against a strong earthquake should be checked immediately and necessary retrofitting should be implemented. Each school should prepare a safety manual for students to be used in preparation for the occurrence of disasters. An evacuation drill for students should be practiced periodically.

Table 6.1.3 List of Schools

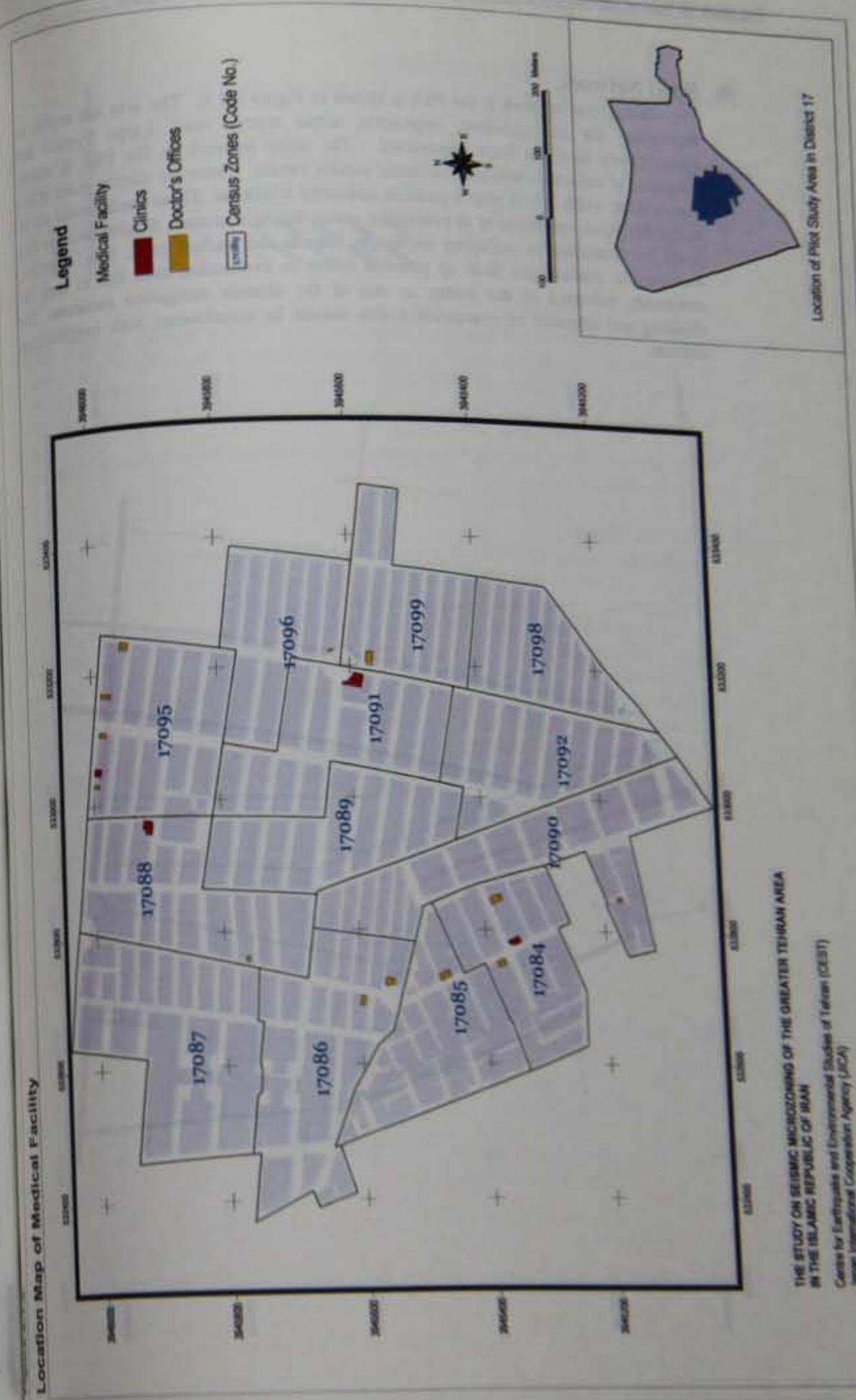
School No.	Name	Education Type	Year Founded	No. of Students	No of Shifts	Total Land Area (m^2)	Building Area (m^2)	Note
1	Abuzas	Secondary	1972	600/650	2	2,108	849	Boys
2	Azadeghan	High	1990	450	1	1,053	627	Boys
3	Imam Khomaynie	Primary	1979	500/500	2	2,120	762	One shift for boys. The other shift for girls.
4	Imam Komaynie	Primary & Secondary	1972	420/420	2	777	396	Both shifts for boys. One shift for primary education. The other shift for secondary education.
5	Meshkaat	High	1980	400	1	3,164	1,387	Girls
6	Somayyeh	Secondary	1980	300/300	2	3,164	1,387	Girls
7	Bent-al-Hoda	Primary	1980	340/340	2	3,164	1,387	Girls
8	17th of Shakrivar	Primary	1972	460/460	2	741	544	Girls
9	Hezb-al-Allah	Primary	1951	340/340	2	328	148	Boys
10	Iran	Primary	1995	90	1	390	235	Boys
11	Shahid Kolahdooz	Primary	1961	200/200	2	200	140	Girls
12	Shahid Firoozi	Primary & Secondary	1975	250/250	2	475	291	Girls
13	Ghods	Primary & Secondary	1995	400/600	2	2,617	524	Boys

Source: the Study Team (2000)



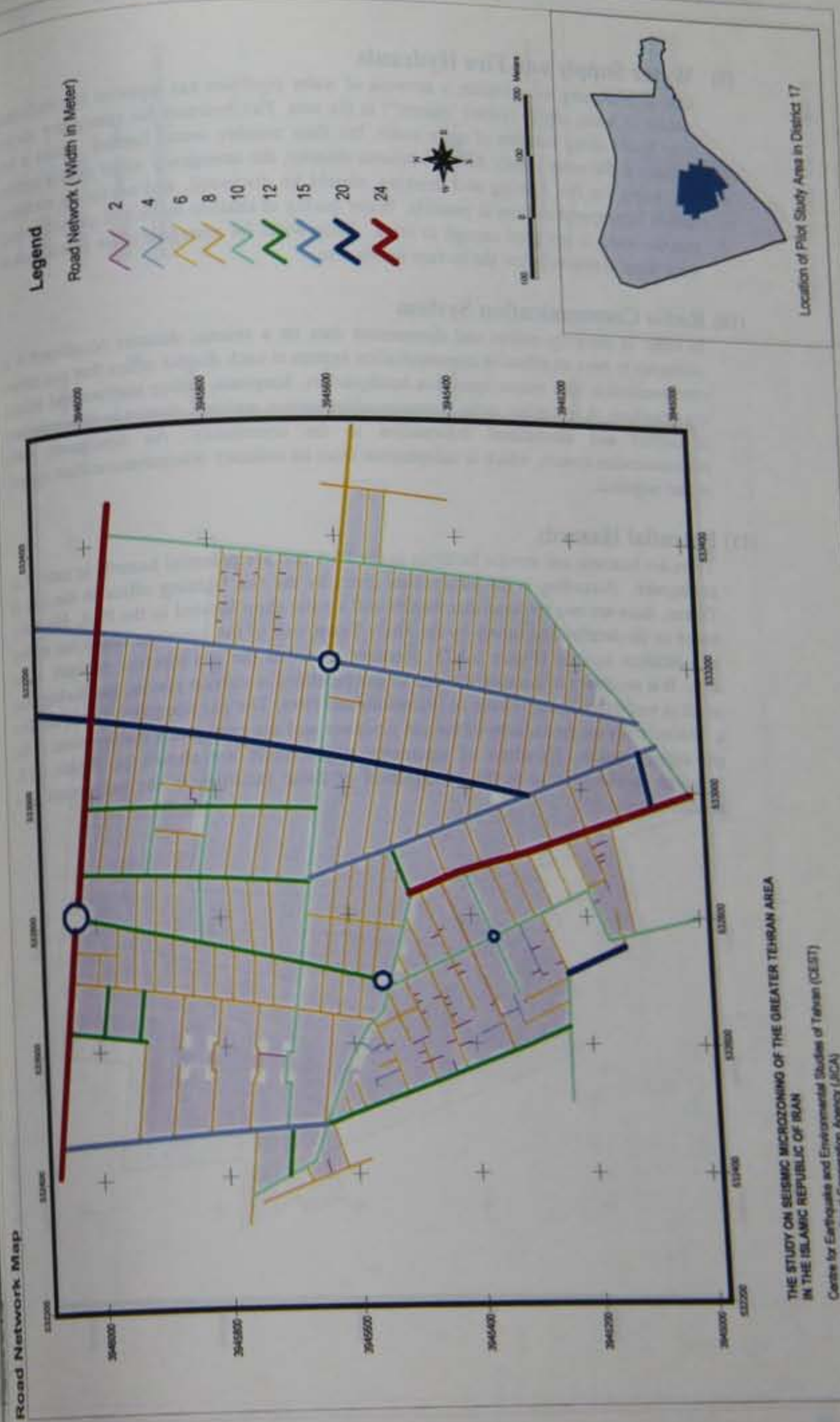
(7) Hospital and Medical Services

Only two public hospitals/clinics are operated in District 17, and one is located in the PSA. There are seven doctors, which consist of four dentists and two nurses that work from 8:00 AM to 8:00 PM in two shifts. The clinic is closed at night, and emergency response medical service is not available then. The clinic keeps only two oxygen tanks for emergency purposes. In order to utilise the clinic's facility in a seismic disaster occurrence, its building structure should be checked first and necessary reinforcements should be made. The clinic should also stock an adequate supply of medicine and water. It should also be equipped with a self-sustaining generator and a radio communication system to keep in touch with rescue operation headquarters. There are also private doctors serving the area. Numbering 27, these doctors work in 15 different places, including three medical buildings (Figure 6.1.5). Most of them are general practitioners, internists, pediatricians and dentists.



(8) Road Network

The existing road network in the PSA is shown in Figure 6.1.6. The area has neither an expressway nor an equivalent, large-scale, urban arterial road. Large flyovers and embankments have not been constructed. The street network in the PSA is mainly composed of collector roads and residential service streets. There are narrow roads of less than 6-meter width, which pose a problem in case of a disaster. These roads would not be useful for rescue operations or as evacuation routes during a seismic disaster because they could be obstructed by collapsed buildings, fences, and parked cars. It is, therefore, necessary to confirm and draw up possible routes to evacuation sites and to keep the community informed of this matter as one of the disaster mitigation measures. The checking and selection of evacuation routes should be coordinated with neighbouring districts.



(9) Water Supply and Fire Hydrants

Due to increasing urbanisation, a network of water pipelines has replaced the traditional system of water supply (called "quanat") in the area. Fire hydrants for emergency use are now found along the side of main roads, but their number seems limited. Since a key concern is the water supply during a seismic disaster, the emergency water supply system, i.e., water for fire fighting and drinking, should be discussed, and necessary measures should be prepared as soon as possible. Water quality of shallow wells and quanats is such that the water is not good enough to drink. Deep wells for emergency use should extend more than 50 meters below the surface in this area.

(10) Radio Communication System

In order to correctly collect and disseminate data on a seismic disaster occurrence it is necessary to have an effective communication system at each district office that can ensure communication with rescue operation headquarters, hospitals, police stations and related organisations. A secondary radio communication system within a district is also necessary to collect and disseminate information to the community. An emergency radio communication system, which is independent from an ordinary telecommunication system, is also required.

(11) Potential Hazards

There are business and service facilities in the PSA that are potential hazards in case of an earthquake. According to the information given by the fire fighting office in the city of Tehran, there are two kerosene distributors and a paint shop located in the PSA. However, based on the detailed site survey by the Study Team, one of the kerosene stores has moved to a different location (Figure 6.1.7). Another hazard is the gas pipeline network in the area. It is necessary to estimate damage to gas pipelines at certain places; gas leakage can result in secondary disasters such as explosions and fires. The gas company should conduct a detailed study on the security of the gas pipelines and the emergency management of the gas supply system. Locations of electricity transformers are shown in Figure 6.1.8. Attention should be paid to the management of these facilities in the occurrence of a seismic disaster.

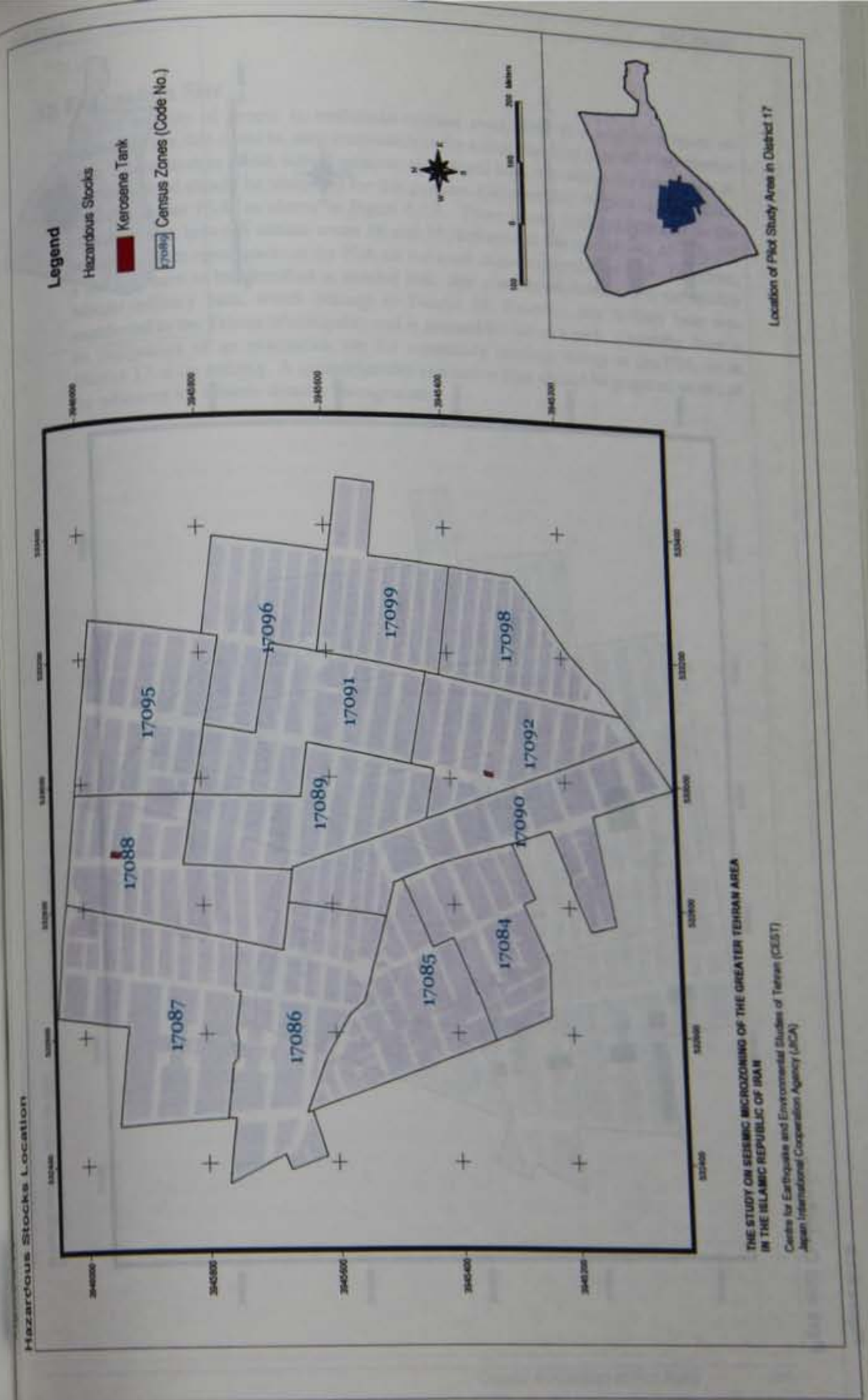
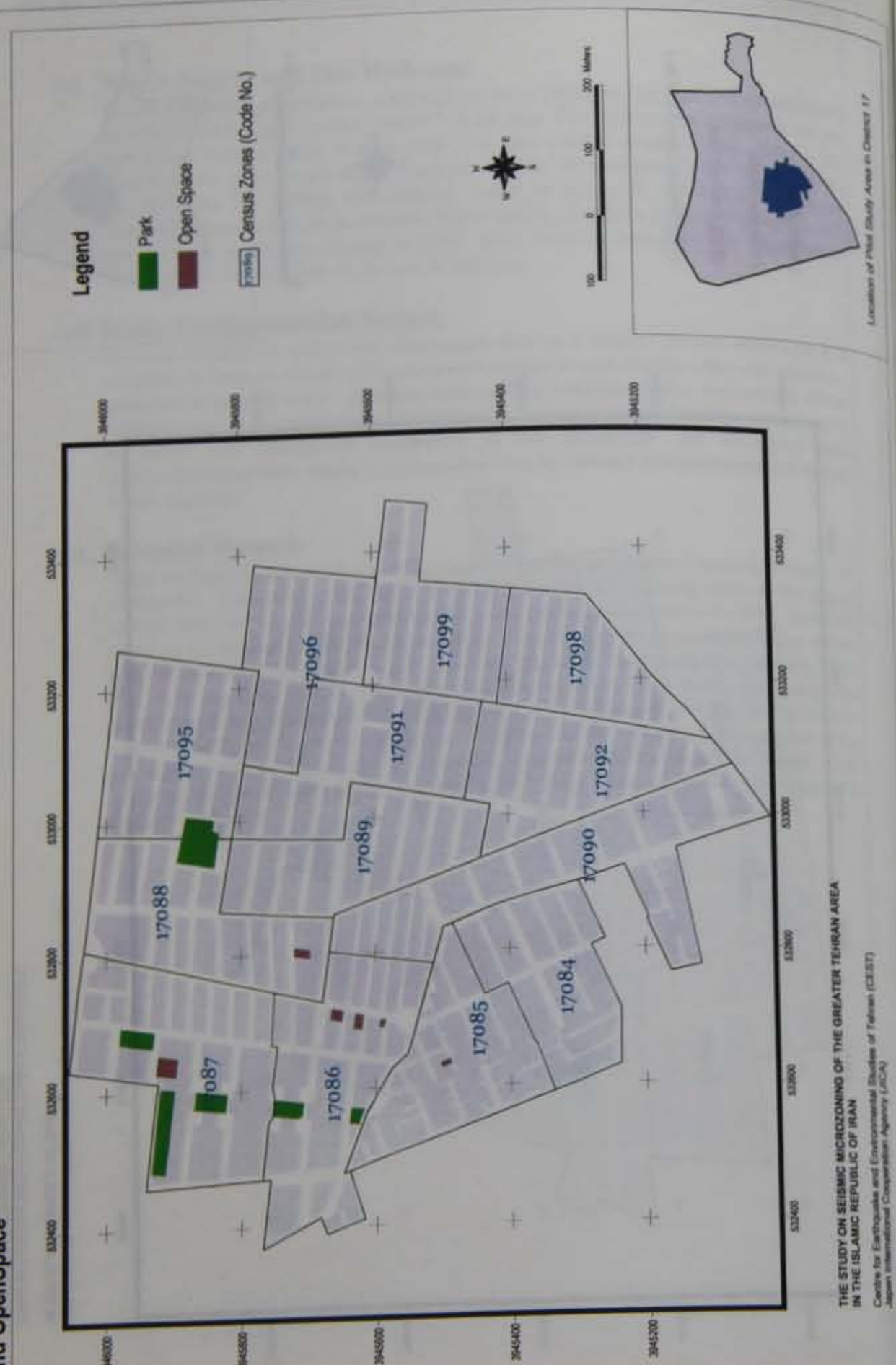


Figure 6.1.8

Park and OpenSpace



(12) Evacuation Site

For the security of people in earthquake-stricken areas, there is a need to prepare an evacuation site that could be used temporarily or for a long period of time after the disaster. Open spaces such as parks, school grounds, agricultural land, etc. within the community or neighbourhood should be identified for this purpose. Unfortunately, there is no such space available in the PSA, as shown in Figure 6.1.9. There is one small park located in the boundary area between census zones 88 and 95; however, it has a total area of only 0.5 hectares. Other open spaces in the PSA are too small to use as evacuation sites. Therefore, a site will have to be identified in another area. One possible candidate site is the Ghaleh Morghi military base, which belongs to District 19. Recently, this military base was transferred to the Tehran Municipality and is planned for use as a park. Currently, there is no designation of an evacuation site for community residents living in the PSA, or in District 17 in its entirety. A comprehensive evacuation plan should be prepared as one of the measures for seismic disaster management.

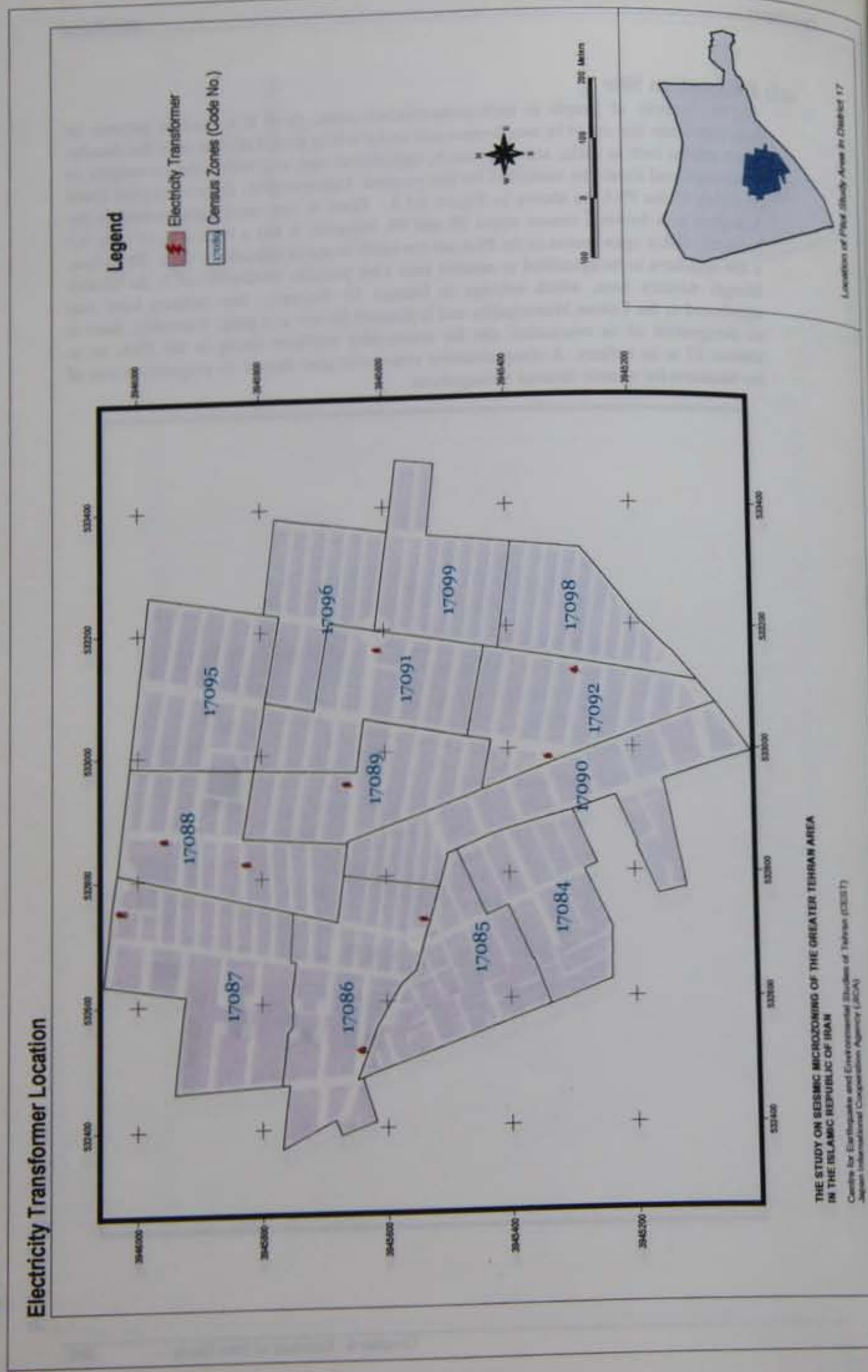


Figure 6.1.9 Electricity Transformer Location

(13) Community Organisation

Community organisation plays a significant role not only in first aid activities during a seismic disaster, but also for collection and dissemination of disaster information to the entire community. Community leaders should work together with district officials to draw up proper and necessary instructions for evacuation, first aid operations and the security of the community. However, community groups have not yet been organised in the PSA. Therefore, their establishment on a housing block basis should be, at least, discussed for the mitigation of a possible disaster. General community participation in disaster mitigation should also be discussed and planned.

(14) Disaster Prevention Awareness

It is necessary to raise the people's awareness on seismic disaster prevention based on proper dissemination of disaster prevention information through administrative organisations, school education and mass media. The main purpose of raising public awareness on seismic disaster prevention is to minimise human casualties as much as possible. The effective promotion of disaster prevention measures hinges not only on the improvements of arrangements by the city of Tehran, the district office and concerned institutions, but also on the active involvement of citizens. Presently, the activities of Tehran, including those of the district office, for the raising of public awareness on disaster prevention is not clear. However, the people should, at least, be given the necessary information that would be helpful in case of a seismic disaster.

6.1.5. Issues for Seismic Disaster Prevention in the PSA

A detailed site survey of the PSA was conducted to identify existing problems and issues for seismic disaster prevention. Building and population data were checked to update the data of the 1996 census, which was based on parcels. Building use was also verified to determine the general urban land use. Intensive discussions concerning seismic disaster prevention were held with responsible persons for disaster management of District 17. All data, discussions and results of the site survey were combined and analysed from the point view of seismic disaster prevention.

Based on the above, the Study Team reached a clear conclusion that the PSA, including its surrounding area, has no defence system against a potential strong earthquake. In the worst-case scenario, huge damage is estimated in these areas; therefore, necessary measures for seismic disaster mitigation, at least to save human lives, must be prepared as soon as possible. The following items should be implemented for seismic disaster mitigation in a planned manner:

1) Urban seismic disaster prevention and a risk management plan must be prepared by Tehran immediately. Under the direction of the plan, each district must take and prepare necessary measures for seismic disaster mitigation. It is also necessary to clarify the role of community in disaster prevention efforts such as first aid, evacuation and information collection and dissemination. The city of Tehran and each district office should work together to formulate an earthquake disaster prevention and risk management plan.

2) The most urgent project is retrofitting structurally weak school and public facility buildings in the PSA. There are 13 schools and 4,000 students in this area; however, the resistance of school buildings against a strong earthquake is not sufficient. The earthquake resistance of each school building should be checked immediately, and necessary retrofitting, reconstruction and even school relocation should be implemented. Public facilities such as the district office building, hospitals or clinics, and related public buildings should also be checked and necessary reinforcement of these buildings should be conducted.

Chapter 7:

Recommendation to Formulate a Comprehensive Urban Disaster Prevention and Management Plan

Chapter 7. Recommendations to Formulate a Comprehensive Urban Disaster Prevention and Management Plan

7.1. Introduction

7.1.1. Review of Seismic Damages to the City of Tehran

In chapter 4, damages were estimated for various items. Here major damages are reviewed. Damages to residential building and human casualties were estimated as Table 7.1.1. The damage of bridges was estimated as Table 7.1.2. Damages to major public facilities were estimated as Table 7.1.3.

Table 7.1.1 Building Damages and Human Casualties

	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model	Current Condition
Building Damage	483,000	313,000	113,000	446,000	Number of Buildings
Building Damage Ratio	55%	36%	13%	51%	876,000
Damage Cost (% of GDP) (Re-construction cost of residential buildings)	22.7%	14.30%	5.16%	20.38%	Gross GDP (1998) 109 Billion US$
Number of Dead People	383,000	126,000	20,000	302,000	Population
Death Ratio	6%	2%	0.3%	5%	6,360,000

Note: Damage cost is calculated by using published GDP(1998) at price of US$50,000 per building (government official exchange rate 1US$=Rls.3,000)
Human casualties are case for of night-time and no rescue operation.

Table 7.1.2 Damage of Bridges

Fault Model	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
Collapsed	6	0	0	0
Unstable	5	7	0	10

Table 7.1.3 Damages to Public Facilities

	Number of Damage and Damage Ratio (%)																	
	Govern-mental Facility		Police		Traffic Police		Fire-Fighting		Hospital		Elementary School		Inter-mediate school		High School		Higher Education Center (University)	
Ray Fault Model	18	(40)	27	(43)	7	(52)	28	(52)	56	(50)	623	(57)	369	(54)	340	(52)	66	(42)
NTF Model	11	(25)	18	(28)	5	(35)	21	(38)	33	(29)	376	(35)	250	(36)	242	(37)	61	(39)
Mosha Fault Model	4	(8)	7	(11)	2	(16)	7	(12)	11	(9)	133	(12)	81	(12)	75	(12)	18	(12)
Floating Model	16	(36)	26	(41)	6	(48)	28	(53)	50	(44)	558	(51)	350	(51)	331	(51)	76	(48)

7.1.2. Outline of General Approach and Conclusion

In order to mitigate an urban earthquake disaster, comprehensive measures are required for the following four stages:

- Prevention stage, to plan for the mitigation of damage in the event of an earthquake;
- Emergency stage, to mobilise effective and efficient evacuation and rescue/relief operations and other essential activities after an earthquake;
- Rehabilitation stage, to reactivate urban functions and lifelines as soon as possible, without compromising the safety of people; and
- Reconstruction stage, to rebuild a stronger Tehran that is able to sustain the effects of earthquake occurrences.

The Study Team considers that the most effective and proper way to address the reality of Tehran being at risk of an earthquake disaster involves the following:

1) Enhancement of legal measures,
2) Establishment of clear organisational structures for policy-making and for the execution of these policies,
3) Financial arrangements for required prevention, emergency, rehabilitation and reconstruction measures,
4) Formulation of a Comprehensive Urban Disaster Prevention and Management Plan, and
5) Formulation of Action Plans and Programs.

Table 7.1.4 shows contents of consideration of the Study. Table 7.1.5 shows summary of existing conditions, issues, and recommendations for Urban Seismic Disaster Prevention.

Table 7.1.4 Contents of Consideration

Subject	Contents of Consideration	Section No in this Report
Legal Measures	Chronology of Legislated Measures for Natural Disasters in Iran	7.2.1.
	The National Committee for Natural Disaster Reduction (NCNDR)	7.2.2.
	Ministry of the Interior: Executive Agency for Natural Disaster Management	7.2.3.
	Issues on Legal Measures	7.2.4.
	Recommendation to Enhance Legal Measures	7.2.5.
Organisational Structure	Present Organisational Structure for Natural Disaster Reduction Policy-Making	7.3.1.
	Issues Regarding the Present Organisational Structure	7.3.2.
	Proposed Organisational Structures	7.3.3.
Financial Measures	Allocated Natural Disaster Reconstruction Fund	7.4.1.
	Additional Financial Measures	7.4.2.
Comprehensive Urban Disaster Prevention and Management Plan	Past Trends of Related Studies and Activities in Iran	7.5.1.
	Required Fields of Comprehensive Urban Disaster Prevention and Management Plan	7.5.2.
	Required Fields to Formulate Policy and Objectives	7.5.3.
	Damage Estimation and Hazard Map (Seismic Microzoning)	7.5.4.
	Formulation of Prevention Plans • Prevention Plan for Ground-based Disaster • Fire Prevention Plan • Evacuation Plan with Facilities Development • Prevention Plan for Building Damage (details are compiled in Chapter 8) • Prevention Plan for Lifelines • Prevention Plan for Damages to Transportation Facilities • Reinforcement Plan for Urban Structures • Organisation Plan for Urban Disaster Prevention and Management • Guideline and Manual for Disaster Prevention Awareness • Earthquake Disaster Study and Research Plan (details are compiled in Chapter 9)	7.5.5.
	Emergency Operation Plans • Disaster Task Force System and Organisational Structure • Fire Fighting Plan • Rehabilitation of Heliport • Evacuation Plan • Maintenance Plan for Emergency Roads and Evacuation Road Network Functions • Emergency Rescue Operation Plan and Law • Relief Operations and Medical Service Plan and Law • Evacuation Area Plan • Emergency Water Supply Plan • Emergency Food Supply Plan • Other Emergency Goods Supply Plan • Preventive Measures for Epidemics, Cleanliness, and Health Care • Locating Dead Bodies, Preparing Morgues, Burials and Burial Grounds • Rehabilitation of Educational Function • Distribution Plan of Monetary Donations for Disaster Victims • Acceptance Plan of Donation for Disaster	7.5.6.
	Rehabilitation and Reconstruction Plan • Road and Transportation Rehabilitation Plan • Urban Infrastructure (Lifelines) Rehabilitation Plan • Rehabilitation and Reconstruction Plan of Social and Public Service Facilities • Housing Damage • Socio-Economic Revitalisation and Stabilisation Plans	7.5.7.
Formulate Action Plans and Programs		7.6.

Table 7.1.5 Matrix of Existing Situation/Issues/Recommendation for Tehran Urban Seismic Disaster Prevention (1)

	Period /Sector	Existing Situation	Issues	Recommendation
Legislation	Before disaster stage	NCNDR is only legislated at present. The other required prevention and mitigation measures and organisation for urban natural disaster damages are not legislated yet.	Lack / unclear prevention measures for urban natural disaster damage before earthquake.	1. Comprehensive and integrated prevention measures on the three stages should be clearly defined on the proposed 'Comprehensive Urban Seismic Disaster Prevention Plan for Tehran'. 2. Roles and functions of each related government agencies and private sectors for the required prevention measures on each stages should be clearly demarcated and stated with financial and organisational background by legislated measures.
	Emergency stage		Unclear / duplicated / lack of indispensable task for emergency measures between government agencies and private sectors.	
	Rehabilitation/ reconstruction stage		Unclear rehabilitation / reconstruction measures and task distribution to public and private sectors.	
Organisation	General	Systematic organisation for policy making and execution has been established as follows,	Functions and members of Provincial Committee of NCNDR and Provincial NDTF are duplicated.	Function of Provincial NCNDR could be substituted by Provincial NDTF.
	Policy Making/ Inter Ministerial Coordination	1. NCNDR was established to formulate the national policy for natural disaster prevention.	National policy is set under the inter-ministerial coordination by NCNDR, which is organised by the minister of Interior.	For the policy making under the ministerial coordination, The president of Iran is proposed to be the head of NCNDR supported by the Minister of Interior (deputy for the committee) and the present secretariat office in Ministry of Interior.
	Execution before disaster stage	2. NDTF system for central / regional levels is established to execute all of required prevention measures.	There is no Seismic Disaster Prevention and Management Plan, and no appropriate organisation to implement and manage the plan exists in the country	1. Appropriate organisation should be established to prepare "Urban Seismic Disaster Prevention and Management Plan for Tehran" under direct control of Tehran Mayor. 2. To implement the proposed plan, sufficient organisation should be established or improved within Tehran Municipality.
	Execution on emergency stage		Lack / unclear community levels of disaster task forces to tackle to the huge scale of urban disaster emergency operation (evacuation, rescue, fire-fighting, food / water supply, etc.).	For huge scale of urban disaster damage on Metropolitan Tehran, community level, residential block and family level of Disaster Task Force Units and Groups are proposed to establish.
	Execution on rehabilitation / reconstruction stage		Unclear measures for rehabilitation of lifelines and reconstruction of more than a half of collapsed public and private buildings.	Disaster Task Forces on each lifeline agencies and companies are proposed to establish. The present organisation for urban reconstruction should be improved for huge scale of estimated reconstruction demand.

Table 7.1.5 Matrix of Existing Situation/Issues/Recommendation for Tehran Urban Seismic Disaster Prevention (2)

	Period /Sector	Existing Situation	Issues	Recommendation
Financial	Before disaster stage	Funds and budgets have not been properly allocated for prevention measures.	Funds / budgets and plan for prevention measures is not cleared to improve weak structure of public and private buildings, road / urban structures, lifelines and emergency facilities / goods before disaster damages.	Proper budget to implement three staged measures should be identified and allocated on the proposed 'Comprehensive Urban Seismic Disaster Prevention Plan for Tehran'.
	Emergency stage	Funds and budget has not been properly allocated for emergency facilities and goods.	Funds / budget and plans for emergency operation is not cleared to improve emergency facilities and goods.	
	Rehabilitation / reconstruction stage	Reconstruction Funds for public facilities / road / lifelines and collapsed private buildings has been allocated.	The allocated funds for reconstruction could not be enough for the estimated reconstruction demand.	
Prevention		Prevention plan for urban natural disaster is not formulated in Iran.	Lack of prevention and mitigation plans and measures for urban natural disaster for Tehran and others.	1. Formulation of 'Comprehensive Urban Seismic Disaster Prevention Plan for Tehran' is recommended to be the top priority. 2. Implementation of prevention and mitigation measures of urban disaster damage before disaster is recommended on the above-formulated plan. 3. Urgent action or action program to improve school building and disaster center (municipality / district offices, police / traffic police, fire-fighting station, etc.) is recommended based on the above-formulated plan.
		Training / drill for natural disaster is held on the national disaster day.	Community / establishment levels of natural disaster drills is not well organised on the plan.	
Emergency		Emergency operation plan for Tehran is formulating by Red Crescent Society of Iran.	Red Crescent Society of Iran is taking major roles for emergency operation but their capability is not enough for the huge scale of Metropolitan Tehran Urban Disaster.	
		Financial resources for the emergency operation plan are arranging.		
Rehabilitation and Reconstruction		Housing Foundation (Ministry of Housing and Urban Development and Islamic Revolution) has experience of urban natural disaster reconstruction on Manjil earthquake.	The estimated magnitude of urban disaster damages of Ray Fault model will be huge, which is over several ten times larger than that of Manjil earthquake.	

Approximately 140 facilities (half of the listed facilities) are estimated as collapsed almost completely by the Ray Fault Model scenario earthquake. The expected functions and tasks of each centre cannot be carried out with these heavily damaged building. Therefore, these buildings need to be reinforced or reconstructed for seismic resistance before the earthquake event.

The headquarters of ministries, which are almost all located in the north and south centre of the city's heavily damaged districts, are excluded from the facility list. The nation's capital functions could not be sustained if these ministries and commercial/financial centres are heavily damaged because of weak structures. Before an earthquake occurrence, an assessment of all public facilities should be made by an expert, and recommendations made to reinforce or reconstruct for seismic resistance should be carried out.

Table 7.5.1 Estimated Building Damage for Centres of Disaster Task Forces

District	Government Office			Police Station			Traffic Police Station			Fire Fighting Station			Public Hospital			Total		
	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio
1	2	9	18%							0	1	10%	0	2	15%	2	12	17%
2	1	2	30%	1	3	23%	0	2	20%	2	4	38%	1	3	20%	4	14	27%
3	0	1	20%	3	15	21%				2	4	43%	2	5	30%	7	25	26%
4				1	5	20%				1	4	33%	2	7	27%	4	16	26%
5	0	1	20%	1	2	40%	1	2	60%	2	4	40%	1	4	23%	5	13	36%
6										2	4	40%	5	14	35%	7	18	36%
7	3	7	37%	4	12	35%	1	1	50%	1	1	60%	6	12	48%	14	33	41%
8	1	2	40%	1	1	50%	0	1	40%	2	2	75%	3	5	54%	6	11	54%
9	1	3	43%	1	2	45%							1	2	45%	3	7	44%
10	1	2	60%				1	2	60%	2	3	50%	5	10	53%	9	17	54%
11	1	1	70%	5	5	90%	1	1	60%	4	6	67%	7	10	70%	17	23	73%
12							1	1	100%	2	3	60%	4	7	60%	7	11	64%
13				1	1	50%				1	3	37%	1	2	65%	3	6	48%
14	2	5	48%	2	4	48%	0	1	40%	1	2	50%	7	12	54%	12	24	51%
15	4	9	48%	1	3	40%	1	2	55%	2	3	73%	2	2	80%	10	19	55%
16										1	1	60%	4	6	70%	5	7	69%
17	1	1	70%	2	2	75%				1	1	100%	2	2	80%	5	6	80%
18				1	2	70%				1	1	100%	4	6	65%	6	9	70%
19										1	1	60%				1	1	60%
20	1	2	65%	4	5	84%				2	2	90%	1	1	90%	8	10	82%
21				0	1	40%				1	2	45%				1	3	43%
22										1	2	30%				1	2	30%
N*	6	22	27%	10	38	27%	3	6	42%	11	26	40%	19	52	36%	48	144	33%
S*	12	23	52%	17	25	66%	4	7	61%	18	28	63%	37	60	62%	88	143	61%
T	18	45	40%	27	63	43%	7	13	52%	28	54	52%	56	112	50%	136	287	47%

Note: Damaged No.*1 is the number of heavily collapsed facilities, Facility No.*2 is the listed number of facilities with building structure information. N* is the sum and average of the northern districts 1 to 8 and 22. S* is the sum and average of the southern districts 9 to 21.

Source: Number of facilities is supplied by 22 district offices, JICA Study Team

Prevention and Improvement Plan for Educational Facilities

More than 2,500 educational facilities in Tehran are evenly and densely distributed in local communities, and they could, in theory, serve as the most suitable locations for community evacuation. However, standards for educational facilities in Iran do not call for these facilities to have an appropriate amount of open space to serve as primary evacuation community assembly points, much less for seismic resistance that would give the facilities the ability to survive an earthquake disaster. It is estimated that 54% of listed school buildings will be heavily damaged.

Reinforcement or rebuilding of structurally weak schools, which should be assessed and identified by an expert, are recommended in order to provide appropriate school building structures for coming generations and to provide appropriate emergency evacuation spaces for local communities during a disaster.

It is recommended that, before an earthquake event, the above proposals be planned and implemented as much as possible.

c. Agreement to Replace Block and Brick Enclosures with Hedges

Brick and block enclosures are commonly utilised as private property boundaries in Tehran. In an earthquake disaster, brick and block enclosures will not only collapse and cause human casualties, but also disturb emergency operations by obstructing roads with their debris.

In Japan, it is encouraged that brick and block enclosures be replaced with hedges under community agreements and with government financial support, in order to avoid human casualties and minimise road obstructions.

This system of community agreements and government financial support to replace the hazardous brick and block enclosures is also recommended for Tehran.

d. Regulation for Building Set-Back, Wall Materials/Finishing, and Signboard

Within the old quarter and city centre areas, almost all private and public traditional buildings are not properly set back, and some buildings have overhangs, originally planned to provide shade to pedestrians, that are located directly above pedestrian walkways.

In an earthquake, building collapse and falling wall and window materials will cause secondary disasters and human casualties.

It is recommended that regulations for the set-back of buildings and appropriate securing measures for walls and windows be formulated as part of the Urban Development Zoning Plan in the near future.

(5) Prevention Plan for Lifelines

The supply of water, power, natural gas and telecommunication services could be categorised as lifelines and infrastructures for socio-economic activities in Metropolitan Tehran. As estimated by the Study, each of these facilities will suffer enormous damage, which should be quickly prevented on a priority basis by the responsible agencies, as follows:

a. Prevention Plan for Municipal Water Supply

There will be an estimated 4,000 damaged points along the 8,520 kilometre-long municipal water supply network according to the Ray Fault Model. This damage will be concentrated in the southern district (88% of total points), especially in the southern-central districts (75% of total points) as mentioned in section 7.5.6(9). The estimated damage to the water supply network has been estimated on the macro data of water pipeline length, which was provided by the Tehran Province Water and Sewage Company.

In the formulation of the prevention plan, the following impacts of estimated damages should be considered (the main objective of the prevention plan should be the uninterrupted connection of all areas to lifelines):

- Reinforcement of row water transmission;
- Reinforcement of water purification plants, reservoirs, pumping stations, and the city's main pipeline network; and
- Reinforcement of distribution pipeline network and fire hydrant system

b. Rehabilitation Plan for Electric Power Supply

The electric power supply network in Tehran is composed of 4,063 km of 20kV high-tension main lines and 11,110 km of 400V distribution lines. 65% of 20kV and 50% of 400V networks are laid underground, which has stronger seismic resistance.

Damage to power lines is estimated at approximately 18.5km (0.12% of the total length); 92% of the estimated damage is expected in the southern district, especially the southern-central districts as follows:

Table 7.5.2 Electric Power Lines and Estimated Damage

		line length (km)		damaged length(km)		Ratio
Northern Districts		7,672	51%	1	7%	0.017%
	Fringe Districts:1-5/22	5,381	35%	0	0%	0.000%
	Center Districts:6-8	2,291	15%	1	7%	0.058%
Southern Districts		7,501	49%	17	93%	0.228%
	Fringe Districts:9/13/14/21	1,282	8%	1	8%	0.115%
	Center Districts:10-12/15-20	6,219	41%	16	85%	0.251%
Municipality Total		15,173	100%	18	100%	0.121%

Note: Ratio is percentage ratio of damaged length / total length of line.
Source: JICA Study Team

The Electric Power Company should formulate a prevention and improvement plan, especially for weak overhead sections of the power distribution and city main network as follows:

- Improvement of electric poles or change to underground cable box system,
- Upgrading and strengthening of the city main network to be seismic resistant
- Upgrading and strengthening of sub-stations and transformers to be seismic resistant

c. Prevention Plan for Natural Gas Supply

The present natural gas pipeline network in the municipal area is composed of high pressure (250 psi) and middle pressure (60 psi) steel pipeline and low-pressure polyethylene pipeline. Approximately 7,000 km of the present gas pipeline will be damaged at 540 points, which was estimated based on the lifeline damage analysis as follows:

Table 7.5.3 Gas Pipeline by District/Area and Estimated Damage

		pipeline (km)		damaged points		d.p./km
Northern Districts		3,449	49%	80	15%	0.023
	Fringe Districts:1-5/22	2,249	32%	20	4%	0.009
	Center Districts:6-8	1,201	17%	60	11%	0.050
Suthern Districts		3,605	51%	450	85%	0.125
	Fringe Districts:9/13/14/21	1,235	18%	90	17%	0.073
	Center Districts:10-12/15-20	2,370	34%	360	68%	0.152
Municpality Total		7,054	100%	530	100%	0.075

Change entry in table above to "Southern Districts"
Note: damaged points / km* is number of damaged points per kilometre of pipeline.
Source: JICA Study Team

The Natural Gas Company should formulate the prevention and improvement plan, including security measures, to avoid secondary disasters as follows:

Security Measure:

A new automatic safety valve system (from the present manual valve) with seismometer and telemeter network is proposed to avoid secondary disaster and to simulate and estimated seismic damages for quick and proper emergency responses before disaster occurrence.

Preventive Measure:

Improvement and upgrading of pipeline joint system to make it seismic resistant. Establishment of a wireless communication system between headquarters, branch offices and key facilities is also proposed.

d. Prevention Plan for Telecommunication Network

The telecommunication network in Tehran is a dual system of 10,360 km of telephone lines and mobile phones. Presently, the majority of subscribers are covered by a cable telecommunication system.

Telephone lines consist of 681 km of optical fibre, 8,404 km of copper cable, and 1,275 km of cable with conduit. Majorities of telephone lines are laid underground except connection lines to subscribers. According to the Ray Fault Model, the estimated damage to telecommunication lines is 12.8 km, which is around 0.12% of the total length of the network. Earthquake damages for the mobile system and exchange facilities was not estimated because the data available was limited.

The Telecommunication Company should be formulated a prevention and improvement plan of the telecommunication network based on a revised damage analysis that takes into account a proper database.

To promote and enhance the mobile phone system, it is recommended that the emergency telecommunication system for DTFs and citizens be strengthened.

Table 7.5.4 Telecommunication Network and Estimated Damage

		length of line (km)		damaged length(km)		ratio*
Northern Districts		5,226	50%	1	9%	0.02%
	Fringe Districts:1-5/22	3,539	34%	0	0%	0.00%
	Center Districts:6-8	1,687	16%	1	9%	0.06%
Suthern Districts		5,138	50%	12	91%	0.23%
	Fringe Districts:9/13/14/21	1,237	12%	1	9%	0.09%
	Center Districts:10-12/15-20	3,901	38%	11	82%	0.27%
Municpality Total		10,364	100%	13	100%	0.12%

Note: Ratio is percentage ratio of damaged length/total length of telephone line
Source: JICA Study Team

(6) Prevention Plan for Damages to Transportation Facilities

A prevention plan to minimise disaster damages to transportation facilities should cover roads, bridges, railways and commuter rails, and airports should be based on an adequate database. Road and bridge damages are estimated in the damage analysis study.

All of the above transportation modes are indispensable to mobilise and deploy experts and manpower for emergency operations and to transport emergency goods after an earthquake event.

A road and bridge improvement and reinforcement plan should be formulated for emergency roads and evacuation road networks. The works should be based on detailed diagnoses of their seismic resistant condition by experts. Designated emergency road

b. Responsibility: Mayor of Tehran Municipality

The Mayor of the Tehran Municipality should take responsibility for evacuation as follows:

- Financial arrangement to prepare evacuation areas in coordination with the NDTF, and
- Decision-making and order to evacuate in coordination with the NDTF

c. Implementation: District Mayors

District Mayors will implement and open required primary and secondary evacuation areas for damaged sub-districts or community zones under the evacuation order.

Primary evacuation area

In Japan, primary evacuation areas, which should be provided for each community zone, usually utilise public primary and intermediate schools, community halls or other public facilities with strong structures resistant to seismic events. However, the predicted building damage ratio in Tehran is over 55%, which could be understood to mean that public facilities will be unusable as evacuation areas. Appropriately, distributed public facilities with strong seismic resistant buildings are not available in each community zone. Parks and open spaces will be candidates for primary tent evacuation areas. In the southern districts, additional public open spaces are required to accommodate the estimated number of evacuees.

After the opening of the evacuation area, all important details pertaining to the evacuation area, i.e., location and time of opening, number of evacuees, forecasted period, and required emergency goods supply, should be reported to the Municipal Disaster Task Force centre by the district DTF. In Japan, the operation period of an evacuation area is legislated at not more than 7 days after a disaster. After 7days, operation of the evacuation area could be expanded, but, principally, evacuees should be removed to temporary housing or villages.

Secondary evacuation area

A secondary evacuation area is used to transfer evacuees from a primary evacuation area, when there is danger of fire or explosion of hazardous facilities or difficulty of operation of emergency water and goods supply. Regional- or district-level parks are usually utilised as secondary evacuation areas, which are required for sub-district or district level communities.

d. Expense and Cost of Operation

The Government of Iran and Tehran Municipality should bear all operation costs and expenses under the legislated financial measures.

(9) Emergency Water Supply Plan

The following facilities contribute to the municipal water supply system of Tehran:

- Surface water sources: Karaj, Lar, Latiyan dams (605 Mm^3/annum, 70%)
- Ground water sources: 200 deep wells (250 Mm^3/annum, 30%)
- Raw water transmissions: 176 km to water treatment plants,
- Water treatment plants: 4 existing (16.7 m^3/s)/1 under construction (15 m^3/s)
- Treated water mains: 147 km pipelines with 5 pumping stations to reservoirs,
- 50 reservoirs (1.55 Mm^3) and 26 reservoirs with pumps,
- Municipal water distribution pipeline: more than 8,500 km.

Damage to water distribution pipelines is estimated to occur at approximately 3,900 points, mostly located in the southern districts. However, water supply throughout the municipality will be cut off because of a number of damaged pipelines, except for parts of Districts 1 and 22.

Principally, the damage analysis of Tehran's water supply network should be reassessed further, in order to provide an accurate database of water supply pipeline information for the Urban Disaster Prevention and Management Study in the future.

Table 7.5.5 Municipal Water Distribution Pipeline and Damaged Points

		Pipeline (km)		Damaged points	
Northern Districts		3,957	46%	500	13%
	Fringe Districts:1-5/22	2,727	32%	200	5%
	Center Districts:6-8	1,230	14%	300	8%
Southern Districts		4,560	54%	3,400	87%
	Fringe Districts:9/13/14/21	1,220	14%	500	13%
	Center Districts:10-12/15-20	3,340	39%	2,900	74%
Municpality Total		8,517	100%	3,900	100%

Source: Tehran Province Water and Sewerage Company and JICA Study Team

For areas where municipal water supply could be cut off in case of a disaster, emergency water supply systems should provide the required minimum potable water for evacuees and residents, as explained below.

a. Initial Stage

Data collection and compilation of damage to dams, intakes, raw water transmissions, treatment plants, main municipal water pipelines and pumping stations, reservoir with pumps, distribution pipes based on task distribution.

1) Assessment of potential cut-off areas and possible amount of water supply by the existing municipal water supply system,
2) Emergency adjustment by valve control for areas with limited water sources,
3) Emergency water supply,
4) The Mayor of Tehran should be responsible for emergency potable water supply for evacuees and residents in areas cut off from municipal water supply,
5) Temporary emergency water supply points and systems include:
   - Existing reservoirs,
   - Fire hydrants (though they are not appropriately distributed throughout the entire municipal area),
   - Tank lorry (they cannot serve individual homes/buildings), and
   - Preparation of temporary or permanent water tanks with supply system in evacuation areas
6) Standard ration of water per person should be more than 3 litres/person/within 7 day limit (standard in Japan)
7) Request to the surrounding provinces and districts for emergency water supply manpower/machinery,
8) Information dissemination of water supply cut off conditions/zones, emergency water supply service/locations by the use of vehicles with loudspeakers, and

Table 7.5.6 Estimated Building Damage for Educational Facilities

District	Elementary School			Intermediate School			High School			University			Total		
	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)
1	24	67	36%	12	37	34%	18	44	42%	4	13	33%	59	161	37%
2	37	106	35%	37	101	37%	35	96	37%	9	24	36%	118	327	36%
3	15	38	39%	13	39	34%	17	48	35%	13	41	32%	58	166	35%
4	22	76	29%	20	63	32%	17	59	28%	5	17	30%	64	215	30%
5	17	45	38%	21	48	44%	18	48	37%	2	6	25%	57	147	39%
6							1	3	20%				1	3	20%
7	24	49	50%	17	35	49%	16	33	47%	9	19	48%	66	136	49%
8	33	58	56%	19	32	61%	25	39	63%				77	129	59%
9	14	33	41%	11	26	41%	10	25	42%	2	5	46%	37	89	41%
10	29	39	75%	15	20	77%	13	18	74%	0	1	40%	58	78	75%
11	59	70	84%	40	53	75%	30	42	71%	10	13	74%	138	178	78%
12	8	11	73%	8	11	69%	10	16	64%	2	4	58%	28	42	67%
13	33	65	50%	23	45	51%	11	22	51%	2	3	57%	68	135	51%
14	24	42	57%	11	19	60%				1	1	50%	36	62	58%
15	109	149	73%				1	1	60%				109	150	73%
16	45	59	75%	31	39	79%	27	35	77%				102	133	77%
17	25	30	82%	10	12	87%	18	23	77%				53	65	81%
18	33	50	66%	27	37	72%	21	28	75%	3	5	68%	84	120	70%
19	15	18	82%	17	22	77%	6	9	67%				38	49	77%
20	55	73	76%	33	43	76%	43	52	82%	4	6	67%	135	174	77%
21	3	4	80%	2	3	77%	5	8	64%				11	15	71%
22	1	1	60%	1	4	28%							2	5	34%
N*	173	440	39%	141	359	39%	145	370	39%	42	120	35%	501	1289	39%
S*	450	643	70%	228	330	69%	195	279	70%	24	38	64%	897	1290	70%
T	623	1083	57%	369	689	54%	340	649	52%	66	158	42%	1,398	2,579	54%

Note: Damaged No.*1 is the number of heavily damaged facilities, Facility No.*2 is the number of facilities listed with building structure information. N* is sum and average of the northern Districts 1 to 8 and 22, and S* is the sum and average of the southern Districts 9 to 21.

Source: Number of facilities is supplied by 22 district offices; JICA Study Team

(15) Distribution Plan of Monetary Donations for Disaster Victims

The NCNDR should prepare standards and criteria for monetary donations from the national government to surviving victims of urban and regional natural disasters by a legislation process. The National and Tehran Municipal Disaster Task Forces should be responsible for the preparation of the distribution plan.

(16) Acceptance Plan of Donation for Disaster

Once news of the disaster is reported by national and international news agencies, donations will start pouring in from within and outside the country.

The Tehran Municipal Disaster Task Force, which could be supported by the National Disaster Task Force, should prepare a mechanism that could handle this enormous task and inform the same to international agencies, foreign embassies, news agencies, and the media.

7.5.7. Rehabilitation and Reconstruction Plan

The objectives of the rehabilitation and reconstruction plan are to repair damaged public and social service facilities and infrastructure and to improve and upgrade urban seismic disaster prevention functions for the future.

Plans for required rehabilitation and reconstruction measures should include the following:

- Rehabilitation plan for road and transportation facilities,

- Rehabilitation plan for urban infrastructure,
- Rehabilitation and reconstruction plans for social service and public facilities, and
- Socio-economic revitalisation and stabilisation plans.

It is recommended to incorporate incentives, such as tax exemptions, in the financing plan for reconstruction of private housing and industries, and for revitalisation of trade and goods circulation.

(1) Road and Transportation Rehabilitation Plan

Responsible agencies for road construction and maintenance should inspect and rehabilitate facilities damaged by the earthquake disaster, with a focus on the following:

a. Slope Protection

Fixing of facilities and landslide rehabilitation plans for the northern mountain area is required.

b. Roads and Bridges Rehabilitation Plan of Emergency Road Network

The plan for damaged bridges and road sections blocked by obstacles and landslides should describe how to perform a 'quick-search' of such areas, the required rehabilitation work and describe the agencies responsible for the removal of road obstacles.

In case quick rehabilitation for damaged and interrupted road sections is difficult, bypass routes should be set up and communicated for emergency vehicle access

c. Recommended Preventive Measure

For damaged bridges, reconstruction and/or reinforcement work to improve their seismic resistance is recommended, along with urgent structural assessment by an expert.

(2) Urban Infrastructure (Lifelines) Rehabilitation Plan

The supply of water, power, natural gas, and telecommunication network systems could be categorised as lifelines and infrastructures for socio-economic activities in Metropolitan Tehran. As estimated by the Study, each of these facilities will suffer enormous damage, which should be quickly rehabilitated on a priority basis by responsible agencies as follows:

a. Rehabilitation Plan for Municipal Water Supply

In case of the Ray Fault Model earthquake scenario, there will be an estimated 4,000 damaged points on the 8,520 kilometre long municipal water supply network. Damages will be concentrated in the southern district (88% of total points), especially in the southern-central districts (75% of total points). The estimated damage of the water supply network has been focused on the macro data of water pipeline length, which is provided by the Tehran Province Water and Sewage Company.

The rehabilitation should consider the impacts of estimated damages in the formulation of the plan as follows (the main objective of the rehabilitation plan should be the uninterrupted connection of all areas to lifelines):

- Inspection and rehabilitation task distribution plan for each water supply district, zone and area;
- Inspection work, rehabilitation work and changing or adjustment of water supply zone to maintain uninterrupted connection to lifelines; and
- Report of power failure information to the responsible agency

Chapter 8:

Recommendation on Structural Design

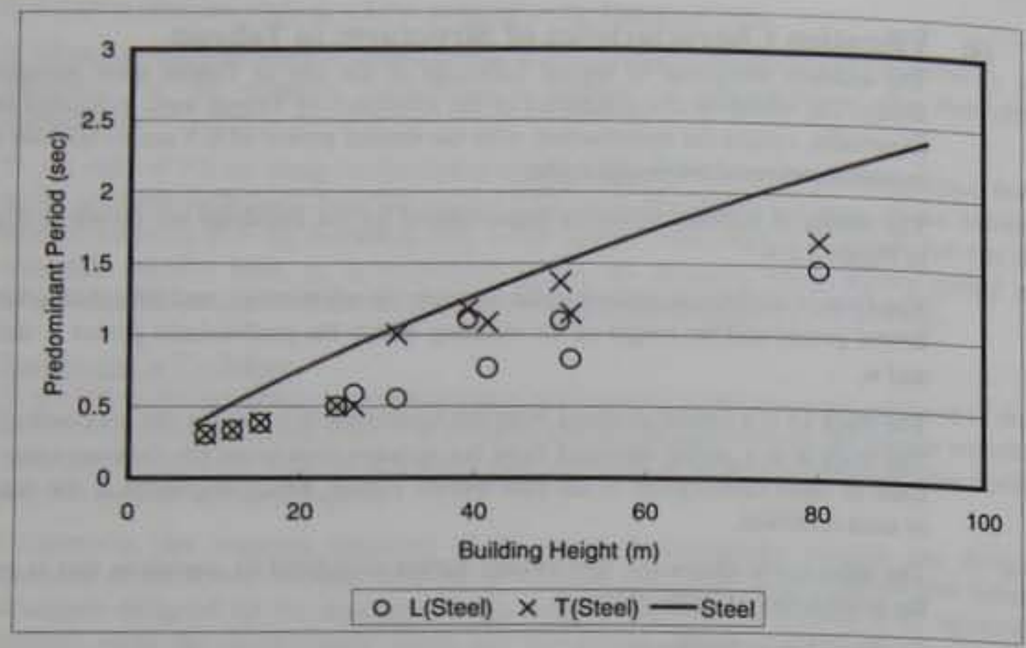


Figure 8.1.2 Relation between the lowest period and the height of the building (Steel)

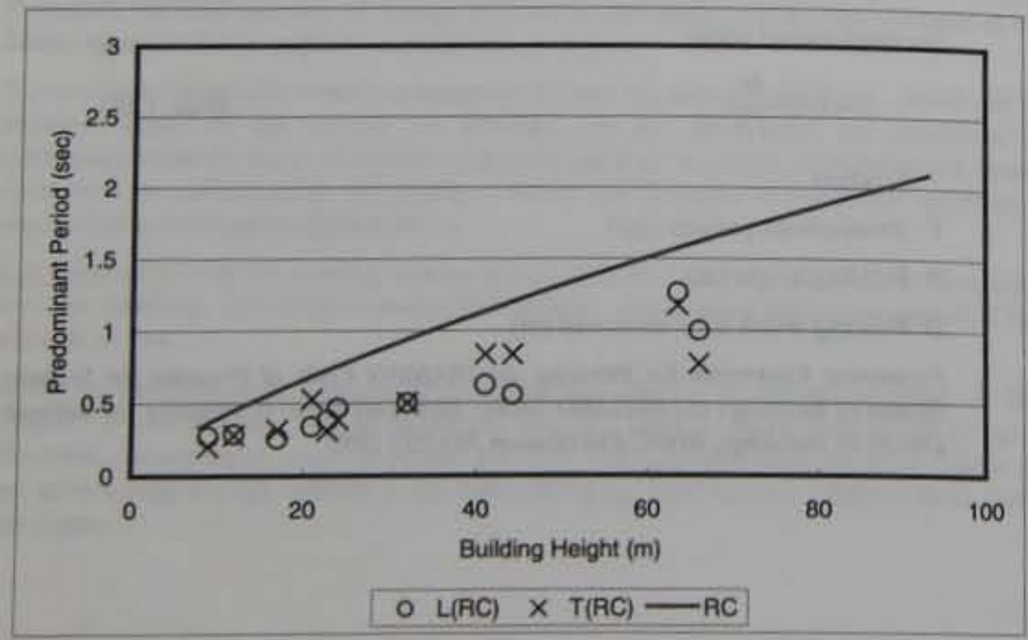


Figure 8.1.3 Relation Between the Lowest Period and the Height of the Building (RC)

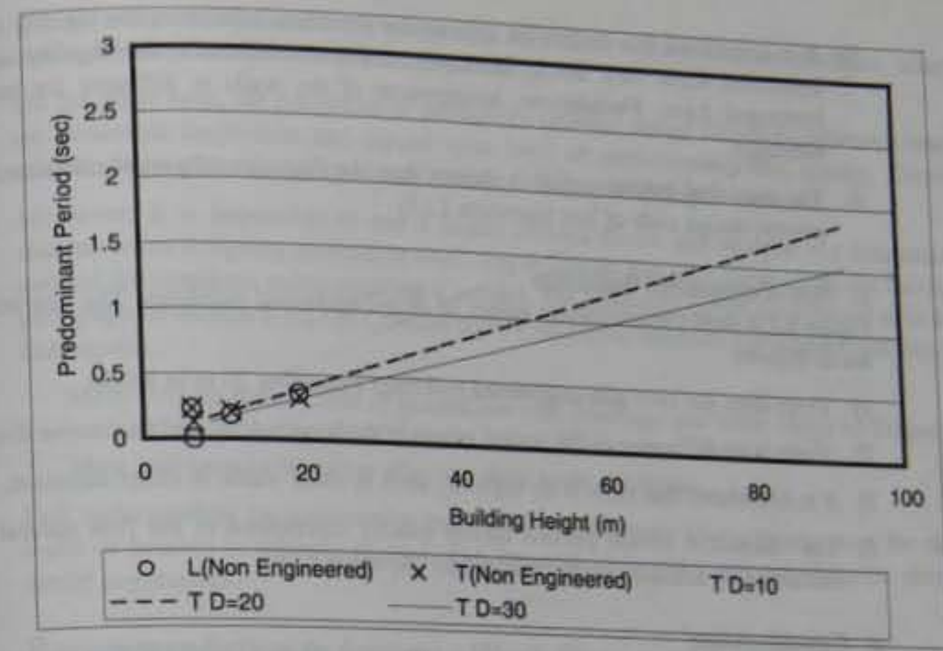


Figure 8.1.4 Relation between the Lowest Period and the Height of the Building (Non-Engineered)

Note: TD is width of buildings to be measured.

a. Steel Framed Buildings

Figure 8.1.2 shows measurement values of steel frame buildings. The characteristics are as follows:

1) The period in the transverse direction is longer than the period in the longitudinal direction, excluding five examples. The exception applies for buildings of less than 27 m in height.

2) Sections of columns and beams are not strong enough. Moreover, arrangement of brace is different for building direction.

3) It is considered that the rigidity against a horizontal force differs very much depending on existence of structural brace. In general, to allow for a window opening, etc., bracing is omitted. The same is true for the building's front panel. Otherwise, bracing is limited to the corners of the structure and the K shape brace is installed. Therefore, the rigidity in the longitudinal direction is lower compared to the rigidity in the transverse direction, and the natural period in the longitudinal direction becomes longer as a result.

4) The measured natural period is shorter than the first natural period calculated by the seismic design code of Iran (equation 1.12).

b. RC Framed Buildings

Figure 8.1.3 shows the measurement values of RC framed buildings. The characteristics are as follows:

1) There is a difference in the period values in the longitudinal direction and the transverse direction. In addition, longer-period direction is not clear.

2) Section of column and beam is not strong enough. In addition, infill brick walls and RC walls are enclosed by the columns and the beams.

Table 8.1.3 Major Earthquakes and Resulting Events in Japan

1891, October 28 - Nobi Earthquake, M = 8.0
1892 Earthquake Prevention Investigation Association started
1923, September 1 - Kanto Earthquake, M = 7.9
1926 "Road Design Standard" (Department of the Interior) was established
1939 The "Steel Highway Bridge Specifications" (Department of the Interior) was established
1946, December 21 - Nankai Earthquake, M8.0
1948, June 28 - Fukui Earthquake, M7.1
1952, March 4 - Tokachi-oki Earthquake, M8.2
1953 SMAC Strong-Motion Earthquake Record Business Promotion Conference started
1956 The "Steel Highway Bridge Specifications" (Japan Road Association)
1964, June 16 - Niigata Earthquake, M7.5
1967 "Guideline Honshu-Shikoku Bridge Design for Earthquake-Resistant Design" was established
1968, May 16 - Tokachi-oki Earthquake, M7.9
1969 Coordinating Committee for Earthquake Prediction started
1971 "Guideline Road Bridge Design for Earthquake-Resistant Design" was established
1977 "New Earthquake-Resistant Design Method" (PWRI tentative) was established
1978, June 12 - Miyagi-ken-oki Earthquake, M7.4
1979 Earthquake-proof check and reinforcement was executed
1979 "Guideline Railway Structure Design for Earthquake-Resistant Design" (JNR tentative) was established
1980 The chapter of "V Seismic design" was added to the "Road and Bridge Specifications"
1982, March 21 - Urakawa-Oki Earthquake, M7.1
1983, May 26 - Nihonkai-Chubu Earthquake, M7.7
1990 The "Road and Bridge Specifications" were revised
1990 "Design Standard for Railway Structures" (JNR) was established
1993, January 15 - Kushiro-Oki Earthquake, M7.8
1993, July 12 - Hokkaido-Nansei-oki Earthquake, M7.8
1994, October 4 - Hokkaido-Toho-oki Earthquake, M8.1
1994, December 28 - Sanriku-Haruka-oki Earthquake, M7.5
1995, January 17 - Hyogo-ken Nanbu (Kobe Earthquake), M7.2
1995 Tentative notice and comments for road bridge specifications : "Specification Concerning Restoration of Roads and Bridges Struck by the Hyogo-ken Nanbu Earthquake" was published
1996 "Design Specifications of Highway Bridges, Part V, Seismic Design" were revised
2001 "Design Specifications of Highway Bridges, part V, Seismic Design" revision work is progressing now

Table 8.1.4 Example of a Bridge in which the Seismic Code of a Foreign Country is Applied

Name of the Bridge	Roads at the Intersection		Seismic Coefficient	Applied Code
	Road -1	Road - 2		
S - 10	Hemmat	Modarres	0.13	AASHTO
S- 6	Hemmat ramp	Modarres	0.15	AASHTO
Telu	Telu road	Babaie	0.15	AASHTO
Ray	Ahang	Ray	0.2	AASHTO
Pasdaran	Hemmat	Pasdaran	0.14	AASHTO
S - 7	Hemmat	Modarres	0.14	AASHTO
S - 8	Hemmat	Modarres	0.15	AASHTO
Parastoo	Hemmat	Parastoo	0.14	AASHTO
Kordestan	Hemmat	Kordestan	0.15	AASHTO
Mollasadra	Chamran	Mollasadra	0.13	AASHTO
17 Shahrivar	Ahang	17 Shahrivar	0.12	AASHTO
Shariati	Hemmat	Shariati	0.15	AASHTO
Ozgol	Babaie	Ozgol	0.16	AASHTO
Lavizan	Babaie	Darabad	0.15	AASHTO
Kan river bridge	Karaj special road	Kan river	0.12	AASHTO
Mirdamad	Modarres	Mirdamad	0.1	AASHTO, DIN
Kordestan	Hemmat	Kordestan	0.15	AASHTO
Azadegan	Karaj special road	Azadegan	0.15	AASHTO
Abe - Ali	Babaie	Abe - Ali	0.1	AASHTO,DIN
S - 5	Hemmat	Modarres	0.1	AASHTO
Fadaiyan Islam	Besat	Fadaiyan	0.1	AASHTO
Afsarieh	Besat	Afsarieh	0.1	AASHTO
Vali - asr- Chamran	Chamran	Vali - asr	0.35	AASHTO

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