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.

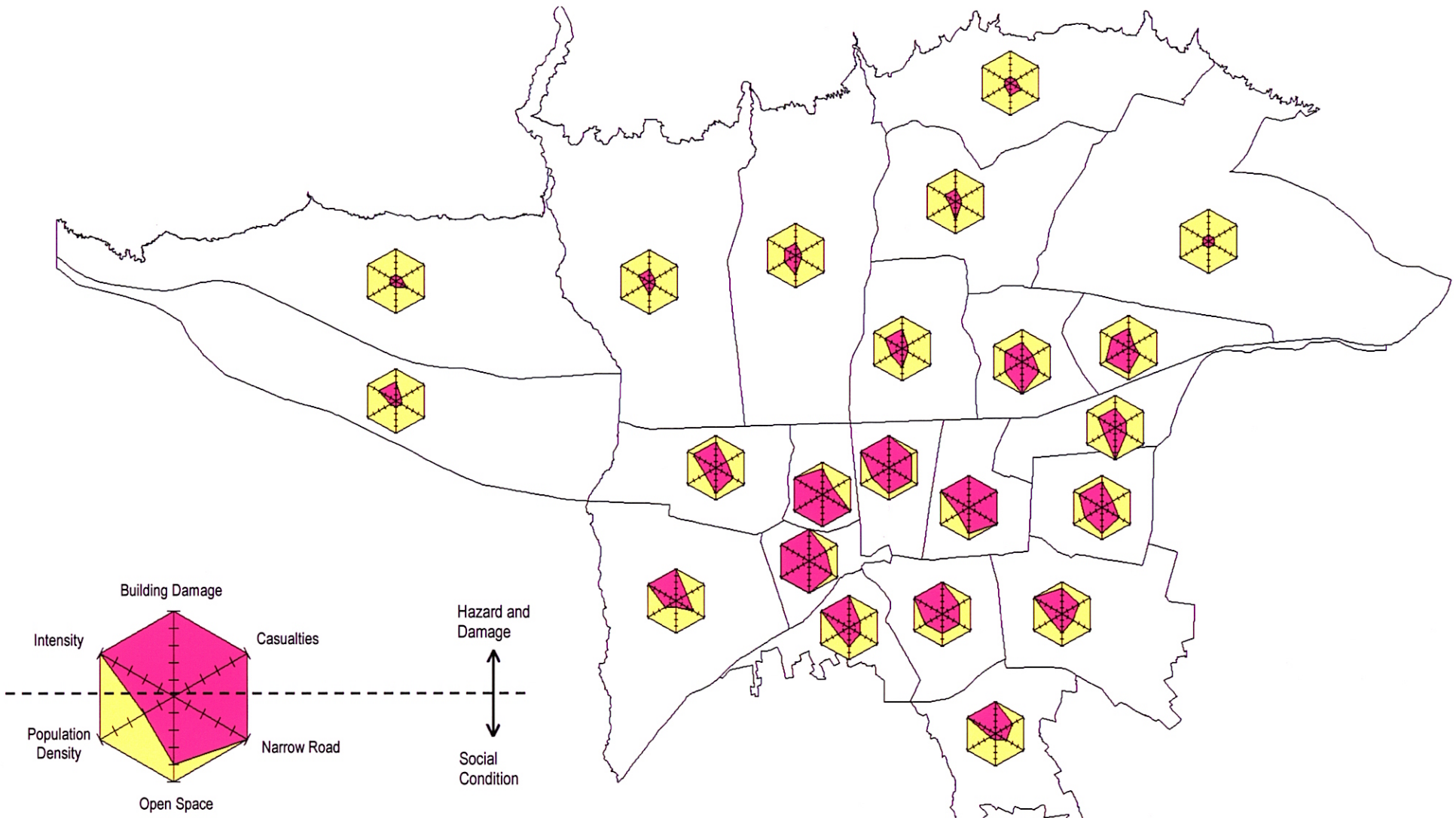
As a whole, the southern area of the city has relatively high disaster risk. However, it is considered that in the suburban area, including Districts 18 and 20, rescue, evacuation and recovery operations will be relatively less difficult to carry out.

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)



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5.2.2. NTF Model

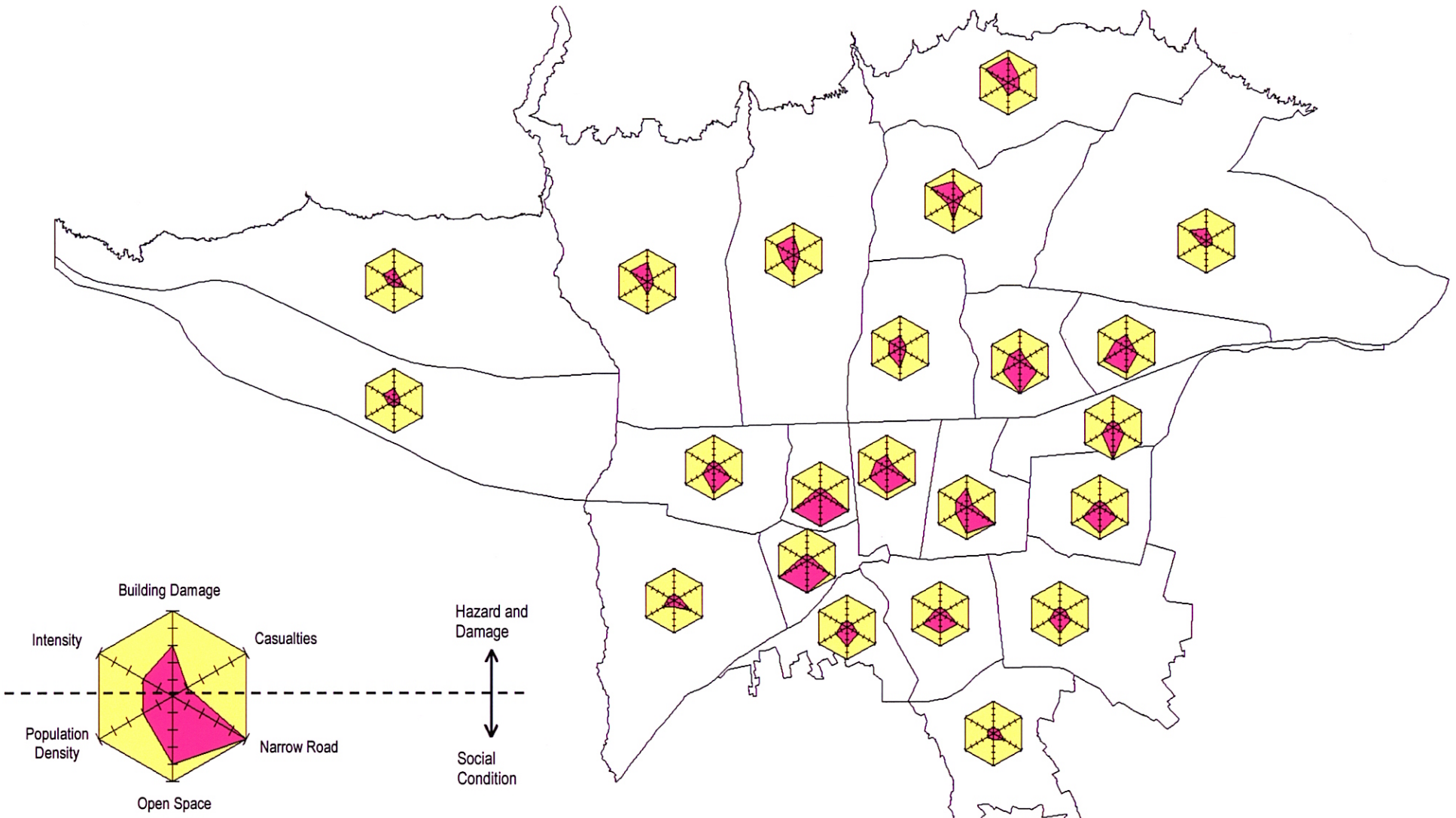
A summary of the evaluation results is shown in Table 5.2.2 and Figure 5.2.2. In the case of the NTF Model, the northern part of the city recorded higher seismic hazard and damage risk, because the NTF is located at the northern edge of the city. Overall, the disaster is considered lesser than that attributed 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

Figure 5.2.2

Evaluation of Seismic Hazard Risks (NTF model)



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5.2.3. Floating Model

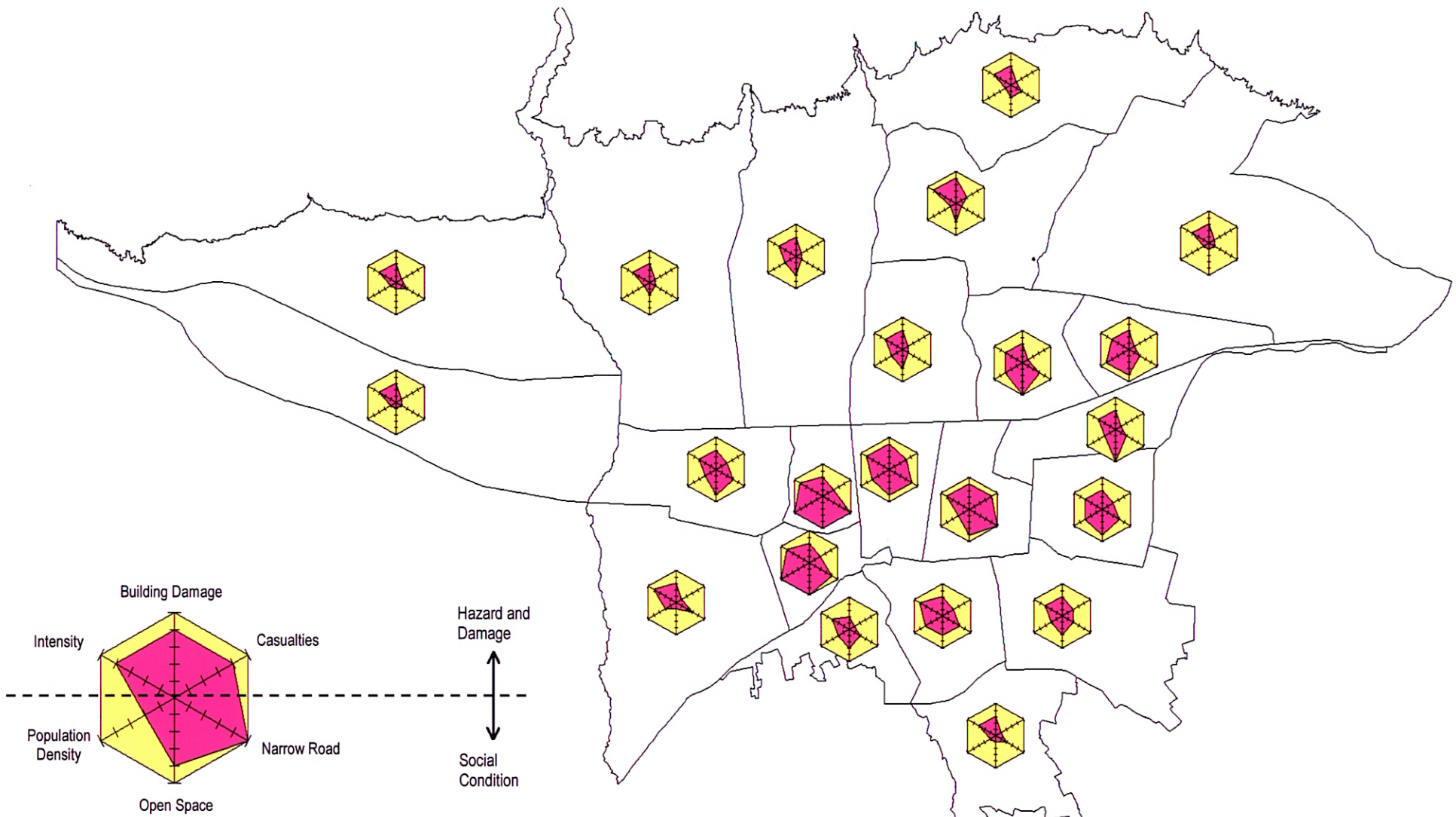
A summary of the evaluation results is shown in Table 5.2.3 and Figure 5.2.3. Relative seismic damage risk that is not caused by a specific earthquake was evaluated using the Floating Model. In this model, District 10 is evaluated as the most hazardous, followed by Districts 12 and 17. Districts 4 and 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

Figure 5.2.3

Evaluation of Seismic Hazard Risks (Floating Model)



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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.

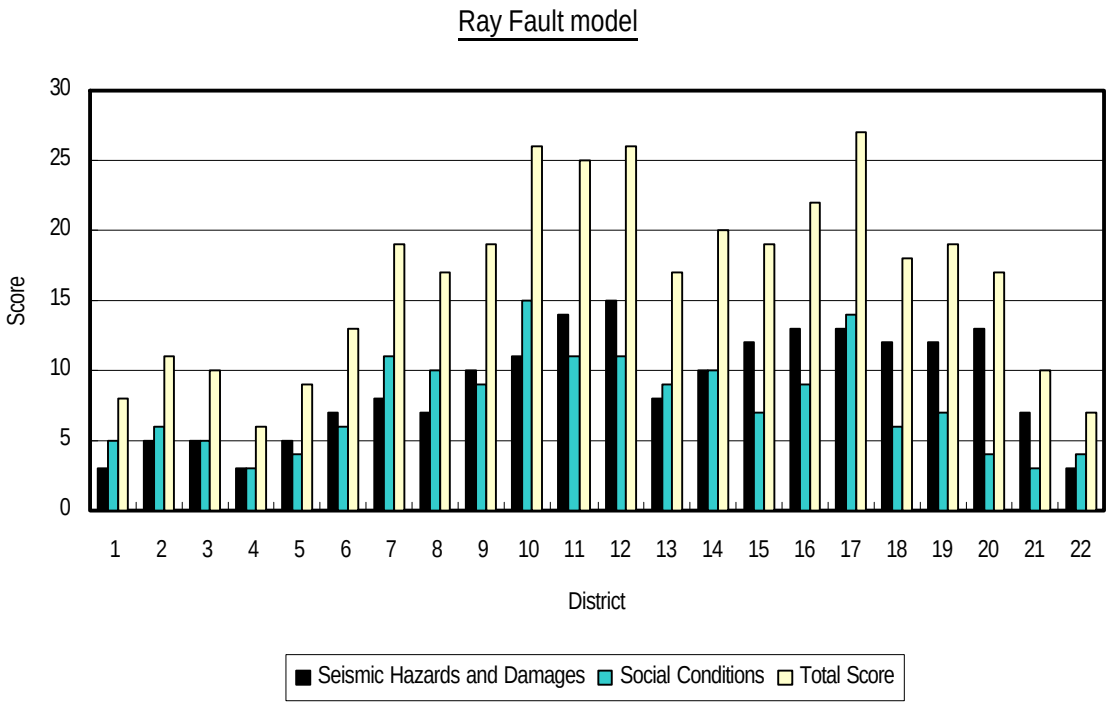

Figure 5.3.1 Summary of Risk Score Evaluation -- Ray Fault Model

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