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.

Following items are considered for 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 operation, 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 shown by radar charts in Figure 5.2.1 to Figure 5.2.3

Table 5.1.1 Evaluation Criteria of Risk Items

Item / Rank	Seismic Hazards and Damages			Social Conditions		
	Average Seismic Intensity (MMI)	Residential Buildings Damage Ratio (%)	Death Ratio (%)	Population Density (persons / hector)	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 3m and 6m width and dividing by total length of road within each district.
(Length of 3m, 6m / 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 evaluation results is shown in 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.

5.2.2. NTF Model

A summary of the evaluation result is shown Figure 5.2.2. In the case of 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 condition and social condition of the northern part are better than the southern part. In this model, seismic hazard and damage risk is high in the northern part and social condition risk is high in the southern part, but no district is extremely vulnerable. However, it must be noted that the damage to residential houses is relatively large in District 2, 3 and 12. Furthermore, there is relatively smaller damage in the southern area but there might be some problems caused by shortage of land for evacuation places and of temporally evacuation houses.

5.2.3. Floating Model

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

Figure 5.2.1

Evaluation of Seismic Hazard Risks (Ray Fault Model)

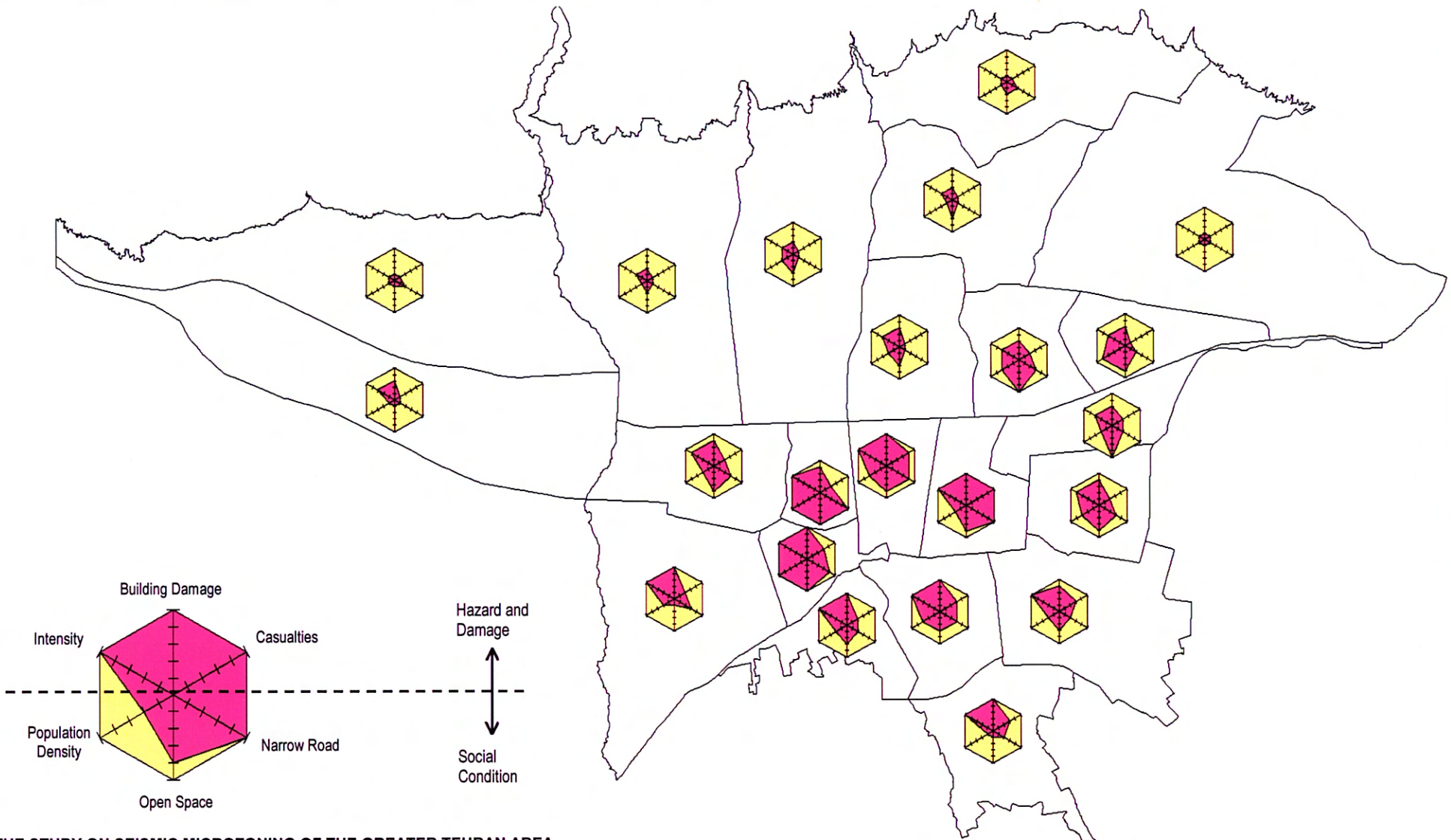

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Figure 5.2.2

Evaluation of Seismic Hazard Risks (NTF Model)

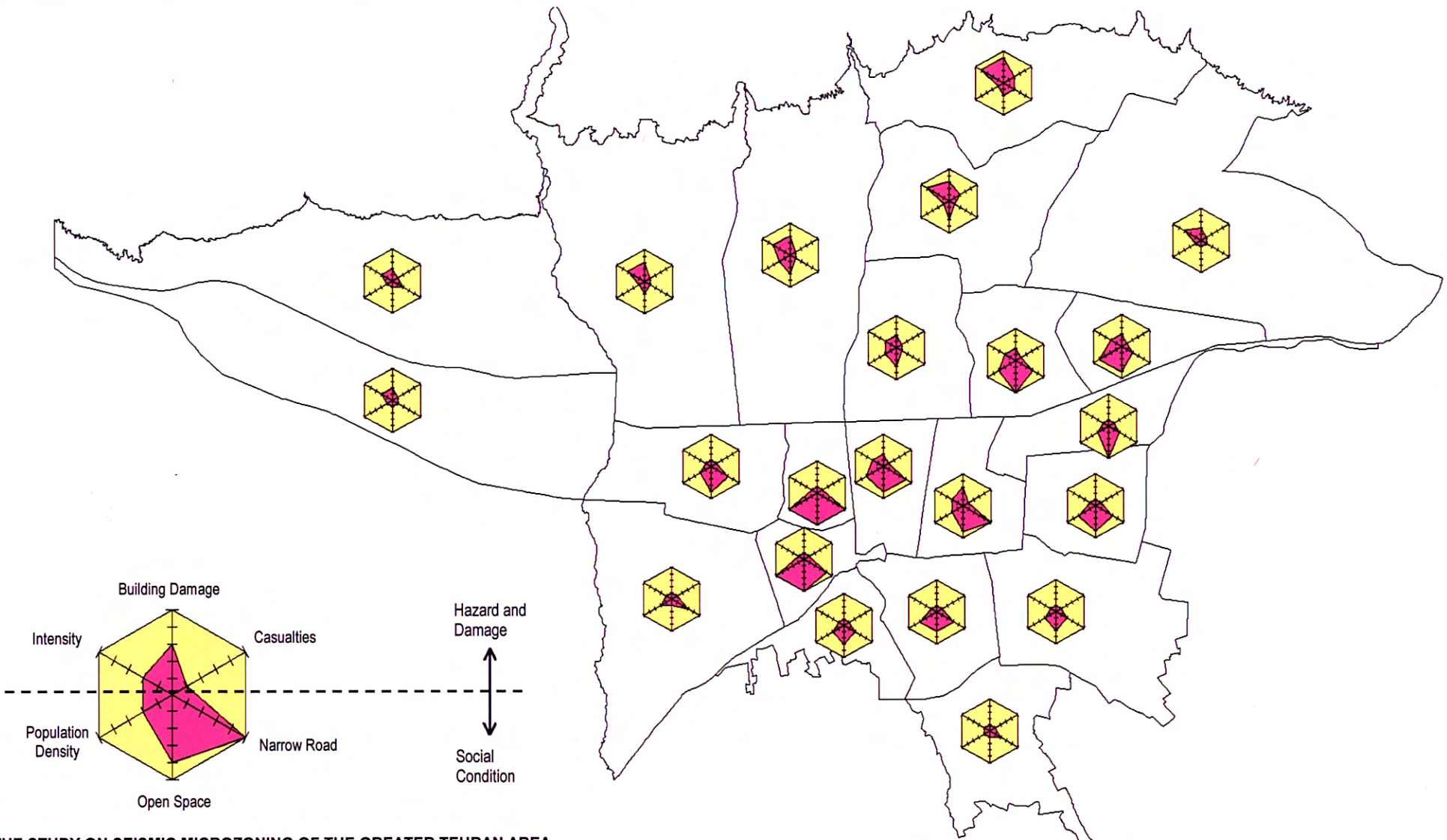

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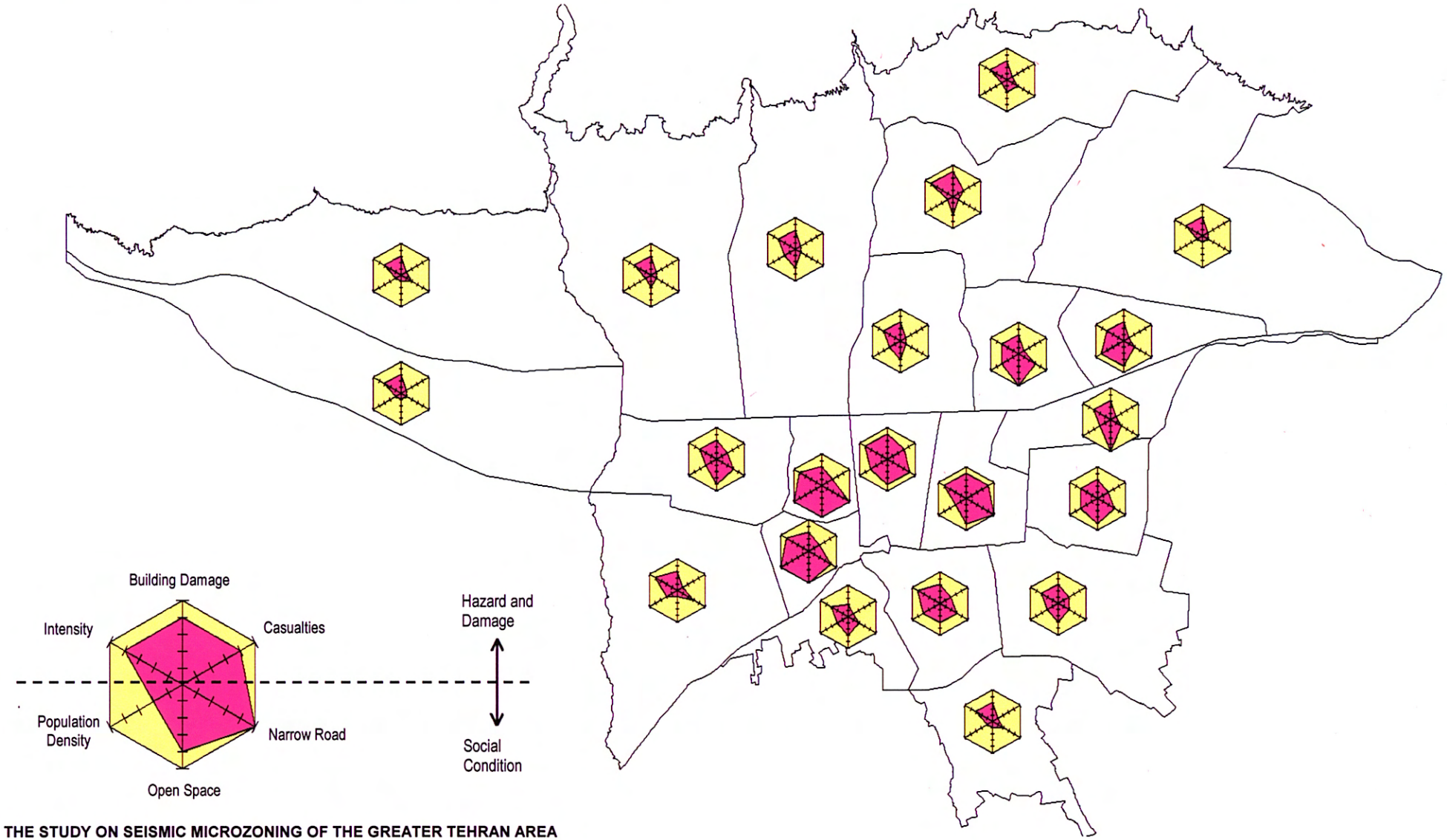
Figure 5.2.3

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 condition) 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.

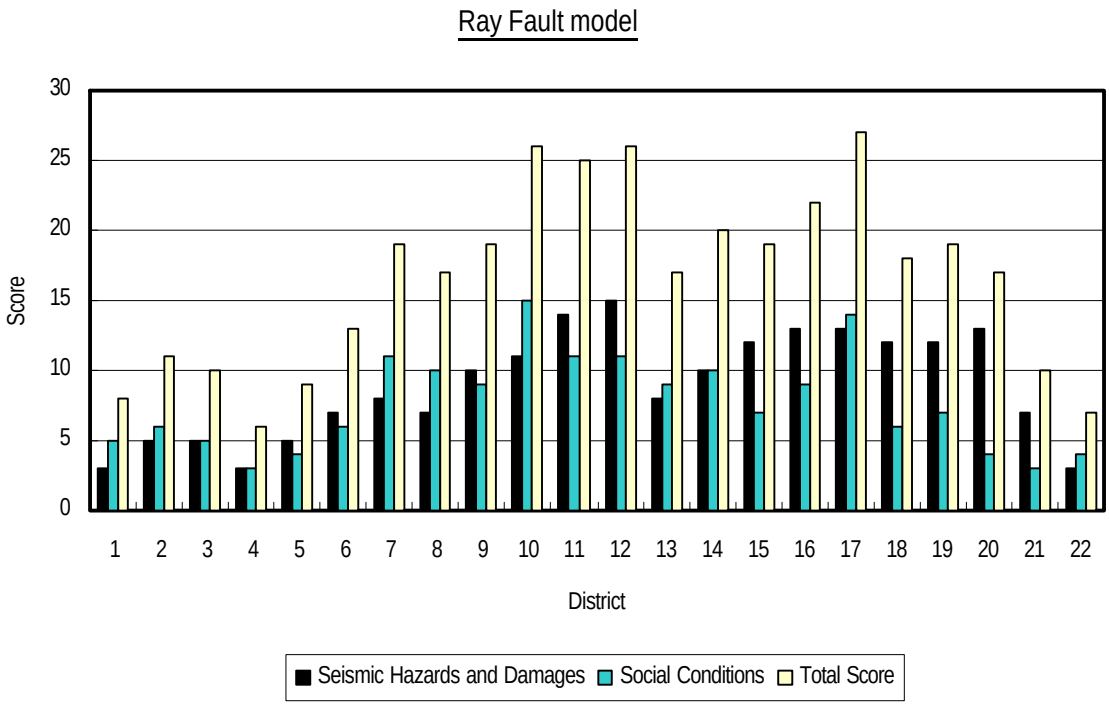


Figure 5.3.1 Summary of Risk Score Evaluation -- Ray Fault Model

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 condition" criteria are critical.

(2 "Seismic hazard and damage" criteria are critical.

(3 "Social condition" 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

Chapter 6. Conduct of Pilot Study

6.1. Selection of Pilot Study Area (PSA)

The seismic damage analysis carried out for the entire Tehran area indicates that the southern part of the city of Tehran will be severely damaged in the event of an earthquake caused by fault activity of South Ray Fault. One reason for the expected, huge seismic damage is that the southern part of Tehran is not only located close to an earthquake source, but also has many buildings that are constructed with traditional materials such as brick, masonry, wood and steel. Building structures of this area also seems to be non-resistant to strong earthquakes. Besides these conditions, the population density of the area is the highest in Tehran, and even one of the highest in the world. According to the 1996 Census Data, a number of its census zones have a population density of over 500 persons per hectare and, sometimes, exceed 700 persons per hectare. Due to the combination of these physical and social conditions and the growth of population, the potential vulnerability against a strong earthquake seems to be growing every year. The Pilot Study Area (PSA) has been set in District 17 in order to identify and collect basic information for the preparation of necessary measures to mitigate a seismic disaster District 17 has been designated as the Pilot Study Area (PSA) in order to identify and collect basic information for the preparation of necessary measures to mitigate a seismic disaster. Detailed building and urban land use surveys were conducted. Based on these surveys and analyses, existing problems for seismic disaster prevention/preparedness in the PSA were identified and are discussed below.

6.2. Outline of the PSA

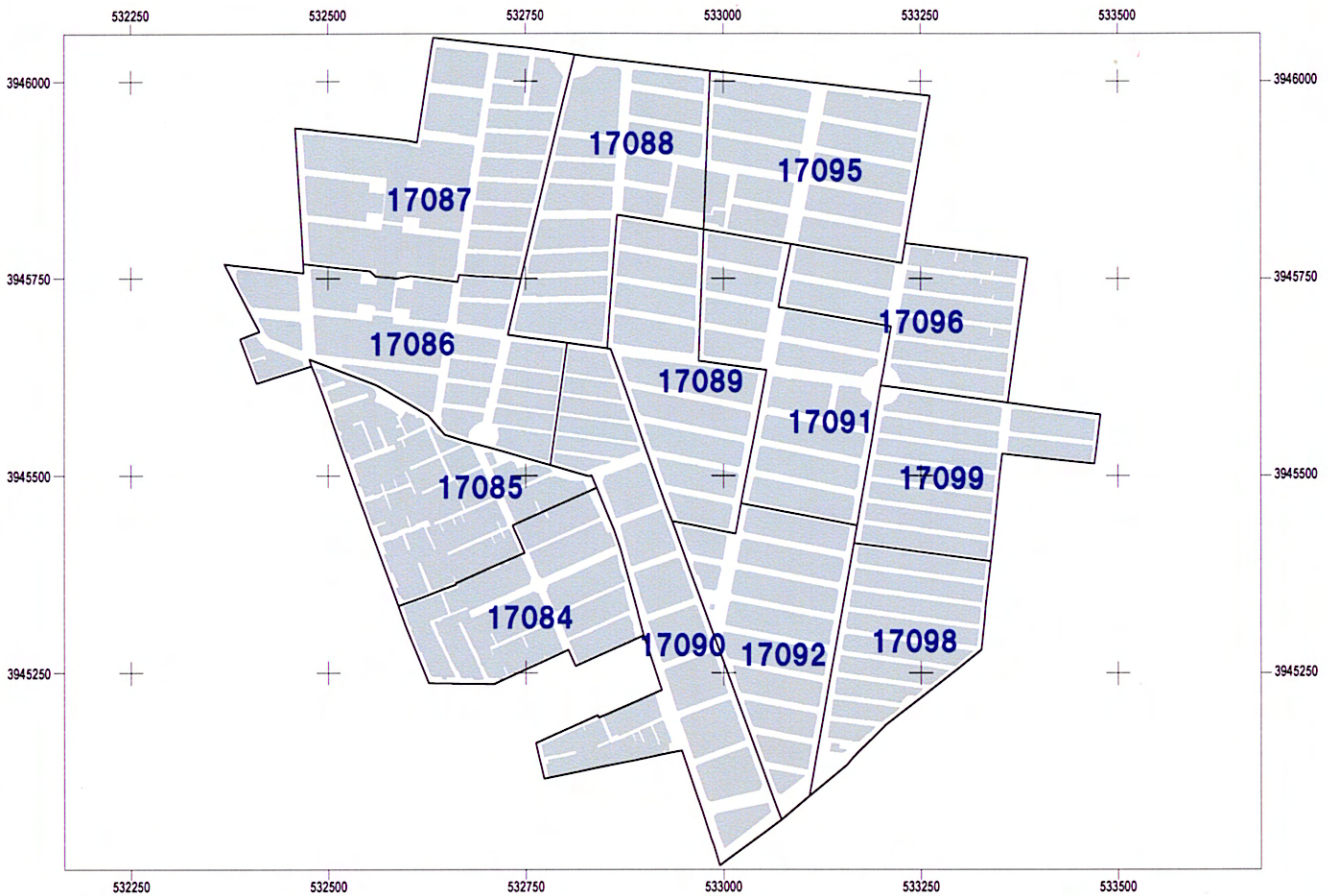
The PSA is located in the central part of District 17 (Figure 6.2.1). As of 1996, the district consists of 13 census zones: census zones number 84, 85, 86, 87, 88, 89, 90, 91, 92, 95, 96, 98 and 99. These zones are subdivided into 150 blocks in total. The combined population of these zones is 32,239, with a population density of 465 persons per hectare. The total number of buildings in these zones is 4,843.

The geographical location of the PSA is the southern part of Tehran where the lowest edge of a large alluvial fan is formed from north to south by several rivers flowing down from the Alborz Mountains. The topographical elevation of the area ranges from 1120 m to 1110 m above sea level and the ground surface is gently sloped from north to south. The ground condition is mainly composed of stiff clay including fine sand.

Urbanisation of this area has been progressing since the 1960' s, owing to the concentration of population in Tehran. Before the urbanisation took place, the area had been extensively used as agricultural land. Building development in this area is mainly targeted for residential use; therefore, almost all of the buildings in this area were constructed with less than three stories. There are a limited number of buildings in the area with more than five stories that are mainly used for residential purposes, but the sides of these buildings facing the street are used for business or commercial purposes, : e.g., small shops and small-scale industries. A combination of steel, brick and wood is used as building materials, although this combination is very weak against a strong earthquake.

Figure 6.2.1

Location Map (Pilot Study Area)



Legend

17084 Census Zones (Code No.)

Census Blocks

N
W
E
S

0 100 200 Meters

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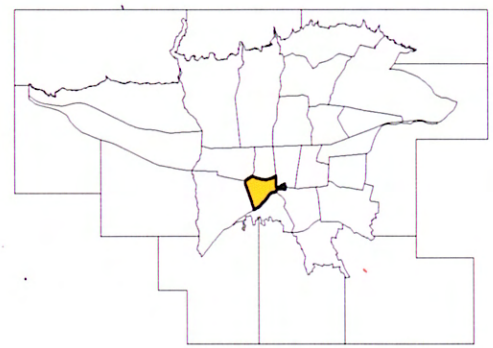
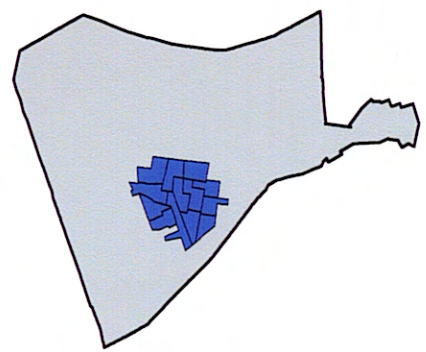


Location of District 17 in Greater Tehran



Location of Pilot Study Area in District 17

6.3. Issues for Seismic Disaster Prevention in 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.

3) Identification and designation of evacuation sites for the people living in the PSA is quite important. At the present time, there is no suitable open space to serve as an evacuation site in the PSA except a small green area. Evacuation sites to be used in case of a seismic disaster occurrence should be discussed and prepared in the neighbourhood of the PSA under the coordination of the city of Tehran and the related district office. Evacuation routes should also be confirmed and designated by the district office. All this information must be relayed to the community through the proper channels.

4) Emergency response measures must be taken soon by the district office. Seismic disaster prevention bases, or headquarters, should be prepared in the district office building, and basic supplies for emergency response, such as food, water, medicine, tools for preliminary rescue operations and generators should be kept in stock. Emergency medical services should also be planned.

5) People' s participation and public awareness on seismic disaster prevention should be promoted. First-aid rescue operations are the most important in saving human lives. If these rescue operations are conducted in a timely manner, there will be a 25% drop of casualties. In order to facilitate this, it is quite essential to promote community participation in seismic disaster management by raising people' s awareness on disaster prevention.

6) Basic materials explaining earthquake disaster and measures for disaster mitigation should be prepared and disseminated properly. School education for younger generations

should also be promoted.

7) Reinforcement of residential buildings must be discussed in depth. If buildings were to be built strong enough to withstand an earthquake, then building damage could easily be minimised. However, economic conditions dictate use of the most economical and higher cost performance structures and materials for building construction. The building code for construction regulated by the government will always be kept at the minimum level of its technical instructions. Thus, due to the long-term practice of this kind of system, some parts of the urbanised area accumulate urban structures that are very vulnerable to earthquakes. It is necessary to redevelop these vulnerable areas for the security of people living there. However, the issue of urban redevelopment in large cities always requires a long time to reach a consensus on among the people concerned. Therefore, the restructuring of urban land-use for disaster mitigation should be pursued under a well-coordinated and planned manner by the city of Tehran from mid- to long-term points of view.

8) In relation to urban redevelopment, relevant institutional frameworks, such as tax incentives, low interest housing loans, and bonuses for floor to area ratio etc., should be formulated to create stronger urban structures against seismic disaster. Formulation of these policies should also be discussed from a long-term point of view as one measure for disaster prevention.

Chapter 7 :

Recommendation to Formulate a Comprehensive Urban Disaster Prevention and Management Plan

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

7.1. Introduction

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 mobilize an effective and efficient evacuation and rescue/relief operation 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 7.1.1 shows summary of existing conditions, issues, and recommendations for Urban Seismic Disaster Prevention.

Table 7.1.1 Matrix of Existing Situation/Issues/Recommendation for Tehran Urban Seismic Disaster Prevention

	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	In 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 be newly established.
	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.

	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.	

7.2. Recommendation for Legal Measures

In the Islamic Republic of Iran, natural disaster prevention and management measures have not been actively legislated as yet. In the future, all the required institutional and implementation measures requires to either prevent or manage natural urban disasters should be legislated with a clear demarcation of roles and tasks of related government agencies, NGOs, and the private sector, under a formulated National, Regional and Urban Disaster Prevention and Management Plan.

7.3. Recommendation for Organisational Structure

The Ministry of Interior has the primary role of mobilizing disaster prevention and management functions, which should principally be carried out by the two organisational systems of policy making and of execution.

7.4. Recommendation for Financial Measure

Implementation of the required disaster prevention and management measures, which are identified in the recommendation for Urban Disaster Prevention and Management Plan of the Tehran Municipality, should be supported by financial measures both before and after the disaster.

These required financial measures should be supported by legislative measures, which describe the available financial resources, responsible agencies, distribution procedures and any condition and criteria.

7.5. Recommendation for Comprehensive Urban Seismic Disaster Prevention and Management Plan

The Tehran municipality has the potential and experience of earthquake and landslide disasters, and it remains at risk of reliving the estimated disaster damages. Thus, the formulation of a ‘ Comprehensive Urban Seismic Disaster Prevention and Management Plan’ is recommended for Tehran Municipality.

Required, proper and comprehensive measures for preventive, emergency, rehabilitation and reconstruction efforts to mitigate urban earthquake disasters should be well-coordinated and integrated in the ‘ Urban Seismic Disaster Prevention and Management Plan’ . The development of the Plan is considered the most urgent action to take before a disaster occurs.

Urban seismic disaster prevention and management is one of the most important administrative mandates of municipal governments, and hence, a Seismic Disaster Prevention and Management Plan is to be formulated under the initiative of the Tehran Municipality. However, Tehran Municipality does not have appropriate implementing body for the proposed plan, therefore, it is strongly recommended to reorganise and strength organisation body for proper implementation of the proposed plan.

7.5.1. Required Fields of Comprehensive Urban Disaster Prevention and Management Plan

Formulation of a ‘ Comprehensive Urban Disaster Prevention and Management Plan for Tehran Municipality’ could efficiently utilise the results of the JICA Study on Seismic Microzoning for Greater Tehran. The Plan should cover the following aspects:

- Policy and objectives
- Damage estimation and hazard map (seismic microzoning)
- Plan for preventive measures

- Plan for emergency measures
- Plan for rehabilitation and reconstruction measures

7.5.2. Required Fields to Formulate Policy and Objectives

The following fields should be clearly defined and stated at the onset:

- Objectives of the plan
- Legislative background and institutional identification for the plan
- The fundamental law for the ' urban disaster prevention and management plan for Tehran Municipality' should be legislated, if it is not available.
- Program of activities and intervals to review the plan
- Information and dissemination campaign to introduce the Plan to related agencies and citizens
- Research and training programs to fully absorb the rationale of the plan and thus, facilitate its execution

7.5.3. Damage Estimation and Hazard Map (Seismic Microzoning)

The required premises to formulate the plan are the existing conditions and damage forecast, which are covered almost entirely by the JICA Study Team, as follows:

- Natural conditions
- Socio-economic conditions
- The supplied and imputed data of lifelines and public facilities and hazardous facilities were macro-base data, which were not appropriate for the damage analysis of the Study. The data needed to be improved before it was used in the Study.
- Potential earthquakes
- Damage estimations (human casualties, buildings, public facilities, lifelines, and hazardous facilities)
- Location map of natural disaster prone and hazardous areas

7.5.4. Recommendation for Formulation of Prevention Plans

Prevention plans should cover all aspects required to prevent an earthquake disaster, as follows:

(1) Prevention Plan for Ground-based Disaster

The plan should cover landslides, soft ground, liquefaction, residential areas and cut and fill slope of roads. Hazardous areas in the city that have been identified and assessed include the following:

- Landslide disaster area: located on the northern mountain skirts. Residential areas, oil tanks, roads, newly planned raw water transmission pipes are located in the identified area.
- Soft ground area: not found in the city.
- Liquefaction disaster area: some areas with liquefaction potential are found in the southern end of the city.

(2) Fire Prevention Plan

The plan should cover fire outbreaks, extinguishing fire at the earliest possible time, and protecting against its spread.

(3) Evacuation Plan with Facilities Development

After an earthquake disaster, all residents in a disaster area should be evacuated to a safe area. But even before an earthquake event, municipality and district offices should have already formulated an evacuation plan, covering evacuation zoning, site selection and development of gathering and evacuation area, route selection and improvement of evacuation routes.

(4) Prevention plan for building damage

Human casualties by an earthquake disaster in Tehran will be mainly caused by building collapse. Improvement measures for structurally weak public and private facilities are recommended to minimise the estimated human casualties.

Collapsed structurally weak block or brick enclosures and falling objects from building will also add to the number of human casualties and affect emergency and evacuation road networks.

(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:

- Prevention plan for municipal water supply
- Rehabilitation plan for electric power supply
- Prevention plan for natural gas supply
- Prevention plan for telecommunication network

(6) Prevention plan for damages of transportation facilities

A prevention plan to minimise disaster damages on transportation facilities should cover roads, bridges, railways and commuter rails, and airports should be based on an adequate database. Damages to road bridges are estimated in the Study.

All the above transportation modes are indispensable to mobilize and deploy experts and manpower for emergency operation and to transport emergency goods after 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 networks should link the DTF centres, evacuation areas, emergency goods storage and distribution centres, regional roads and airports, etc.

(7) Reinforcement Plan of Urban Structure

According to the results of the damage analysis, the Ray Fault Model earthquake will almost destroyed residential and others buildings, especially in the central and southern districts of Tehran. In the area, seismically vulnerable building structures and weak urban structures on narrow roads are prevailing. In these area, there is also a significant lack of adequate public space for evacuation.

A reinforcement plan of urban structure is required in order to avoid and mitigate the estimated heavy damages in the specific districts due to an earthquake disaster. The seismic resistant strengthening of urban structures should cover the following fields:

- Designation for reinforcement district and areas,
- Designation and improvement of emergency roads and evacuation road network,
- Designation and preparation of proper evacuation areas (including site expansion, building reinforcement of schools and developments of multi-functional public open space to serve as evacuation areas),
- Seismic resistant reinforcement and rebuilding of public facilities, which would serve as DTF centres,
- Implementation of urban reconstruction projects for the above areas (including highly populated small scale and structurally weak residential areas).

(8) Organisation Plan for Urban Disaster Prevention and Management

For the estimated large-scale urban earthquake disaster, the Tehran Municipality should establish systemised and hierarchical Disaster Task Forces, including community disaster task force before and after disaster occurrence.

Required facilities development plans for each DTF should cover the need for emergency communication devices, emergency goods and equipment, emergency potable water supply tanks and systems, and emergency vehicle and helicopters and pads, etc.

(9) Guideline and manual for disaster prevention awareness

Task to upgrade disaster prevention awareness are currently taken on mainly by the Red Crescent Society of Iran.. However, the estimated disaster damages have great and impacts on all citizens, communities, and establishments in Tehran Municipality.

Disaster prevention awareness could be upgraded and its momentum maintained to prevent and mitigate disaster damages on a family and community basis.

Guidelines and manuals for disaster prevention awareness should include fields as following aspects:

- Diffusion of scale and danger of earthquake disaster in Tehran,
- Diffusion of disaster prevention measure on a family and establishment basis, and
- Diffusion of emergency response activities to minimise damage on a family and establishment basis.

Implementation of awareness raising programs are proposed as follows:

- Each level of DTFs in the municipality supported by emergency operation bodies such as Red Crescent Society, Fire-fighting Dept., Traffic Police, Police, etc.
- Curriculum in social science and emergency drills in elementary, intermediate and high schools.
- Periodical training and drill on disaster prevention and emergency response operations and activities in establishments

(10) Earthquake Disaster Study and Research Plan

Earthquake disaster study and research activities on active faults conditions are required to establish an earthquake disaster database in the DTF municipality centre and to improve the disaster prevention plan.

In addition, establishment of a ground and earthquake motion monitoring system with damage simulation models is recommended. The system allows the DTF centre to input earthquake event details and obtain quick information necessary for the formulation of informed emergency operation plans immediately after an earthquake event. The proposed items are as follows:

- GIS database system to support disaster prevention and management planning,
- Earthquake damage simulation system to aid in the implementation of proper emergency operations, and
- Research activities with national and international research institutes (on ground conditions and ground movement, seismic resistance of existing building facility building structures, housing, and bridges, research of human activities on emergency/evacuation circumstances, etc.).

7.5.5. Recommendation for Formulation of Emergency Operation Plans

Plans for required emergency measures should cover the following:

- Organisational structure of disaster task force system
- 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 operation 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, health care
- Locating dead bodies, preparing morgues, burial and burial grounds
- Rehabilitation of educational function
- Distribution plan of monetary donation for disaster victims
- Acceptance plan of donation for disaster

7.5.6. Recommendation for Rehabilitation and Reconstruction Plan

The objectives of rehabilitation and reconstruction plan are to repair damaged public and social service facilities and infrastructures 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 exemption, in the financing plan for reconstruction of private housing and industries, and for revitalization of trade and goods circulation.

(1) Recommendation for Road and Transportation Rehabilitation Plan

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

- Slope protection
- Road and bridges rehabilitation plan of emergency road network
- Recommended preventive measure

(2) Recommendation for 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 forecasted 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:

- Municipal water supply
- Electric power supply
- Natural gas supply
- Telecommunication network

(3) Recommendation for Rehabilitation and Reconstruction Plan of Social and Public Service Facilities

Social and public service facilities could be categorised into three groups, as follows, from the viewpoints of disaster prevention and management:

- Disaster Task Force and Centers on disaster period
- Evacuation Facilities and Areas for emergency period
- Other Public and Social Service Facilities

(4) Recommendation for Housing Damage

Rehabilitation and reconstruction plan for damaged housing will be required to cover the following aspects and procedures:

- Diagnosis of structural damage by experts
- Designation and plan formulation of urban reconstruction zone
- Proper enforcement of regulation for reconstruction and rehabilitation of housing with the financial and tax incentives
- Expansion of allocated reconstruction fund for housing and commercial buildings
- Support and arrangement to supply and distribute construction material
- Promotion and enhancement of construction

(5) Recommendation for Socio-economic Revitalisation and Stabilisation Plans

This plan should focus on supporting self-revitalization of socio-economic activities for disaster victims by granting grace periods, reductions, or exemptions from tax payments;

financing for rehabilitation of housing and commercial building reconstruction; and rehabilitation of goods transportation and circulation.

- Tax incentive for evacuees
- Financial incentive for reconstruction/rehabilitation activities
- Rehabilitation of consumer goods supply and circulation

7.6. Recommendation to Formulate Action Plans and Programs

Action plans and program covering a period of five years should be selected and formulated from a long list of plans and programs, which, in turn, should be drawn up based on the proposed ' Comprehensive Urban Disaster Prevention and Management Plan (CUDPMP) for Tehran Municipality' , by the following process.

- Preliminary estimation of restoration cost for earthquake damages
- Preliminary cost estimation for the identified plans and programs
- Comparative evaluation of the identified plans and programs
- Identification of available financial resources for preventive measure
- Priority assignment to the listed plans and programs
- Formulation of action plans and programs

The formulated action plans and programs should also be assessed based on economic analysis and preliminary environmental impacts.

Chapter 8 :

Recommendation on Structural Design

Chapter 8. Recommendation on Structural Design

This chapter describes the recommendation for legal measures to improve structural design and improvement measures for weak structure buildings in Teheran City. Moreover, some ideas of countermeasures, which should be reflected from the structural aspect in the earthquake disaster prevention plan, are presented. They are divided into "Urgent measures" and "Long-term measures" taking into consideration the changes of city structure with the passage of time.

Countermeasures may be abandoned if they are not executed within five years from the time the danger is recognized, because they become ineffective after this period. Thus, in this report, those measures, which should be concretely implemented within five years are called " urgent measures" and those which need a longer time frame are called " long-term measures."

8.1. Improvement Measures for Building Codes and Structure

In the future, the earthquake scenario on the study would be revised, when more reliable additional data is available. On the other hand, proposed measures for building design standards and seismic resistant code should also be revised periodically on the conditions as follows,

- Urban expansion and structural change
- Socio-economic growth (up-grading of investment capability)
- Up-grading of construction method and skill,
- New seismic resistant technology, and
- Revised earthquake scenario.

For review of earthquake scenario, the experience of seismic damage in a nearby area can produce new findings, and the outlook on earthquakes must be changed accordingly.

Important items that need to be upgraded include the following:

- Establishment of database for building, supper and infra structure
- Earthquake-resistant design code; and
- Calibration of seismic assessment technique and system.

8.1.1. Recommendation for Earthquake-resistant Design Code

According to the present Design Code of I.R.I. Following recommendations are made in the main report chapter 8 in detail.

(1) Strict compliance/enforcement of Code

In case that the present earthquake-resistant code of Iran were strictly followed, most of the structures in the Study Area could withstand the earthquake excitation, which has the intensity of the scenario earthquake. Therefore, what is very much needed is that buildings are built according to the earthquake-resistant code and that the Tehran Municipality strictly enforce the code. The following are further proposed:

- Continuous education of engineers; and

- Strict and proper enforcement of the codes on design approval and in building inspection after construction.

(2) Design earthquake

The fault model that may produce the biggest influence to Tehran is the Ray Fault Model. The response spectrum due to the earthquake and the design spectrum of the Iranian seismic design code are compared.

For the range where the natural period T < 3.0 sec

The response spectrum due to the scenario earthquake exceeds the design spectrum of the Iranian seismic criterion. From this, it is considered that the members of most buildings designed by the equivalent static analysis method of the Iranian seismic criterion exceed elasticity for the Ray Fault scenario earthquake.

For the range T > 0.5 sec

The response spectrum due to the scenario earthquake does not exceed the design spectrum of the Iranian seismic criterion so much. Therefore, it is examined whether to keep the members within the range of structural ductility for the scenario earthquake if the buildings are designed in an elastic manner, based on the equivalent static analysis method. If the structure is kept within the range of structural ductility, it does not become an overall collapse. If a allowable ductility ratio is maintained, the structure whose natural period is longer than 0.5 seconds will not collapse, even though members may yield partially.

For the range T < 0.5sec

The response spectrum due to the scenario earthquake reaches from 5 to 10 times the design spectrum of the Iranian seismic criterion. This shows the possibility for a structure designed according to the equivalent static analysis method to collapse.

The scenario earthquake disaster assessment reflects almost the severest condition, which can be assumed, based on the present day findings. On the other hand, the conditions of earthquake-resistant design should be approved based on economic limitations and agreed upon level of craftsmanship and quality. Careful consideration of the design spectrum is needed when thinking about these issues.

It is emphasised that the existing seismic design code of Iran is not necessarily enough for low-rise dwellings and many commercial buildings, which have the natural period of 0.5 seconds or less. Furthermore,. column-beam joints of general low-rise dwellings and many commercial buildings do not have a high enough ductility ratio. Most buildings have neither effective shear walls nor braces. Therefore, strict compliance and enforcement of the Design Code is required.

(3) Vibration Characteristics of Structures in Tehran

In this investigation, the ambient vibrations of typical buildings were measured. The vibration characteristics of the structures of Tehran can be evaluated as a result.

Steel Framed Buildings

The measured natural period is shorter than the first natural period applied in the Design Code. The period in the transverse direction is longer than the period in the longitudinal direction, excluding five examples, for building heights above 27 m.

It is considered that the rigidity against a horizontal force differs very much. Therefore, the natural period in the longitudinal direction becomes longer.

RC Framed Buildings

The measured natural period is shorter than the first natural period applied in the Design Code. There is a difference in the period values in the longitudinal direction and the transverse direction, but the tendency for periods in either direction to be long is not seen.

It is thought that neither the column nor the beam influences the rigidity against a horizontal force very much.

Non-Engineered Buildings

Measured values almost exactly correspond to the first natural period applied in the Design Code. There is no difference in the period values in the longitudinal and transverse direction. It is considered that there is no stiffener, such as shear walls, present in either direction.

8.1.2. Recommendation to Improve Weak Structural Details

Effective methods are introduced in detail for following items.

(1) Public buildings and dwellings

- Strength of column-beam joint seems to be insufficient.
- There is doubt whether the brick wall can work as the shear wall.

Recommendation：

Verification by loading test is needed most to obtain an effective solution for problem of steel column and beam structure. Because the panel structure, which is composed of beam-column joint and filled by hollow bricks, is the particular case, then the experiment result of the foreign country cannot give a definite verification for Iranian structure. It is therefore necessary that an official Iranian organization conduct an experiment on this case.

If a conclusion is drawn that the usual Iranian structures do not entirely satisfy the loading test, it is necessary to make an improvements plan or technological innovation.

(2) Bridges

Although the bridges in Tehran City are excellently designed and constructed, there are problems on the following points:

1) Condition of bearing that controls the behaviour of the superstructure is vague.

   Most of the bearing used in Tehran is made of neoprene. Moreover, the condition of movable/fix bearing is not distinguished from the viewpoint of structural details.

   It can be emphasized that there are a lot of examples of bridges that have collapsed as a result of bearing malfunction, including Hanshin Awaji great earthquake.

2) The unseating prevention system is not considered.

3) The shear-reinforcing bar of the pier is not sufficient.

Recommendation：

It is effective to adopt the concept of unseating prevention system to address problems 1) and 2) above.

For instance, it is recommended that the unseating prevention system should possess enough seat width and to have the connection between the adjoining girder in the "Design Specifications for Highway Bridges, Part V, Earthquake Resistant Design, 1990."

For problem 3), steel lining of the pier column can be effective.

8.1.3. Calibration of Seismic Assessment Technique

Building damage is especially serious based on the evaluation made by the study.

Though the forecast of total building damage is appropriate, the following are some issues regarding individual buildings:

- A small number of buildings of high quality could not be distinguished by using the census data and thus were not given enough consideration. Damage function was made giving priority to the structural types of greater number.
- The damage function proposed in the paper of Manjil earthquake is assumed to be representative as a standard earthquake-resistance in the building of Iran. However, further effort should be made to evaluate the earthquake-resistance of buildings in Tehran more appropriately.
- There may be a type of building that has a low number in the disaster region of Manjil earthquake but is increasing in Tehran.

A considerable amount of time is required to further investigate and solve the following problems:

- Diagnosis of earthquake-resistant performance in an individual building should be done. It is necessary to accumulate the result of the diagnosis. The frequency distribution chart of Is-valve of the building in the region should be made.
- The relation between P.G.A. and the rate of building damage in an actual seismic damage should be investigated. Then the reported actual result should be compared with the forecast damage induced from the frequency distribution mentioned above.

When there is a difference between the observed result and the theoretical value, correction should be performed using a stochastic technique.

The stochastic approach of damage function of construction is described in detail in the chapter of " attached material."

It is hoped that efforts to improve the accuracy of damage function following the above-mentioned procedure will be continued in the future.

8.2. Proposed Urgent Measures

The urgent measures are meant to immediately address this serious situation of potential seismic disaster, considering time and lack of necessary data:

- The seismic damage forecast for Teheran City, as described in the Volume of " Damage Analysis, presents a very grim picture. In addition, Teheran City is still growing and its structures are expected to increase in great numbers. Therefore, it is necessary to prepare countermeasures to seismic disaster as soon as possible.
- No seismic damage evaluation has ever been done up to this time. This includes the history of the last large earthquake caused by the fault, and the possible re-occurrence of the earthquake. Therefore, it is necessary to devise a schedule after these scenarios have been clarified.

Lessons can be learned from the aftermath of the great earthquake of Hanshin Awaji, Kobe, Japan, in 1995. Seismic criteria were revised to cover all potential seismic disaster areas. In addition, from 1995 up to the present time, a fundamental check is being done to building structures in Tokyo. Structures that did not satisfy seismic criteria were strengthened accordingly.

8.2.1. Demolish and Rebuild or Strengthen

From an economic point of view, it is unreasonable to rebuild all the structures that cannot withstand an earthquake, although such an action is ideal. Whether to rebuilt or merely strengthen are decisions that will have to be made carefully. Recommendations are made for following items:

- Public Buildings and Dwellings
- Bridges
- Lifelines

8.2.2. Seismic Retrofitting and Seismic Strengthening

The basic concept of seismic retrofitting is to improve the earthquake-resistance of structures without changing its basic framework, which already exists. It should be adopted only when the following has the advantage compared with rebuilding:

- The material and the construction cost can be limited to the minimum.
- The construction period can be limited to the minimum.

It is important to clarify the yield strength seismic intensity before seismic retrofitting is executed and the yield strength seismic intensity after seismic retrofitting.

Though the earthquake-resistance of a structure improves with seismic retrofitting, there can be a few cases in which the structure does not reach the level which completely satisfies the latest seismic code. A decision whether to assume this level to be acceptable is needed.

(1) Public Buildings and Dwellings

Examples of construction for seismic retrofitting and seismic strengthening are as follows:

- To Provide Additional Brace
- Strengthening of Wall
- Steel Lining / Fibre Lining
- Adding brace and hysteresis damping effect for Vibration Suppression

(2) Bridges

There are not many damaged bridges in the evaluation at this time. It is hoped that a steady pace is maintained in order to advance the strengthening plan. In the main report volume 3, following methods are explained as examples for effective strengthening against earthquake.

- Unseating Prevention System
- Steel Lining

Chapter 9 :

Recommendation on Detail Investigation and Evaluation of Seismic Activity

Chapter 9. Recommendation on Detail Investigation and Evaluation of Seismic Activity

It is important for actual disaster prevention planning to estimate the location, magnitude and time of next earthquake.

In this Study, the deterministic approach was applied in the construction of an earthquake scenario. Damages were estimated based upon the scenarios. However, there is little information on earthquake recurrence intervals and the latest earthquake events, and it is difficult to determine when the scenario earthquake will occur. It is strongly desired to investigate characteristics of earthquake source faults and to estimate the time of the next earthquake event. Contents of investigation are summarised in Table 9.1.

Table 9.1 Contents and Procedure for Detail Investigation and Evaluation of Seismic Activity

Evaluation Items	Investigation Items	Procedure of Investigation
3 dimensional location of active faults	Length	● Interpretation of air photograph ● Geological reconnaissance
	Dip	● Seismic Reflection Survey ● Observation of micro earthquake activities by seismograph network
Magnitude	Displacement of fault for one event	● Observation of active fault by trenching ● Deep boring investigation
	Segmentation	● Inventory survey ● Observation of active fault by trenching ● Deep boring investigation
Recurrence interval and time until next event	Time of previous two earthquake events	● Inventory survey ● Observation of active fault by trenching ● Deep boring investigation

The characteristics of earthquake source faults are follows:

North/South Ray Fault

The last event on the North/South Ray Fault occurred in 855. There has been no major earthquake activity in over 1000 years. Earthquake activity on these faults will bring huge earthquake damages, and a detailed investigation and evaluation is required.

North Tehran Fault (NTF)

There is no data in the earthquake catalogue on seismic activities on the North Tehran Fault. Earthquake activity on this fault will bring the next largest earthquake damages (second to the North/South Ray Fault), and a detailed investigation and evaluation is required.

Mosha Fault

The Mosha Fault has been activated repeatedly and major earthquakes have occurred. The latest earthquake occurred in 1830. The Mosha Fault consists of several segments. It is required to evaluate the location and interval for seismic activity of each segment.