13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1358

THE STUDY ON A DISASTER PREVENTION/MITIGATION BASIC PLAN IN ISTANBUL
PART 3
-ANALYSIS OF URBAN STRUCTURE AND RECOMMENDATIONS FOR MITIGATION-

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SUMMARY

Istanbul City has undergone development for thousands of years. There are many historical monuments and landscape-conservation areas. These are registered as world heritage sites. Dense old buildings and narrow road networks exist in the "Old City" area. These are covered by regulations on urban developments and also form earthquake vulnerable areas. Recent rapid urbanization also forms earthquake vulnerable areas, and 65% of the buildings are said to have developed illegally or in an irregular way. Nonetheless, GIS technology is one of the most powerful tools for consideration of these complex urban factors statistically and spatially.

In this study, GIS was applied for assessment of vulnerabilities, and consideration of available measures to achieve earthquake resistant city development. A database system was developed which covers comprehensive data on natural conditions, infrastructure, urban conditions and results of earthquake ground motion estimation and damages.

Vulnerability of urban and building structure were evaluated through analysis of: (a) building damage and the trend of urban/building renewal, (b) excessively high land/building use by urban development type, road density in urbanized area, narrow road ratio and availability of parks, and open space for required preliminary evacuation areas, and (c) built-up area ratio and building coverage ratio for land availability for urban structure improvements. Based on these analyses, improvement measures are proposed, consisting of: (1) improvement of vulnerable building/urban structures, (2) improvement of vulnerable urban structures by reinforcement of the buildings, and (3) redevelopment of building/urban structures and redevelopment of urban structures. These processes are applicable to other similar earthquake-vulnerable urban areas for consideration of earthquake resistant city development.

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INTRODUCTION

Istanbul City has undergone development for thousands of years. There are many historical monuments and landscape-conservation areas. These are registered as world heritage sites. Dense old buildings and narrow road networks exist in the "Old City" area. These are covered by regulations on urban developments and also form earthquake vulnerable areas. Recent rapid urbanization also forms earthquake vulnerable areas, and 65% of the buildings are said to have developed illegally or in an irregular way.

The authors had a chance to undertake “The Study on a disaster Prevention/ Mitigation Basic Plan Including Seismic Microzonation in the Republic of Turkey", supported by Japan International Cooperation Agency during years 2001 to 2002 [1]. The Study covers estimation of earthquake damage and proposal of damage mitigation measures in Istanbul. In this paper, first the characteristics of urban structures and urban vulnerability against earthquake damage are discussed, followed by the results of examination of available measures to achieve earthquake resistant city development.

GIS DATABASE DEVELOPMENT

Geographical Information System (GIS) technology is one of the most powerful tools for consideration of complex urban factors statistically and spatially. In this study, GIS was applied for assessment of vulnerabilities, and consideration of available measures to achieve earthquake resistant city development. The database system was developed which covers comprehensive data on natural conditions, infrastructure, urban conditions and results of earthquake ground motion estimation and damages. The Istanbul Metropolitan Municipality 1/5,000 scale topological maps compiled during 1995 to 1997 were applied for base maps. Building damages for an assumed earthquake was evaluated for a grid system 500 m by 500 m. Urban structure and urban vulnerability were evaluated for a grid system 100 m by 100 m.

METHODOLOGY OF THE ANALYSIS

In order to identify the areas with potential for serious damage, the relationship of the earthquakes and its secondary effects on the urban structure were examined. The following items were considered:

1. Estimated strong earthquake motion
2. Estimated high building damage area
3. Lack of safety evacuation route
4. Lack of safety evacuation space
5. Lack of access road for emergency
6. Lack of emergency response resources
7. Vulnerable lifeline network system
8. Hazardous areas for secondary disaster
9. Lack of reliable primary damage information collection system.

These factors are both the results and causes of the secondary damages. The vulnerability of the urbanized area from the earthquake disaster was assessed based on the available statistical data. The analysis is based on earthquake scenario C. This scenario is the largest earthquake which assumes that the moment magnitude is 7.7. Improvement issues and locations were identified and compiled as the results of building and urban structure vulnerability.

In the Study, factors of vulnerability were assessed in two main fields: building structures and urban structures. In addition, land availability analyses were included to identify areas for future urban structure improvement and required urban redevelopment (see Figure1).

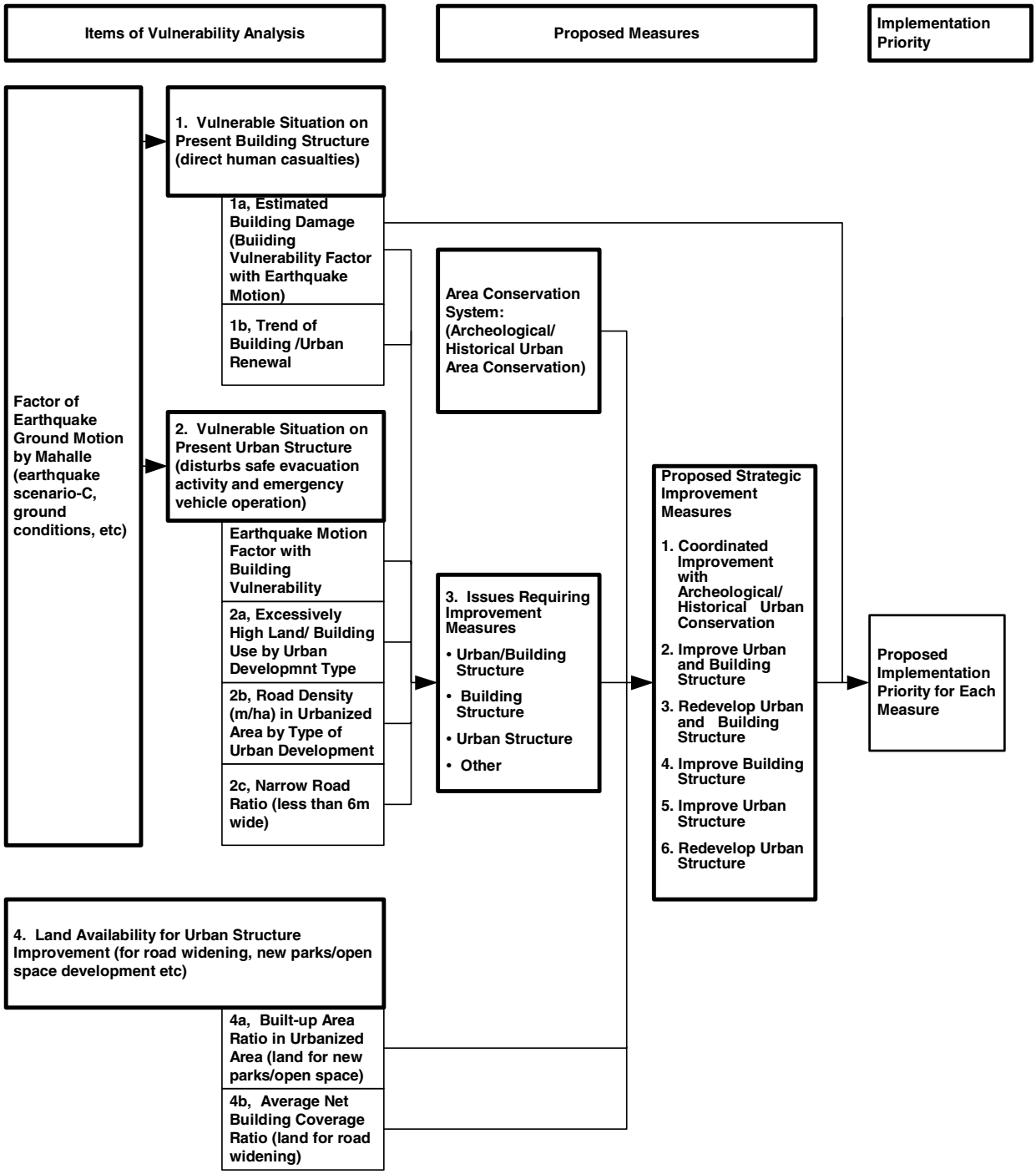

Figure 1: Flowchart of the Vulnerability Analysis

The vulnerability study was implemented and assessed based on 642 mahalles which are the smallest administrative and statistical units in Istanbul. The databases for 8 analyses were integrated into 3 main fields as follows:

1. Vulnerability analysis of the buildings and urban structures
2. Land availability for urban structure improvement
3. Recommendations for buildings and urban structure improvements

VULNERABILITY ANALYSIS OF THE BUILDINGS AND URBAN STRUCTURE

Present Vulnerability of Buildings

Estimated Building Damage

Building damage is the results of a complex analysis of the earthquake motions (estimated by earthquake scenarios, ground conditions, etc.) and building conditions (in terms of damage function) for each mahalle. Building damage conditions were divided into three categories: heavily, moderately and partly damaged. Building share of the estimated heavily and moderately damaged buildings in each mahalle was categorized and assessed according to the vulnerability of building structure. Based on the estimated heavily and moderately damaged building percentages, the mahalle building damages were placed in three categorizes as follows:

- over 40%: catastrophically damaged mahalle
- 30 to 39%: heavily damaged mahalle
- 10 to 29%: moderately damaged mahalle

In the analysis, buildings with 10% and above damages constituting heavily and moderately damaged buildings, were denoted as the mahalles with vulnerable building structures.

The number of mahalles assessed as having vulnerable building structures is 457, which account for 71% of the 642 mahalles in the Study Area. The assessed vulnerable mahalles are concentrated in The Historic District (143 mahalles, 97% of mahalles in this area), on the Marmara Coast of the European side (58 mahalles, 98% of mahalles in this area), in the Inland Area of the European side (52 mahalles, 87% of mahalles in this area), and the Marmara Coast and Islands of the Asian side (105 mahalles, 88% of mahalles in this area) (see Figure 2).

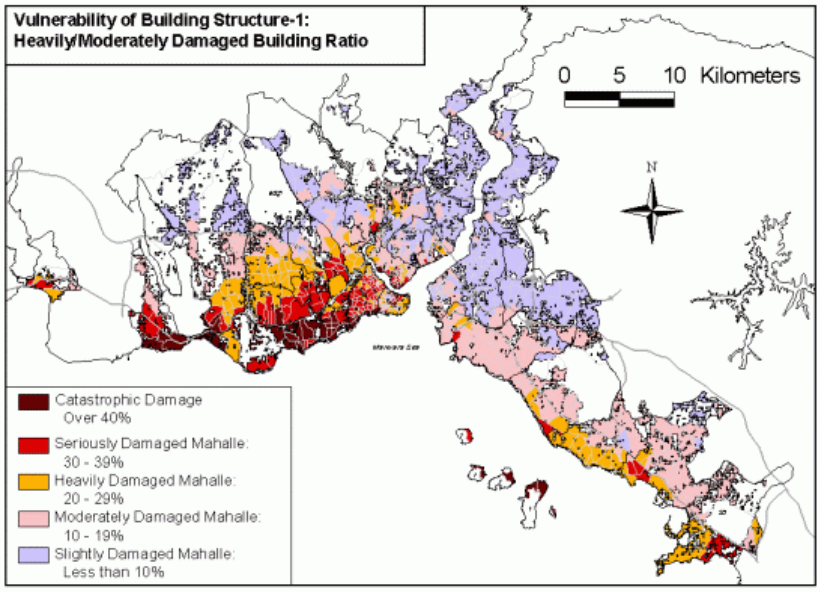

Figure 2: Heavily and Moderately Damaged Building Ratio

Trend of Building/Urban Structure Renewal

Trend of Building/Urban Structure Renewal are the results (year of construction data) of the 2000 Building Census [2] and the Chronological Urban Expansion Map in the Master Plan of Istanbul Metropolitan Municipality (IMM) [3].

The past trends of building reconstruction activities in each mahalle represent enhanced socio-economic activities to adapt to the needs of modern society. Also, these trends can be understood as upgrading to

better building structures and represent progress of urban renewal with appropriate road and urban infrastructure improvements in each mahalle.
In the study, trends of building reconstruction and urban renewal over the past 3 decades are assessed using three categories (see Figure 3)

- Mahalle Characterized by Low and Delayed Urban Renewal: more than half of buildings have not been reconstructed.
- Mahalle Characterized by Moderate Urban Renewal Mahalle: 50 to 75% of buildings have been reconstructed.
- Mahalle Characterized by High Urban Renewal Mahalle: over 75% of buildings have been reconstructed in the period.

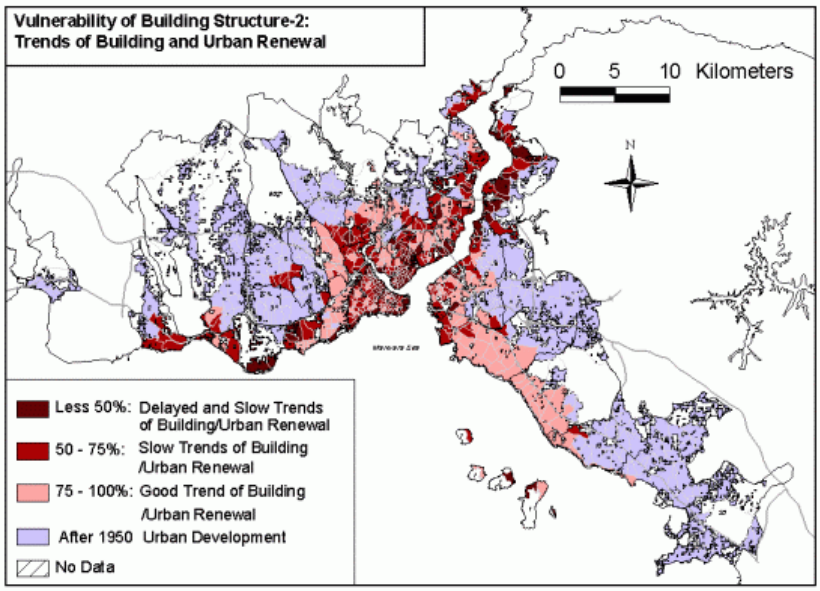

Figure 3: Trend of Building and Urban Renewal

Present Vulnerability of Urban Structures

Excessively High Land and Building Use by Urban Development Type
Excessively High Land and Building Use by Urban Development Type comes from the results of the 2000 Building Census (data on plot area, building coverage area, and number of floors). Net Floor Area Ratio was estimated based on the data of building coverage area, number of stories, and plot area data from the 2000 Building Census. Building Coverage Area Ratio was also estimated based on the data of building coverage area and plot area from the results of the 2000 Building Census. (see Figure 4)
Excessive urban land utilization can exacerbate the damages of earthquake disasters. The blockage of the evacuation routes by the collapsed buildings can increase the number of human casualties, can disturb the emergency response operations, etc. in the areas where building and floor usage is very high (shown with darkest color in Figure 4).

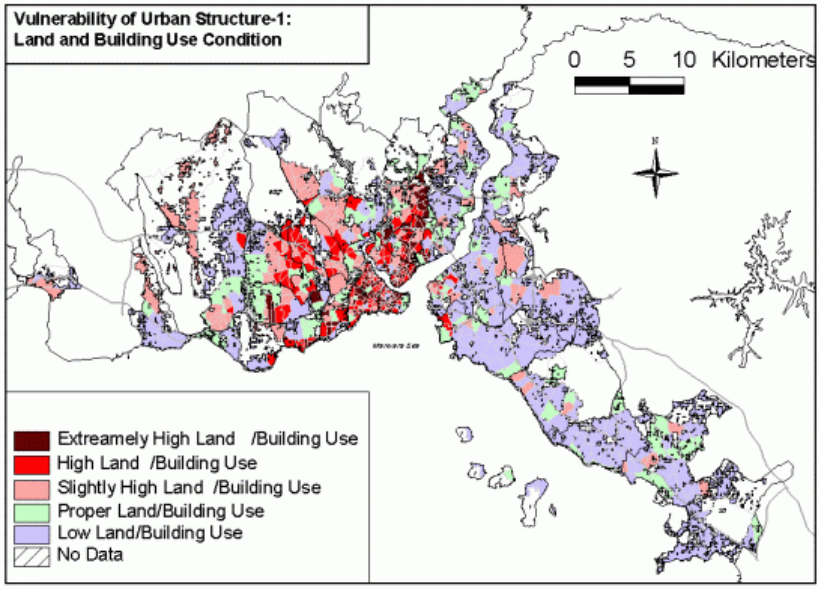

Figure 4: Land and Building Utilization Condition

Road Density (m/ha) in Urbanized Area

During an urban disaster, appropriate road densities are required in order to properly operate emergency response activities and to provide evacuation routes for citizens. Based on the GIS road network database for each mahalle and types of urban and building structures, the existing road density of urbanized areas were assessed and divided into five categories (see Figure 5).

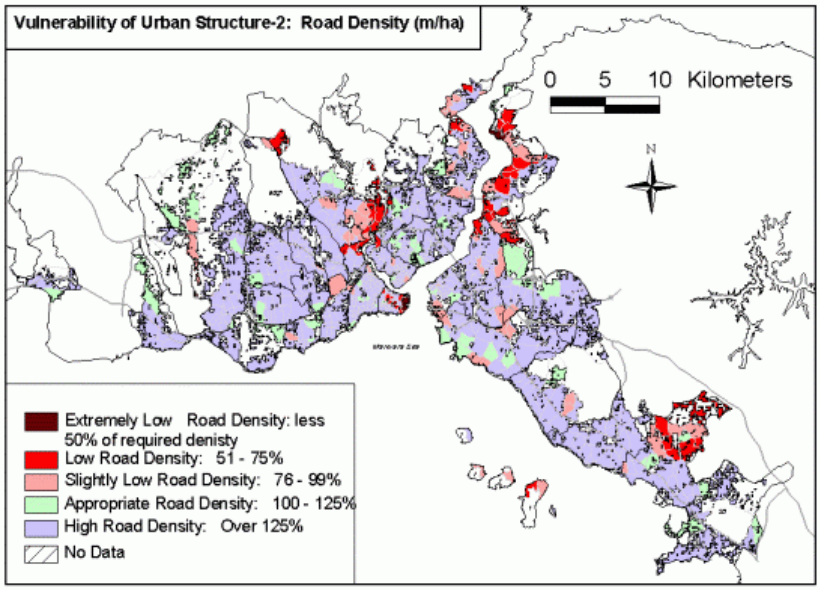

Figure 5: Road Density

- Extremely Low Density (less than 50% of required road density): only 3 mahalles (0.5% of a total of 628 mahalles in the IMM) were categorized as such and are located in the Eminönü, Sarıyer, and Beykoz districts with 160 ha (0.3% of total urbanized area). The mahalles of this category are negligible.

- Low Density (50% to 75% of required road density): 40 mahalles (6% of the total) in Eminönü, Beyoğlu, Sarıyer, Eyüp, Gaziosmanpaşa, Adalar, Pendik and 3 districts of the Asian Bosphorus area with 3,460 ha (7% of total urbanized area).
- Slightly Low Density (75% to 99% of required road density): 54 mahalles (8% of the total) widely distributed over 16 districts with 4,785 ha (9% of total urbanized area).
- Proper Road Density (100% to 125% of required road density): 52 mahalles (8% of the total).
- Sufficient Road Density (over 125% of required road density): 470 mahalles (75% of the total).
- A total of 97 mahalles (15% of the total number of mahalles in the IMM) are assessed as having extremely low, low and slightly low road density with 8,400 ha (18% of the urbanized area in the IMM).

Narrow Roads Ratio

Narrow roads will be serious constraints for the safe evacuation of citizens and proper emergency vehicle operations. There are 8,785 km (65% of 13,567 km of total road length) of narrow roads, 2 to 6 m wide or less in Istanbul. The narrow road ratio was categorized into five groups (see Figure 6).

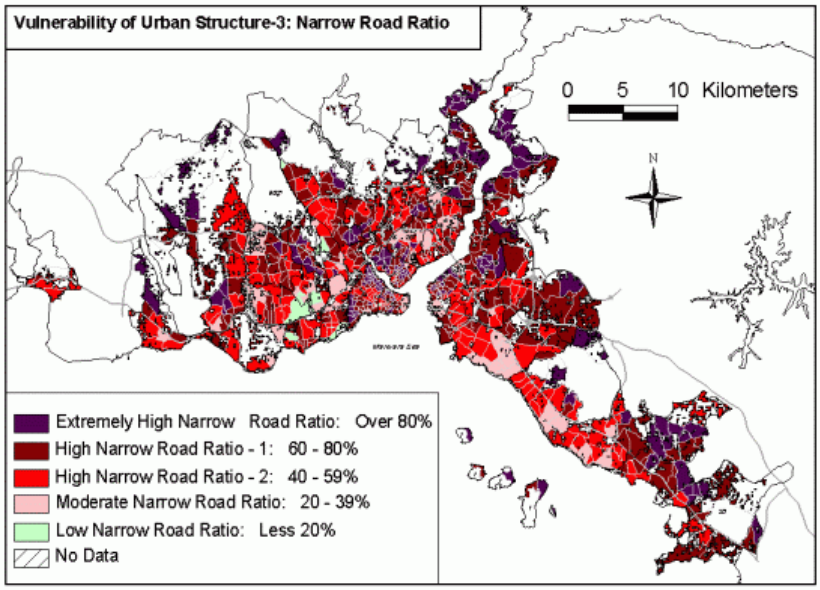

Figure 6: Narrow Road Ratio

- Over 80% of road length is made up of narrow roads: 149 mahalles (23% of the total), or 9,385 ha (19% of the total) of the urbanized area, will have high potential to be isolated based on building damage conditions. These mahalles are widely spread out except on the European Marmara Coast and in Beşiktaş and Kadıköy.
- 61 - 80%: 247 mahalles (38%) and 19,294 ha (38%) of the urbanized area will also have a potential to be isolated. These 247 mahalles are more widely distributed in almost all of districts, except the district of Güngören.
- 41 - 60%: 179 mahalles (28%) and 16,610 ha (33%) of the urbanized area will have evacuation activities and emergency vehicle operations disrupted, and parts of the mahalles will be isolated due to closed roads. These mahalles are also widely spread out over all districts.
- 21 - 40%: 50 mahalles (8%) and 4,657 ha (9%) of the urbanized area will not have evacuation and emergency vehicle operations free to navigate the roads, but substitute access routes were identified. These mahalles are limitedly distributed in the districts with better road conditions.

- 0-20%: 0nly 10 mahalles (2%) and 731 ha of the urbanized area will have evacuation and emergency operation activities disrupted by road closures. These mahalles are mainly located in the districts on the European Marmara Coast.

Integrated Vulnerability of Building and Urban Structures

Based on the vulnerability analyses of buildings and urban structures, vulnerabilities of mahalles were assessed and compiled into categories as follows (see Figure 7):

- Mahalles with Building and Urban Structure Vulnerabilities: 361 mahalles (56% of the Study Area). 11 districts were identified as most serious. Over 80% of the population or urbanized areas in each district are in this category of mahalles.
- Mahalles with Urban Structure Vulnerabilities: 39 mahalles (6%).
- Mahalles with Building Structure Vulnerabilities: 51 mahalles (8%).

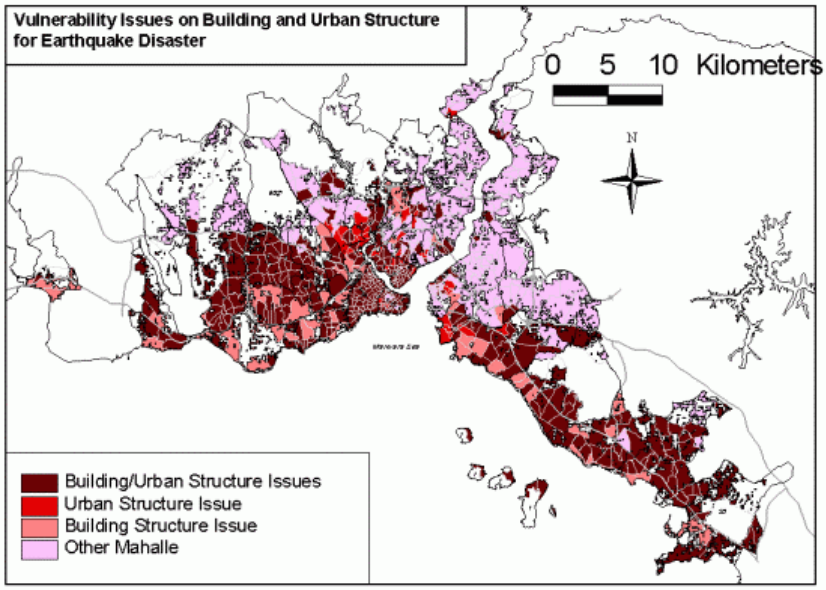

Figure 7: Vulnerability Issues on Building and Urban Structure for Earthquake Disaster

LAND AVAILABILITY FOR URBAN STRUCTURE IMPROVEMENT

Availability of Parks and Open Space for the Required Community Evacuation Areas

The list of parks and open spaces in Istanbul was created by the study of parks/open space availability in Istanbul by Technical University and IMM Mapping directorate [4,5]. The result of the land availability analysis was categorized into five groups (see Figure 8).

- Less than 25% of Demand: The almost total lack of parks/open spaces for primary evacuation areas was identified in 340 mahalles (53% of all mahalles). These mahalles were widely identified in 27 districts. Districts with a high number of such mahalles are Fatih, Beyoğlu, Zeytinburunu, Güngören, Kağıtane, Şişli, Gaziosmanpaşa, Esenler, Bağcılar, Küçükçekmece, Kadıköy, Maltepe, Kartal, Pendik, Ümraniye, Çatalca, and Silivri.
- 25 to 49% of Demand: 79 mahalles (12% of all mahalles) were found to have a limited number of parks and open spaces for primary evacuation areas. In the six districts of Bahçelievler, Avcılar, Kağıtane, Eyüp, Bayranpaşa, and Ümraniye, such mahalles make up more than 20% of all mahalles.
- 50 to 99% of Demand: 68 mahalles (11% of all mahalles) were found to have a shortage of parks and open spaces for primary evacuation areas.

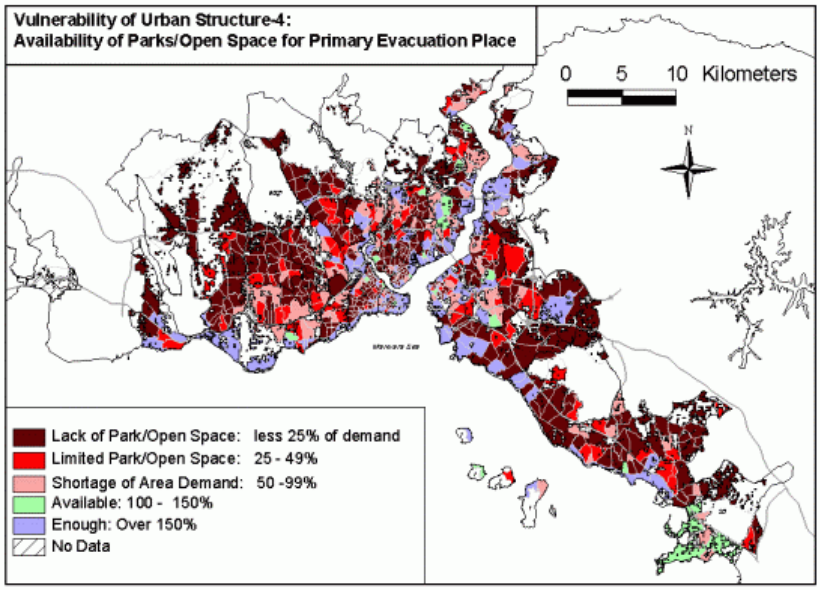

Figure 8: Availability of Parks/Open Space for Primary Evacuation Place

- 100 to 150% of Demand: 23 mahalles (4% of all mahalles) were found to have sufficient existing parks and open spaces for the demand of primary evacuation areas. However, net usable land for primary evacuation areas should be carefully examined considering the surrounding conditions in the district disaster management plan study.
- Over 150% of Demand: Existing areas of parks and open spaces were found to have over 1.5 times of the area demand in 115 mahalles (18% of all mahalles). Also, it is recommended that net usable land be recommended in the district disaster management study.

Built-up Area Ratio in Urbanized Area

The results the 2000 Building Census and GIS building/built-up/urbanized area database were compiled together (see Figure 9). Built-up area ratio in urbanized area was categorized into five types.

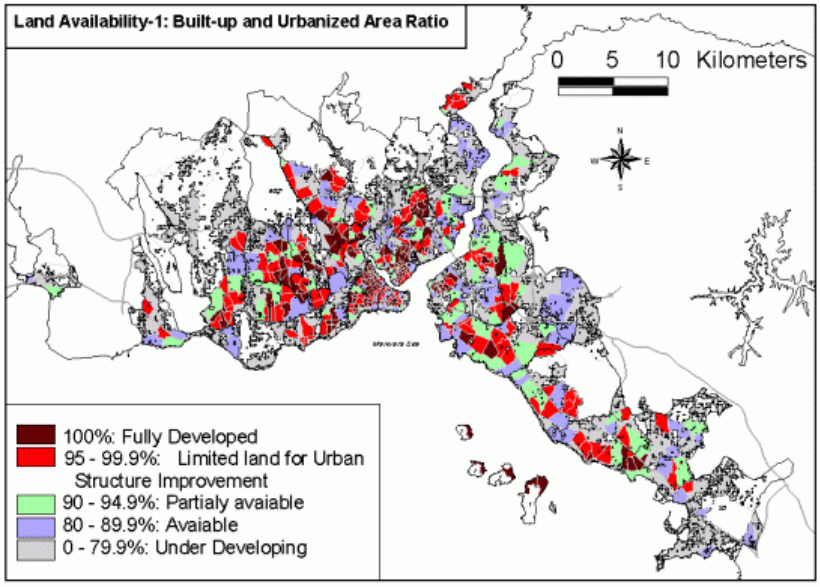

Figure 9: Built-up and urbanized area ratio

- 100% developed: the areas are almost fully developed in 174 mahalles. Required area for urban improvement is not available.
- 95-99% developed: the areas are almost fully developed in 130 mahalles.
- 90-94% limited remaining land: 5-10% of the mahalle is still undeveloped and could be used for improvement.
- 80-89% available land: 10-20% of the mahalle is still undeveloped and could be used for improvement.
- Less 80%: It can be said that 154 mahalles are in an undervalued stage.

Building Coverage area ratio

The results of the 2000 Building Census data were used in these analyses. The analysis shows the use of plots of land in the mahalles (see Figure 10).

- Over 90%- Full coverage: The plots in 40 mahalle are fully developed and there is no available spare land for improvements (widening of road, etc.)
- 80-89% High coverage: The plots in 72 mahalles are fully developed and there is no available spare land for improvements.
- 70-79% High coverage: There are some spare areas, which can be used for the future improvement projects. But even with it, the spare land will not be enough.

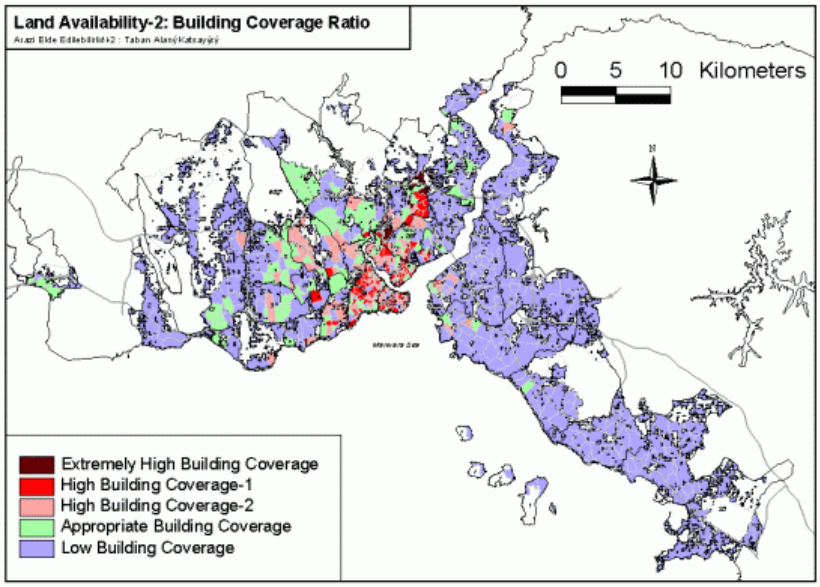

Figure 10: Building Coverage Area Ratio

Land Availability for Urban Structure Improvement

Based on the both building coverage ratio and built-up area ratio analyses, land availability in each mahalle was represented by taking the average score of the two analyses. The resulting land availability analysis can be assessed as one of the following five categories (see Figure 11):

- Category 5 - Not Available: In 77 identified mahalles (12% of the Study Area) with 11 km^2 of urbanized area (2% of the Study Area), both vacant land and frontage setback areas are not completely available for urban structure improvements, since most of the land is already fully developed. These identified mahalles are concentrated in the Historic District, the Marmara Coast, the Bosphorus on the European side, and in the Üsküdar District.

- Category 4 - Highly Not Available: In the 119 identified mahalles (19% of the Study Area) with 37 km^2 of urbanized areas (7% of the Study Area), land for urban structure improvements are also not available. There are, however, some vacant land or frontage setback areas available to fill part of the demand. These mahalles are also concentrated entirely in the districts on the European side and the Üsküdar and Kadıköy districts on the Asian side.
- Category 3 - Slightly Available: There are 169 identified mahalles (26% of the Study Area) with 119 km^2 of urbanized area (23% of the Study Area) where vacant land for park developments or frontage setback areas for road widening are available. These mahalles are widely spread out over almost all districts except Tuzla in IMM.
- Category 2 - Available -1: There are 157 mahalles (24% of the Study Area) with 167 km^2 of urbanized area (32% of the Study Area) where urban development is not completed yet. Building coverage in these mahalles is not very high, and the required land for urban improvement could be identified within each mahalle.
- Category 1 - Available 2: There are 115 mahalles (18% of the Study Area) with 185 km^2 of urbanized area (36% of the Study Area) that may not have land availability issues or need urban structure improvements.

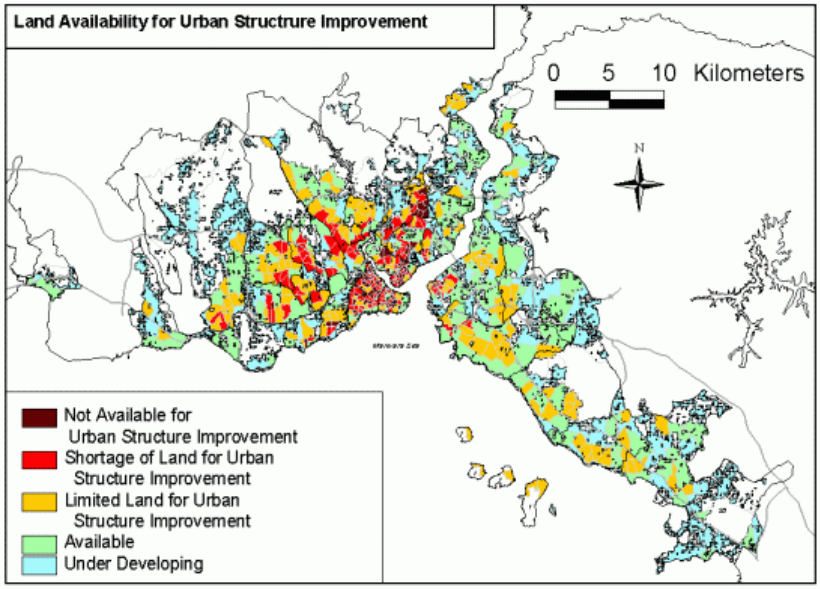

Figure 11: Land Availability for Urban Structure Improvement

PROPOSED STRATEGIC IMPROVEMENT MEASURES FOR THE MAHALLES

The mahalles with serious Building and Urban Structure vulnerabilities were identified as follows:

- Mahalles with Building/Urban Structure Vulnerabilities: 361 mahalles (56% of the Study Area) with 246 km^2 urbanized area (47% of the Study Area) and 4.8 million residents (56% of the population).
- Mahalles with Urban Structure Vulnerabilities: 39 mahalles (6% of the Study Area) with 16 km^2 urbanized area (3% of the Study Area) and 0.4 million residents (5% of the population).

These two categories are included in the strategic measures for improvement or reconstruction based on the previous land availability analysis.

There are many historical monuments and landscape-conservation areas in Istanbul City. Many of them are registered as world heritage sites and development or re-development works are strictly restricted [6]

(see Figure 12). Strategic measures do not covering these conservation areas because the measures for the conservation areas must be proposed based on different considerations.

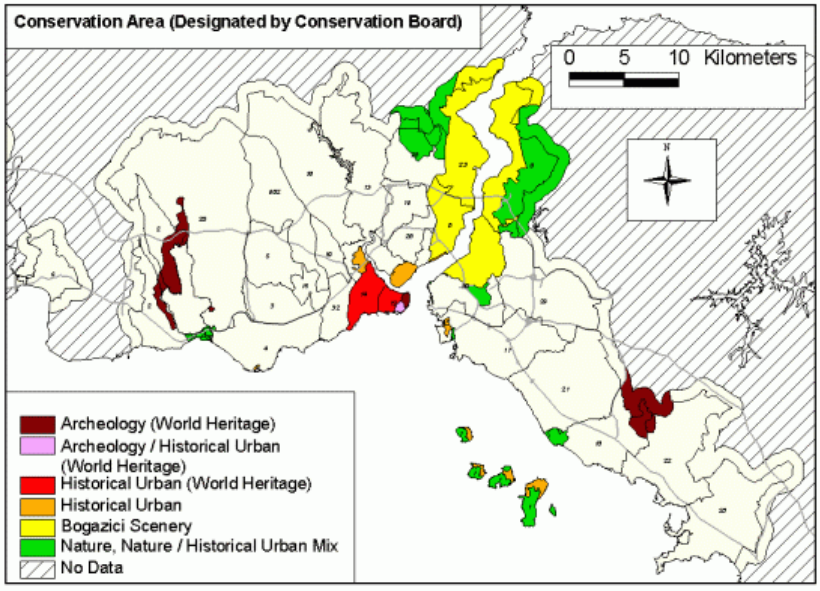

Figure 12: Conservation Areas

The identified strategic improvement areas, where spare land is available for to apply projects to improve building and urban structure vulnerability were identified as shown in Table 1 and Figure 13.

Table 1: Improvement Measures

		Building/ Urban Structure	
		Vulnerable	Not So Vulnerable:
Conservation Area		1. Coordinated Improvement with Archeological/ Historical Urban Conservation	
Land for Urban Structure Improvement	Available	2. Building/ Urban Structure Improvement	4. Building Structure Improvement 5. Urban Structure Improvement
	Not Available	3. Building/ Urban Structure Redevelopment	6. Urban Structure Redevelopment

Strategic Improvement Measures for the Issues of Buildings and Urban Structures

The identified 214 mahalles with 213 km^2 urbanized area and 3.6 million residents combine into 33% of the mahalles, 42% of all urbanized area and 42% of the population, which is the biggest share in the identified six strategic measures.

The mahalles identified for the five strategic measures share over 50% of urbanized area in 11 districts, which are located on both the Asian and European sides of the Marmara Coast, and Bağcılar and Küçükçekmece on the European Inland.

The recommended principal measure to strengthen building structures and urban structures must be applied under the formulated metropolitan and local district disaster prevention master plans. Also, all of the implementation measures and projects should be carefully prioritized and coordinated with each other and with the plan formulation procedures.

The specialized and modified measures applied in designated Historical Urban Conservation Areas should be coordinated with the agencies responsible for conservation.

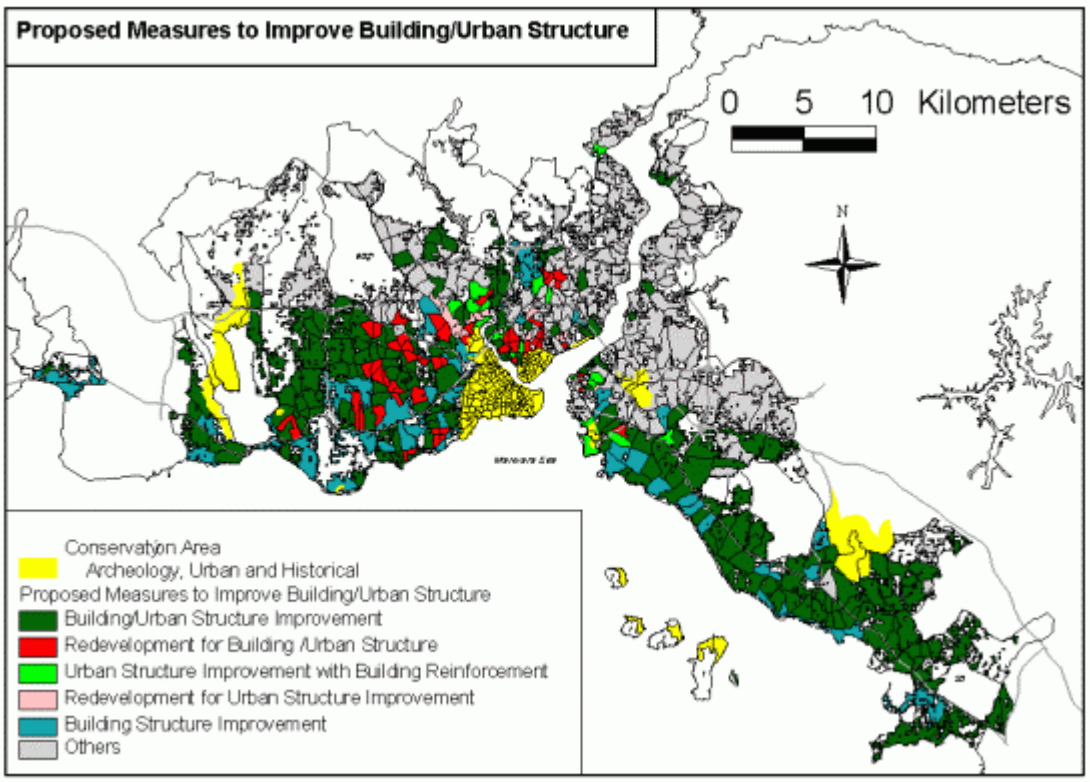

Figure 13: Proposed measures to improve Building/Urban Structure

Strategic Improvement Measures for the Issues of Urban Structures

The 19 mahalles with 11 km^2 of urbanized areas and 0.24 million residents represent only 2 to 3% of mahalles, with the same percentages for urbanized areas and population in the Study Area. The identified 19 mahalles are spread out over 8 districts.

The recommended principal measures to strengthen urban structure issues must be applied intensely in the identified 19 mahalles. Supplemental measures for building structure issues are also required to strengthen the estimated number of damaged buildings (10% to 30% with heavy and moderate damage), in addition to the recommended preliminary seismic resistant assessments (see Figure 13).

Furthermore in the study, some estimation on emergency response and rehabilitation works was done. The demand or framework of the emergency response operation is based on the estimated damages of the worst earthquake scenario model C. The estimated damages were calculated for; community evacuation place, debris removal, emergency rescue operations, emergency first aid, emergency medical care, emergency fire fighting, emergency portable water and food supply, tent villages, temporary housing, cemetery and funeral services, lifeline rehabilitation services.

CONCLUSION

In consideration of proposal for earthquake damage mitigation measures in Istanbul City, characteristics of urban structure and urban vulnerability against earthquake damage were analyzed. Vulnerability of urban and building structure were evaluated through analysis of (a) building damage and the trend of urban/building renewal, (b) excessively high land/building use by urban development type, road density in urbanized area, narrow road ratio and availability of

parks, and open space for required preliminary evacuation areas, and (c) built-up area ratio and building coverage ratio for land availability for urban structure improvements. Based on these analyses, improvement measures are proposed, consisting of (1) improvement of vulnerable building/urban structure, (2) improvement of vulnerable urban structures by reinforcement of the buildings, and (3) redevelopment of building/urban structure and redevelopment of urban structures. Geographical Information System was applied in these considerations. These processes are applicable to other similar earthquake-vulnerable urban areas for consideration of earthquake resistant city development. These analyses are only one method to identify the vulnerability of urban structure and buildings, and these processes are applicable to other similar earthquake-vulnerable urban areas for consideration of earthquake resistant city development.

ACKOWLEDGEMENT

The authors were study team member and counterpart agency personnel in the "The Study on A Disaster Prevention/ Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey" supported by the Japanese Government through the Japan International Cooperation Agency's Development Study Program (JICA DSP). Authors wish to thank them for their support. Throughout the course of the Study, the authors held many discussions with JICA Advisory Committee members, Turkish Technical Advisory Committee members, Istanbul Metropolitan Municipality Government and also many local agencies. Their contributions to this paper have been great and the authors take special pleasure in acknowledging the important part played by them.

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