Chapter 9.
Evaluation of Urban Vulnerability

Chapter 9. Evaluation of Urban Vulnerability

9.1. Buildings

9.1.1. Present aspect of building design and construction

(1) Construction Procedures and Quality Control

In Turkey, vulnerability of buildings are widely known, however, it is not clear that what makes the reason to build such a weak buildings, especially for residential buildings. It is important to know what kind of regulations and quality controls are accepted under construction. This section describes to clear the problem of construction procedure in Istanbul to find out the way to strength the buildings and minimize the human loss against strong Earthquake.

a. Building Permission

For the process of constructing new buildings, building permission has to be accepted by the District Municipalities, where under jurisdiction of construction sites. Directorate of Constriction, Department of Planning and Construction, IMM, also check the registration form and attached documents to inspect the reliability randomly from District Municipalities. According to the meeting with Department of Planning and Construction, they mentioned about the restriction of building permission after the 1999 Izmit Earthquake. As a result, more illegal buildings are increased and number of submissions to get building permission is decreased drastically. In fact, restriction of building permission makes to increase the number of poor construction ironically.

b. Construction

Before the Izmit Earthquake, there was no construction supervision enforcement at the construction site and responsibilities are not clearly defined. Therefore, only major buildings, such as office buildings, shopping centers, which are constructed by major rich companies, are kept high in quality. However, residential buildings, which are constructed mostly not seriously considered about earthquake or lack of budget to build strong buildings against earthquake, are widely accepted without any doubt. In order to minimize such trend, *"CONSTRUCTION SUPERVISION LAW #4708"* was enacted in 2000 controlled by Ministry of Public Work and Settlements and modified in August 2001. Its aims are as follows;,

1) To secure the safety of human life and physical by structures,

2) To avoid no plan/inspection and low quality construction which causes waste of resources,

3) To construct structures which reach recent standards,

4) To secure structure inspection to fulfill item 3),

5) To secure individual rights from loss by damage of structure, and

6) To insure from losses that may be occur in the future.

By this law, each construction site has to employ supervisor(s) from Construction Supervision Company. The company cannot have any function other than supervision to keep clearness of the inspection work.

This law is effective for all construction of buildings except which is single story building without basement floor and less than 180 m^2 of floor area. Supervision duration is from the starting date of submission of building permit and up to end of approval of usage permit.

By enacting of this law, it is true that strong building are built stronger, however, unless there are many ways to evade this law, low quality building may not be decreased in the future. It is strongly necessary to find a way to obey the law strictly.

(2) Earthquake resistant code

A latest earthquake resistant design code is “Specification for Structures to be Built in Disaster Areas (PART III - EARTHQUAKE DISASTER PREVENTION)” that is established by Ministry of Public Works and Settlement, Government of Republic of Turkey in 1997.

This code prescribes through the latest knowledge concerning the basic principles of building structure system, seismic load and details of structure. However, this does not include the provision for earthquake induced earth pressure.

Chambered Office of Civil Engineers published a reference book “*DEPREM MUHENDISLIGINE GIRIS ve DEPREME DYANIKLI YAPI TASARIMI*” that can offer the ways to confirm a safety by calculation.

However, since it is clear from not strict process of building permit, it cannot be said that newly constructed buildings were confirmed a safety by calculation.

(3) Earthquake resistance of existing buildings

A first step of the building survey was carried out to gain a numerical understanding of the earthquake resistance of the buildings in the study area.

The investigated buildings are following 2 schools.

- ÜSKÜDAR TİCARET MESLEK LİSESİ (S-1)
- HAZERFEN AHMET ÇELEBİ İLKÖĞRETIM OKULU (S-2)

Photo 9.1.1 ÜSKÜDAR TİCARET MESLEK LİSESİ

Photo 9.1.2 HAZERFEN AHMET ÇELEBİ İLKÖĞRETIM OKULU

The former school is comparatively old building, completion of design was in 1977, completion of construction was in 1985. The latter school is comparatively new building, completion of design was in 1987. Both of them are designed based on a building standard design named 10403.

The method applied in this survey is based on *first step diagnosis* that is proved in "Specification of diagnosis on RC Composed Existing buildings (version 2001) (Public Works of Construction Japan)". This method gives Seismic Index of Structure *IS* as a capacity of the buildings, by referring "cross section area of columns and walls", "total weight of structure above the corresponding story", and "Uniaxial compressive strength of concrete".

This index can give effective information to quantitative understanding, not a subjective assessment data, nevertheless, there can be some difference between the concept of Turkish RC building structure and the Japanese one.

The process of calculation is shown in Figure 9.1.1. An example of calculation data of ÜSKÜDAR TİCARET MESLEK LİSESİ is shown in Figure 9.1.2.

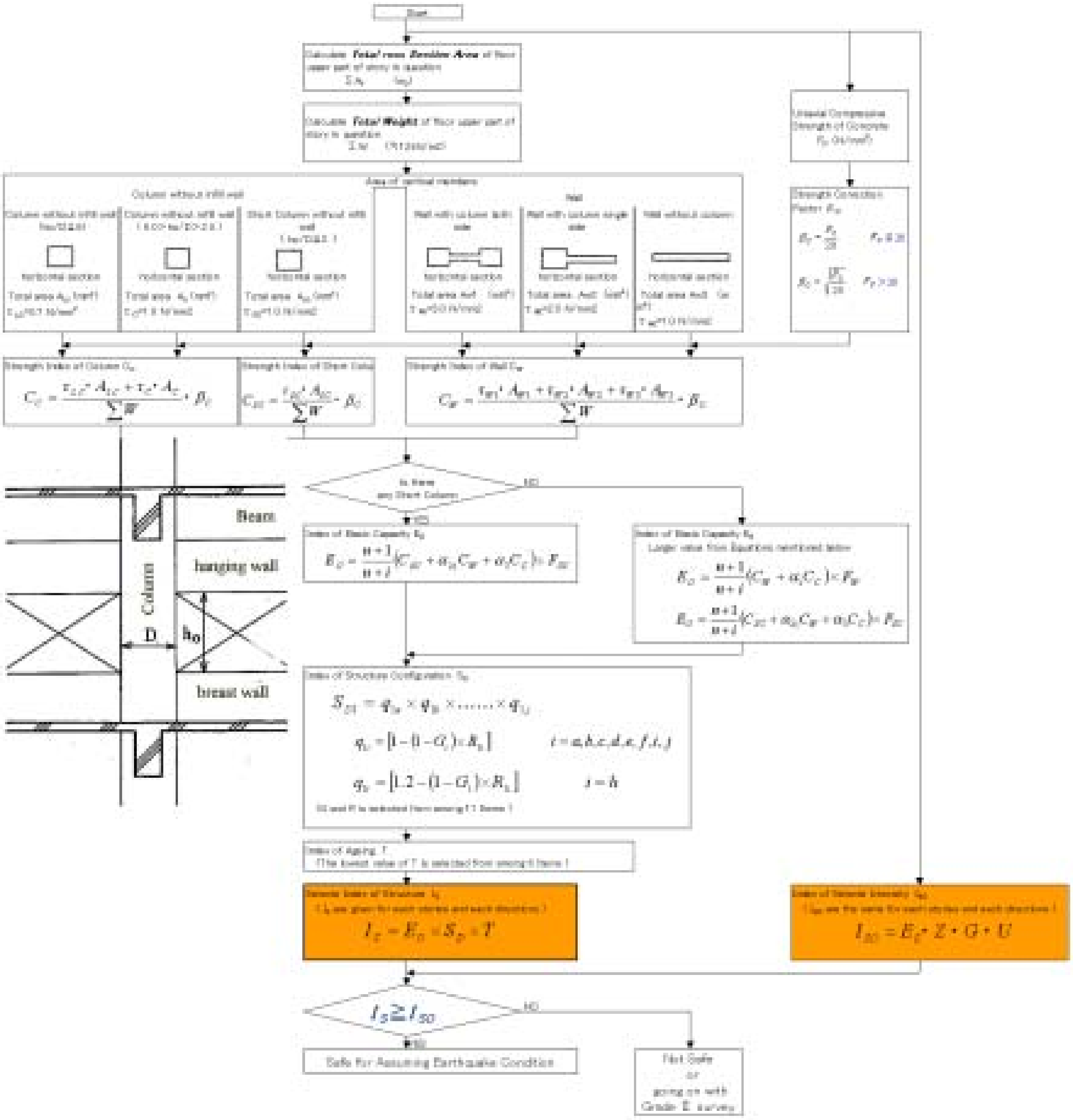


Figure 9.1.1 Process of Calculation (I_S)

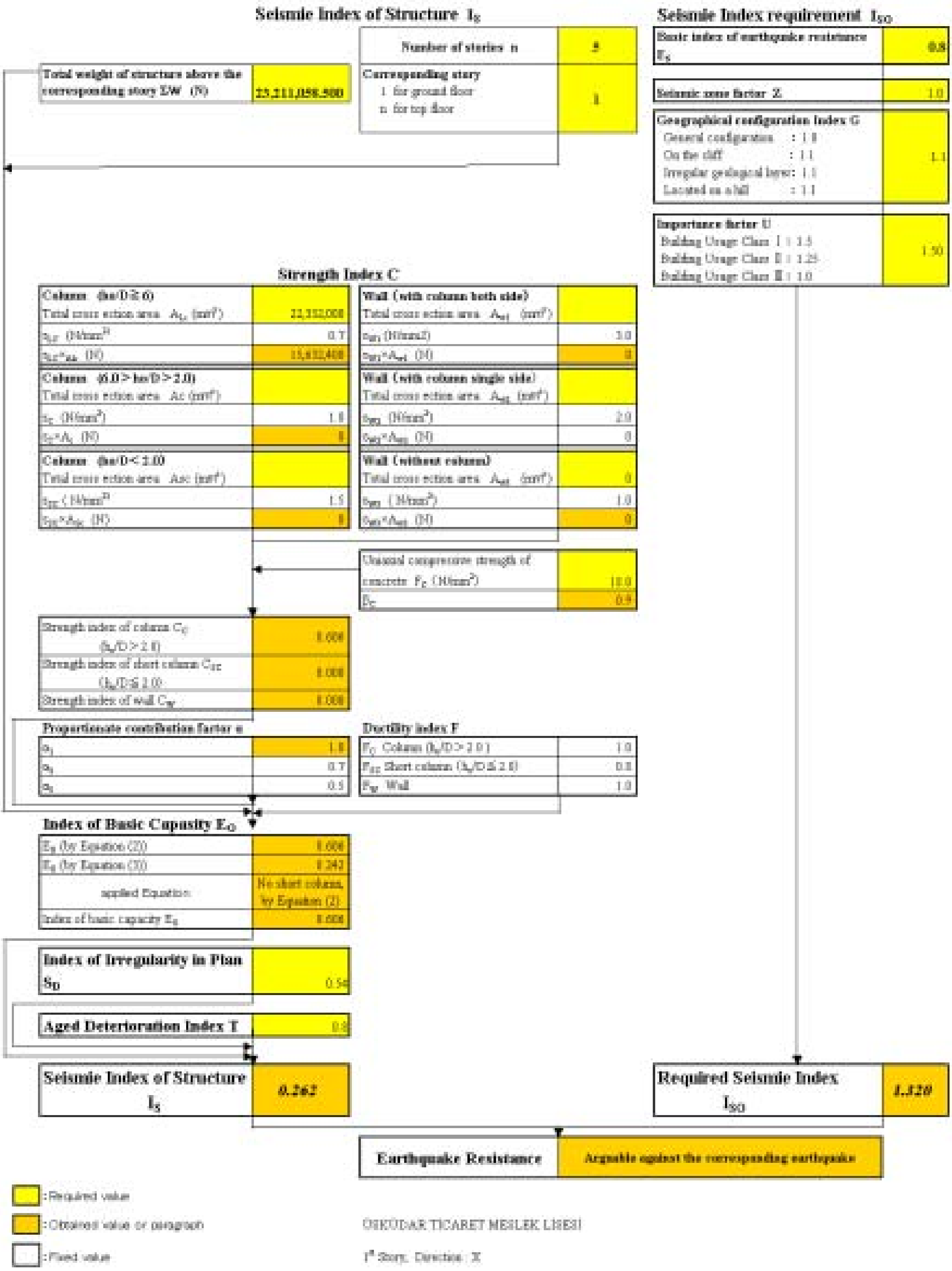


Figure 9.1.2 An Example of Calculation Data of ÜSKÜDAR TİCARET MESLEK LİSESİ (Span Direction)

The assessed result for each direction of each building *Is* is shown in Table 9.1.1 and Table 9.1.2.

Table 9.1.1 Assessed Result for Each Direction of Each Buildings I_S (ÜSKÜDAR TİCARET MESLEK LİSESİ)

		Index of Basic Capacity E_O	Index of Irregularity in Plan S_D	Aged Deterioration T	Seismic Index of Structure I_S
Ridge Direction	5 th story	2.068	0.540	0.800	0.893
	4 th story	1.004	0.540	0.800	0.434
	3 rd story	0.734	0.540	0.800	0.317
	2 nd story	0.645	0.540	0.800	0.279
	1 st story	0.606	0.540	0.800	0.262
Span Direction	5 th story	2.569	0.540	0.800	1.110
	4 th story	1.235	0.540	0.800	0.534
	3 rd story	0.895	0.540	0.800	0.387
	2 nd story	0.771	0.540	0.800	0.333
	1 st story	0.718	0.540	0.800	0.310

Table 9.1.2 Assessed Result for Each Direction of Each Buildings I_S (HAZERFEN AHMET ÇELEBİ İLKÖĞRETIM OKULU)

		Index of Basic Capacity E_O	Index of Irregularity in Plan S_D	Aged Deterioration T	Seismic Index of Structure I_S
Ridge Direction	4 th story	1.683	0.600	0.800	0.808
	3 rd story	0.822	0.600	0.800	0.395
	2 nd story	0.632	0.600	0.800	0.303
	1 st story	0.556	0.600	0.800	0.267
Span Direction	4 th story	1.861	0.600	0.800	0.893
	3 rd story	0.909	0.600	0.800	0.436
	2 nd story	0.697	0.600	0.800	0.334
	1 st story	0.613	0.600	0.800	0.294

Seismic Index of Structure IS value shown in Table 9.1.1 and Table 9.1.2 represent resistivity of building and this index shall be compared with Required *Seismic Index Iso*, then safety against assumed earthquake could be assessed. As it was shown in Table 9.1.1 and Table 9.1.2, *Required Seismic Index Iso* is on the basis of *Basic index of earthquake resistance Es* and its value is 0.8.

The specific value of Basic index of earthquake resistance *Es* was fixed referring the damage distribution of 1968 Tokachi Earthquake and 1978 Miyagi Earthquake. There was only one damaged building in the case of $E_S \geq 0.7$ and no damage was found in the case of $E_S \geq 0.8$.

"Specification of diagnosis on RC Composed Existing buildings (version 2001)" proves an equation in which Basic index of earthquake resistance ES was multiplied by Seismic zone factor Z, Geographical configuration Index G and Importance factor U. As it was shown in Figure 9.1.2, the value of *Iso* shall be 1.32 when following set of value is applied. (Seismic zone factor Z=1.0, Geographical configuration Index G=1.1, Importance factor U=1.5 considering the priority of this building)

Similar method was applied for the damage investigation on 1992 Erzincan Earthquake and relation between the result value of IS and actual damage ratio was compared as shown in Figure 9.1.3.

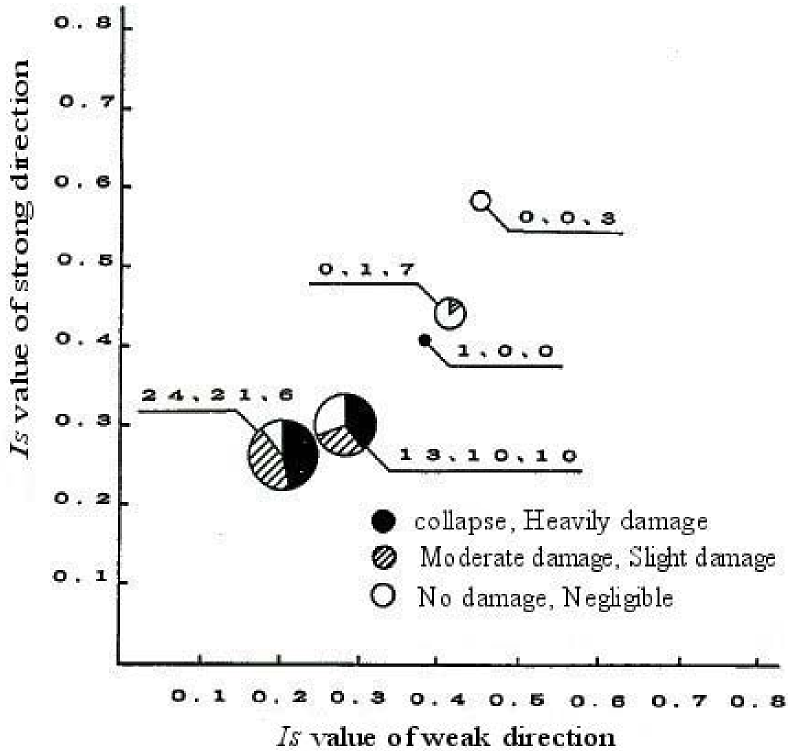


Figure 9.1.3 Relation between the Result Value of I_S and Actual Damage Ratio (1992 Erzincan Earthquake)

- The buildings which have the value of I_S=0.4～0.5 may stay in slight damage under the condition of 1992 Erzincan Earthquake.
- Half of the buildings which have the value of I_S 0.2 may reach collapse or heavily damage under the condition of 1992 Erzincan Earthquake.

The lowest *Is* value of each investigated buildings at 1st story are 0.108 for Üsküdar Ticaret Meslek Lisesi and 0.189 for Hazerfen Ahmet Çelebi İlköğretim Okulu. Therefore, it is possible that these buildings may collapse or heavily damage under the condition of 1992 Erzincan Earthquake. It is easily presumed that almost all the school buildings may have similar earthquake resistance, because these investigated buildings are designed based on the school building design standard.

In addition, there are following remarkable points, which show the reasons why these buildings do not have sufficient earthquake resistance in investigated buildings.

- The story that was designed as a basement was made as 1st story by unknown reason. It means that it is similar to the building with added stories after completion of construction illegally. Nevertheless, cross section of the columns and walls were not increased appropriately. Therefore, the IS value of the buildings is lower than the value that is required to endure the earthquake motion similar to 1992 Erzincan Earthquake. If the 1st story of Hazerfen Ahmet Çelebi İlköğretim Okulu was constructed as the basement as of original drawing and water leakage is not observed, *Is* value increase from 0.189 to 0.429. This assumption means that Hazerfen Ahmet Çelebi İlköğretim Okulu could endure the earthquake similar to 1992 Erzincan Earthquake, if the building constructed following original design and maintained carefully.
- The shear wall layout was changed from the original design standard in order to prioritize convenience of usage. Therefore, the capacity, for the direction of which the shear wall was omitted, becomes lower than the one that originally designed. For instance, in the case of Üsküdar Ticaret Meslek Lisesi, there is no shear wall that is effective for ridge direction, as a result, the *Is* value for this direction give the lowest figure 0.108.
- The torsion mode behavior can occur, if the wall is arranged unevenly.
- Some critical stress concentration will occur, when the walls are arranged carelessly. i.e. the column was reformed to the wall.

Similar observation is also shown in the report on the school buildings in Avcilar district prepared by Prof. Zekeriya POLAT (Y.T.U).

9.1.2. Indication of a controversial point on Structure

Most of Turkish buildings generally have following defect.

(1) The cross section area of the columns is frequently insufficient

The result of school building survey represents the ordinary earthquake resistant level of Turkish buildings. The fact that *Seismic index of structure Is* of investigated buildings is very low means that cross section area of vertical member (column and wall) is insufficient.

The value of *Is* does not only reach the required level of Japanese ordinary building, but also not improved from the level given to damaged buildings of 1992 Erzincan Earthquake.

In addition, many buildings that have more insufficient number of columns compared to surveyed school buildings were found during the field investigation in Istanbul.

(2) The reinforcement of the columns is frequently insufficient

In addition to insufficiency of the cross section area of the column and wall, the number and diameter of re-bar in cross section area is also insufficient.

The re-bar is not connected appropriately through the story. This point has been designated as a reason why the collapse caused by failure of column-beam connection is predominant in Turkey. However, the evident collapse of this kind was observed even at 2002 AFYON Earthquake. This point out that problem in column-beam connection was not improved: nevertheless, brittleness of that part have been cautioned since 1992 Erzincan Earthquake.

The cross section area of the hoops are insufficient, the interval of the hoops are insufficient. In addition, the end of the hoops is usually fixed by 90-degree hooks even though some design code in Turkey prove appropriate detail, (i.e. hoops shall always have 135 degree hooks at both ends hooks shall be bent around a circle).

If fixing of the stirrup end is insufficient, then bar may slip off, and column itself does not exert vertical load-carrying capacity.

The shear failor of the column and the buckling of concrete may occur after the problem of column-beam connection is solved.

Photo 9.1.3 An Example of the Failure between the Column and the Beam

(3) Difference between the mechanism of column and wall is not identified

In general, column is expected to have load-carrying capacity even if it is under large story-drift caused by earthquake excitation, therefore, column must have considerable ductility as well.

However, some amount of stiffness is needed, because load-carrying capacity of the column is lost when it suffer excessive story-drift. Reasonable amount of shear-wall is effective for controlling story-drift. Shear-wall should be arranged for ridge direction and span direction, and should be distributed evenly.

Concerning the buildings in Turkey, there are many examples that is composed of only column. Especially flat section column is used to control the stiffness of horizontal direction. It is doubtable that this kind of column has sufficient ductility, because hoops in this kind of section do not come into effect even if considerable amount of hoops exist. Many examples of failure were found at the columns of subway structures in 1995 Kobe Earthquake.

(4) Framework is confused in many building structure

Beam is not identified clearly in many cases of residence buildings. This kind of framework is not effective for horizontal force.

(5) There are big difference between the indicated strength of concrete and real strength

The concrete that is mixed in-situ is still used frequently. The quality of that kind of concrete is doubtable, because quality inspection and control are not sufficient as many Turkish engineers insist.

(6) Capacity and stiffness for ridge direction is not taken into consideration in many buildings at urbanized area

For instance, when a building that forms a part of one block is demolished, some strut usually placed between neighboring buildings. This treatment shows that neighboring building may be deformed to void space and collapse at last, even though there is no earthquake.

(7) Wrong usage of hollow brick

Hollow bricks are widely used as partition walls, but load-carrying capacity and shear capacity cannot be expected in these walls. However, some buildings that are composed of only by hollow brick are observed. Law prohibits this kind of structure, but frequently exists.

(8) Earthquake resistant design code is not strictly obeyed

Earthquake resistant design code has been improved reasonably up to the present. However, buildings that apply this code seem very limited especially for residential buildings.

9.1.3. Recommendation on earthquake resistant strengthening

There are several levels for the concrete measures of earthquake resistant strengthening.

Regarding the intensity of earthquake to be targeted;

1) The intensity of earthquake caused by the 1999 Izmit Earthquake; it may be easily understood by many citizens in Istanbul. That intensity was not so large in Istanbul, however, some building damages were observed in Istanbul.

2) The intensity of earthquake that is proved in the earthquake resistant design code; probability of exceedance of that earthquake within a period of 50 years may be about 10%.

3) The intensity of earthquake caused by scenario earthquake; this is the largest earthquake that can be expected for Istanbul area.

How much damage can we control against above mentioned intensity of earthquake are as follows;

a) Keep the structure as fully operational,

b) Keep the structure as operational but some repair is needed, and

c) Prevent only complete collapse (i.e. Pancake crush) ; huge numbers of human life can be saved

Therefore, it is very important that which type of measure can be corresponded to which intensity of earthquake. Needless to say that it is not realistic to correspond ③ and a). The main countermeasures for the scenario earthquake are not to prevent structural damage of each building, but to improve the earthquake mitigation system.

Some reasonable correspondence is selected in Table 9.1.3. The most important countermeasure is to correspond ③ and c).

Table 9.1.3 Counter Measure Correspond to Earthquake Intensity

	Earthquake Performance Level		
	a) Fully Operational	b) Operational but Repair is needed	c) Prevent Complete Collapse
① Frequent Earthquake	✓		
② Eartquake that is provided in Present Earthquake Resistant Code		✓	
③ Scenario Earthquake			✓

Some earthquake resistant strengthening was already carried out in Istanbul. The construction methods are;

- Column jacketting with RC
- Beam jacketting with RC
- Adding RC wall
- Changing porous bricks to RC wall

Chambered Office of Civil Engineers regularly hold seminar on the earthquake resistant strengthening design. Certification system for the earthquake resistant strengthening designer named Proje Muhendıisliği (Project Engineering License) exists in Turkey.

There is a following fundamental difference between Turkish understanding of column jacketting and the one in Japan.

Typical distruction mode of Turkish buildings is pulling out of re-bar in the column-beam connection because fixing of re-bar is not sufficient. So the textbook of seminar emphasize that the re-bar must be connected appropriately through the story. Steel plate jacketting of column was not observed in Istanbul area, but this method is introduced in textbook. Connecting by bolt through the story is recommended even the steel plate jacketting.

On the other hand, connecting jacket through the story is rather prevented in Japan. The slit is usually made as shown in Figure 9.1.4 in order to make jacket not to load the axial force. The main purpose of jacketting in Japan is to resist against the shear failure and the concrete buckling of column, because typical distruction mode of Japanese buildings is the shear failure at middle part of the column.

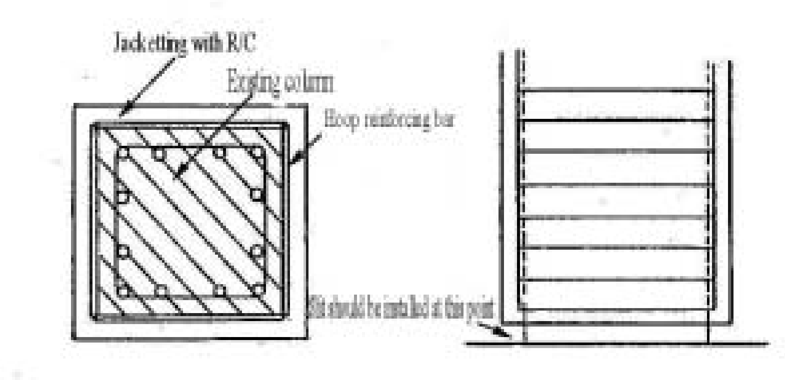


Figure 9.1.4 Schematic Drawing of Slit that is Made at the Column End

The concept of earthquake resistant strengthening in Japan is shown in Figure 9.1.5.

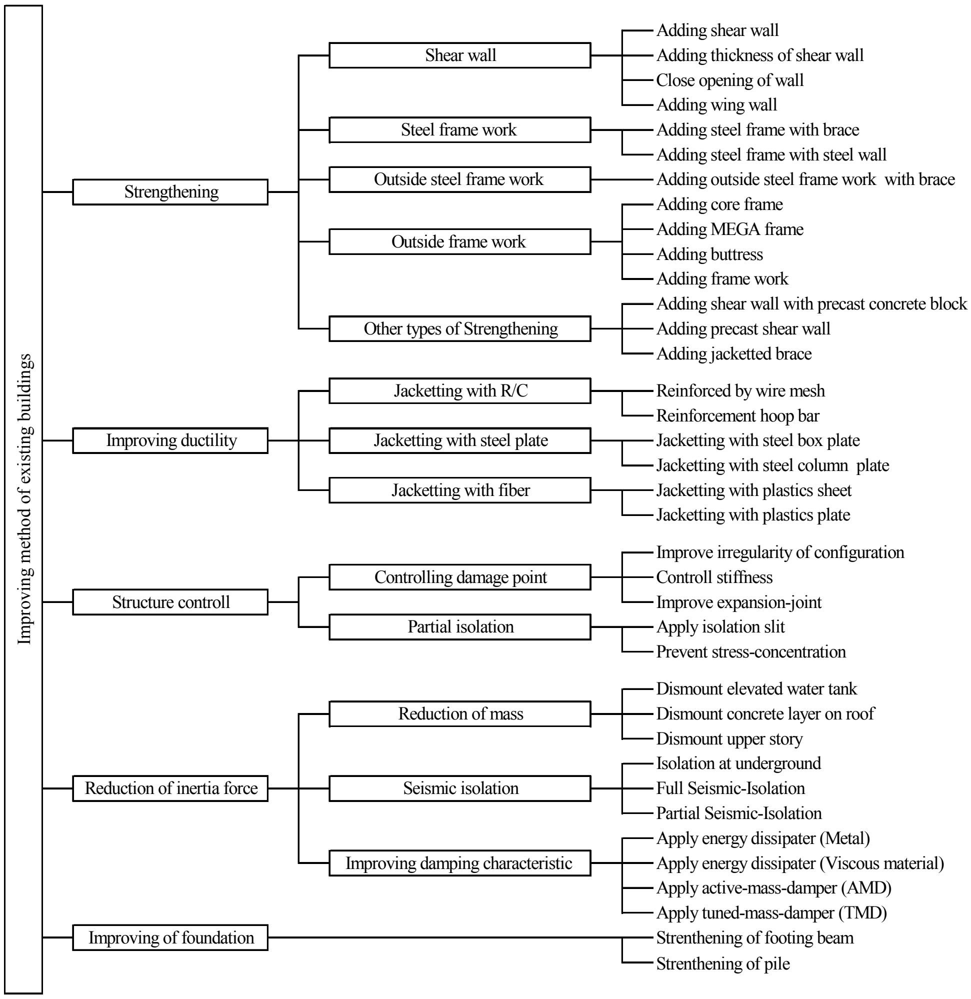


Figure 9.1.5 Concept of Earthquake Resistant Strengthening in Japan

In any case, the main principle of the earthquake resistant strengthening is to redress an imbalance of capacity and to make every members of the building to be able to exert it's own capacity. It must avoid to jackett all menbers. If this kind of measure is needed, the demolishing and reconstruction are more cost effective.

The strengthening method that is considered effective are as follows;

(1) Jacketting column and beam, Adding RC wall

This type of methods is already known and applied by Turkish engineers.

(2) Adding steel frame work

Steel framework is effective to control the story drift. This method also can correct the uneven distribution of stiffeness.

The vertical members of the steel framework also can be expected to carry a part of vertical load when the building suffers excessive story-drift.

However, there are some different characteristics between the Turkish buildings and Japanese ones, therefore, some effort of experimental design and loading tests using speciemen is necessary.

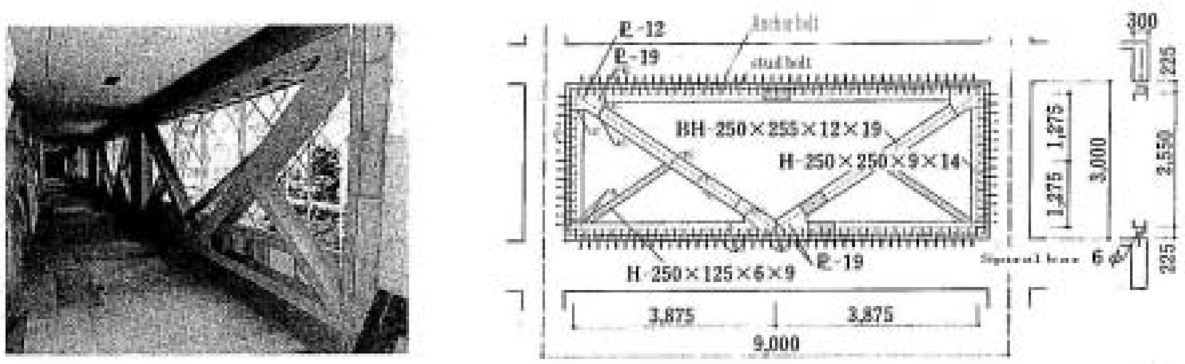


Figure 9.1.6 An Example of Steel Framework

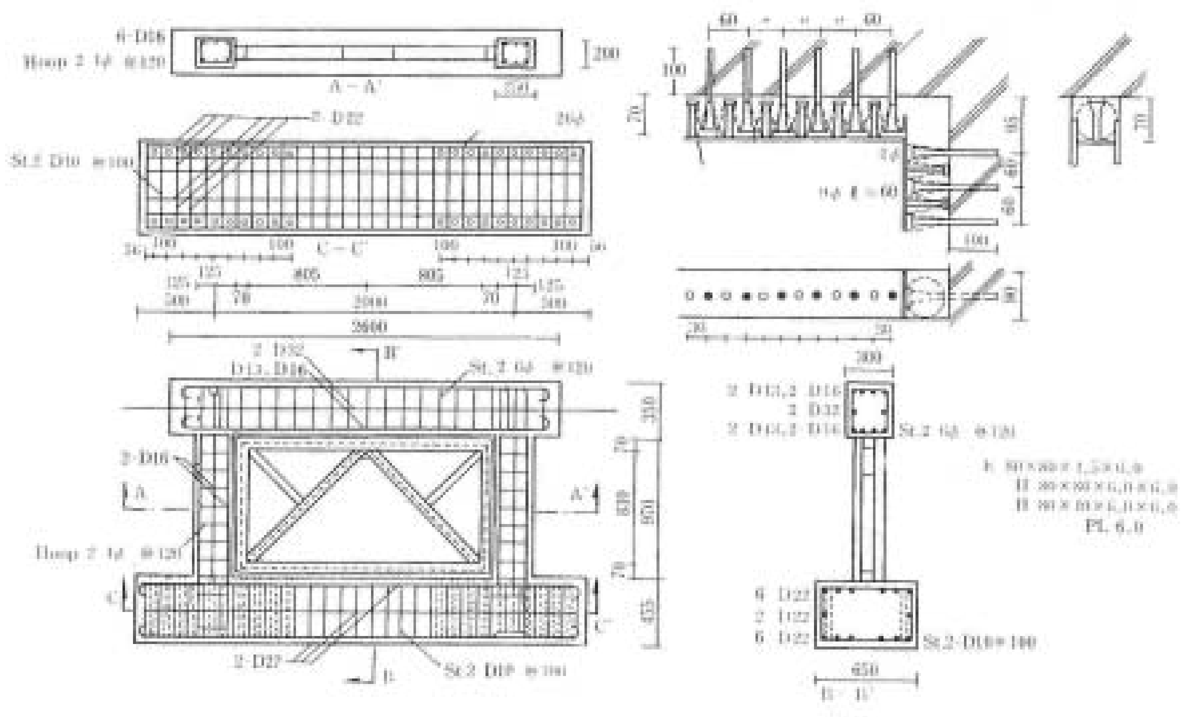
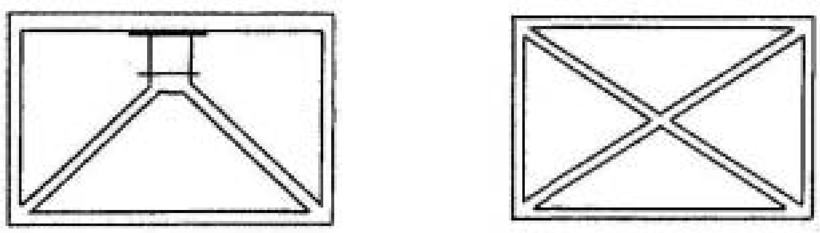


Figure 9.1.7 Test Specimen for Experiment

(3) Applying dynamic structure control

When the Y-configurated steel framework is applied, energy absorption device can be set at the linking point of Y shape. Usually, energy absorption device is composed of high ductility steel plate. This concept is called “dynamic structure control”.



a) Y-shape brace b) X-shape brace

Figure 9.1.8 Y and X Configurated Steel Frame Work

When the X-configurated steel framework is applied, the high ductility steel brace can be set. In this case, the high ductility steel brace is covered by steel jacket, in order to prevent buckling of the brace. The relation between the brace and jackett is made as allow slip, in order not to carry by jacket the axial force and only resist against bending. This type of method is developed by Japanese company and called “combined material brace” or “un-bonded brace”.

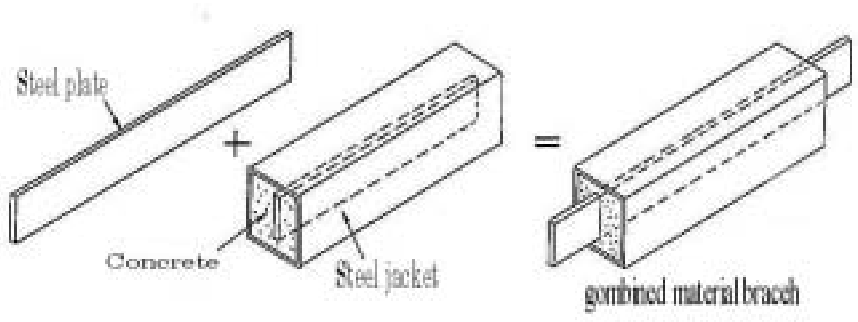


Figure 9.1.9 Schematic Drawing of "Combined Material Brace" or "Un-bonded Brace"

(4) Applying concept of seismic isolation

When the principle of the enlonging natural period is added to the concept of dynamic structure control, it becomes the concept of seismic isolation. The buildings that are designed by this concept are increasing drastically in Japan. This concept is very effective for reducing the inertia force caused by earthquake, but careful examination is needed, if considered about the capacity of Turkish existing buildings.

(5) Objective buildings

If some materials are added to existing buildings, mass of the structure increase necessarily and inertia force caused by earthquake increase. Some kind of *trade offer* relation that is to say more effective increase of capacity than the increase of inertia force must be obtained. If the original structure is excessively poor, that *trade offer* may not be concluded. When highly developed technic is applied, construction cost may also increase. Cost-performance consideration must be taken into account.

When the objective buildings is selected, pilot study has to be carried out at first, taking into account the following stronghold facility for Earthquake Disaster Mitigation. It is realistic to extend by priority.

- School buildings
- Hospital
- Public hall
- Governmental facility
- Fire fighting facility
- Police facility
- General financial institution
- Hazardarous facility

9.2. Major Public Facilities

Many major public facilities have critical roles in the event of an earthquake: For example, office of disaster management, evacuation shelters and medical facilities such as hospitals. Damages on the public facilities by an earthquake would impact on physical, social and economical aspects of human lives. Therefore it is important to have earthquake resistant public facilities. In this section damage estimations on the following public facilities are conducted.

1) Educational Facilities: Primary and High Schools

- Educational facilities can be landmarks of local communities.
- Open spaces in the schools might be used as refuge after evacuation.
- School buildings might serve as temporary houses and shelters if they are not damaged seriously.
- Schools are important for future generation.

2) Medical Facilities: Hospitals and Policlinics

- Medical Facilities are very important places to get medical attention.
- Inpatients need continuous medical care even during and after earthquake and extremely vulnerable; they might get cut on-going medical treatments or/and injured by the earthquake incidence.

3) Fire Fighting Facilities: Fire Fighting Station

- Fire fighting facilities are equipped with all the necessary functions and gears to respond to fire hazardous and to rescue people.
- Fire fighters who are well trained and stationed at the facility can act swiftly for emergency needs.
- Fire fighting station would be a center of the rescue mission.

4) Security Facilities: District Police (İlçe emniyet), Police and Gendarme (Jandarma)

- Security facilities are essential agencies regarding rescues, maintenances of public order and traffic controls, and other domestic security measures.

5) Governmental Facilities: Ministry, Provincial and Municipality

- Governmental facilities are the pivotal points for carrying out counter measures with earthquake damages, disaster mitigation and management, and recovery in/after the event of earthquake.
- Disfunctioning governmental facilities due to the earthquake would impact negatively local lives and activities.

Such major public facilities discussed above should be built strong so that they withstand strong earthquake impact. In general the structures of the public facilities are different form regular buildings. Photo 9.2.1 and Photo 9.2.2 below represent typical school and fire fighting station structures.

Photo 9.2.1 Primary School: Large Floor Area (A) to Height (H) Ratio

Photo 9.2.2 Fire Fighting Station: Garage and Office within the Same Building

Hence, the fragility function for the damage estimation must be set specifically for the public facilities. However, currently sufficient data were not available to determine the fragility function for the public facilities. Therefore damage estimation on the public facilities is conducted using the measure of damage estimation on all buildings as discussed in section 8.1.

Consequently for further analysis it is necessary to keep it in one's mind that the damage estimation on the major public facilities was determined with all buildings-function. Drawbacks of such approximation are stated below.

1) Fragility function on all buildings includes not only buildings whose structures are close to the public facilities but also other buildings. Thus the resultant damage estimation does not entirely represent the public facilities, which have unique structures.

2) The public facilities are made stronger than regular buildings in general. Therefore the predicted damages might have been over estimated.

Also some public buildings, in which seismic retrofitting has been under construction, were not considered in this damage estimation.

Under the above circumstances, the damage estimation on the major public facilities in the entire Study Area represents the whole and each individual district was not estimated. Significances of the damages on the major public buildings were identified by comparing with the damages on all the buildings stated in Section 8.1.

9.2.1. Facilities Data

The parameters of the data used for the scenario earthquake study are shown in Table 9.2.1.

Table 9.2.1 Data and Parameters

Data		Unit	Structure	Story	Construct-ion Year	Numbers of Data	Data used for Damage Estimation
Type	Source						
Educational	Census 2000	Building	O	O	O	2,253	O
	Provincial Disaster Management (May, 2002)	Facility	X	X	X	1,933	X
Medical	Census 2000	Building	O	O	O	635	O
	Provincial Disaster Management (May, 2002)	Facility	X	X	X	468	X
Fire Fighting	The Fire Department of IMM (May, 2002)	Facility	O	O	X	40	O
Security	Provincial Disaster Management (February, 2002)	Building	O	O	X	166	O
Governmental	Provincial Disaster Management (February, 2002)	Building	O	O	X	491	O

Note: The date in ( ) is when the data was given to the Study Team.

(1) Educational Facilities

The data obtained from the province in May 2002 was summarized in a tabulate form for each district according to education level i.e. kindergarten, primary school, and high school. However, the table can only provide the data of the number of schools but not the information of structure, numbers of stories, and construction year for each school. Hence the data of buildings that could be applied for schools were selected from the census and used for the damage estimation.

According to the given data sets, total numbers of the buildings in the schools and of the schools as institution are 2,252 buildings and 1,933 schools (1,385 primary schools and 548 high schools) respectively. The average is 1.2 buildings per school. Our visual site investigation also confirmed that many schools consisted of 1 or 2 buildings. Therefore the building data from the census most likely represent the numbers of buildings at schools.

(2) Medical Facilities

The data obtained from the province in May 2002 were tabulated and summarized form for each district for hospital, policlinic, health center, and dispensary. However, the table can only provide the data for numbers of facilities but not the information for structure, numbers of story, and construction year of each facility. Hence the data of buildings, which could be mostly applied for medical facilities, were selected from the census and used for the damage estimation.

According to the data sets, the total numbers of the buildings in the medical facilities and of the medical facilities themselves are 635 buildings and 468 facilities (hospitals and policlinics) respectively. The average is 1.4 buildings per facility. Our visual site investigation also confirmed that many schools consisted of 1 or 3 buildings. Therefore, the data from the census regarding the buildings most likely represent that of the hospitals and policlinics.

The data must be up dated and added so that more accurate damage prediction could be done. The current problems are:

- Numbers of beds in the table did not include SSK' s.
- Statistics do not match: The number of hospitals according to the data obtained from the province in May 2002 is 201 while the number reported by the Ministry of Health is 185.

(3) Fire Fighting Facilities

The data obtained from IMM Fire Department in May 2002 include information with regard to numbers of facilities, structure, and numbers of stories. Therefore, the data were used for the damage estimation.

(4) Security Facilities

The data obtained from the province in May 2002 include information with regard to numbers of buildings, structure, and numbers of stories. Therefore, the data were used for the damage estimation.

(5) Governmental Facilities

The data obtained from the province in May 2002 included information with regard to numbers of buildings, structure, and numbers of stories. Therefore, the data were used for the damage estimation.

9.2.2. Characteristics of the Facilities

The data of the public facilities, such as structure of building, numbers of stories, construction year, and earthquake intensity are summarized in Figure 9.2.1. The results of the damage estimation are also stated in the figure and will be discussed in Section 9.2.3.

(1) Structure

Table 9.2.2 summarized the percentages of the RC framed buildings and of the masonry buildings.

Table 9.2.2 Building Structure: RC Frame and Masonry (%)

Facility	RC Frame	Masonry
Educational Primary and High School	84.4% (+10.0%)	12.4% (-10.4%)
Medical Hospital and Policlinic	80.5% (+ 6.1%)	16.5% (- 6.3%)
Fire Fighting	95.0% (+20.6%)	5.0% (-17.8%)
Security Police and Gendarme	83.7% (+ 9.3%)	15.1% (- 7.7%)
Governmental Ministry, Province and Municipality	72.1% (- 2.3%)	19.6% (- 3.2%)
All Buildings	74.4%	22.8%

Note: ( ): Facilities(%) - All Buildings(%)

The table shows that more than 70% of the public facilities are made with RC-frame followed by Masonry type building: The ratio of RC framed buildings is higher in the public facilities (except the governmental facilities) than in all the buildings. Hence, it indicates that the public facilities are made more earthquake-resistant than regular buildings.

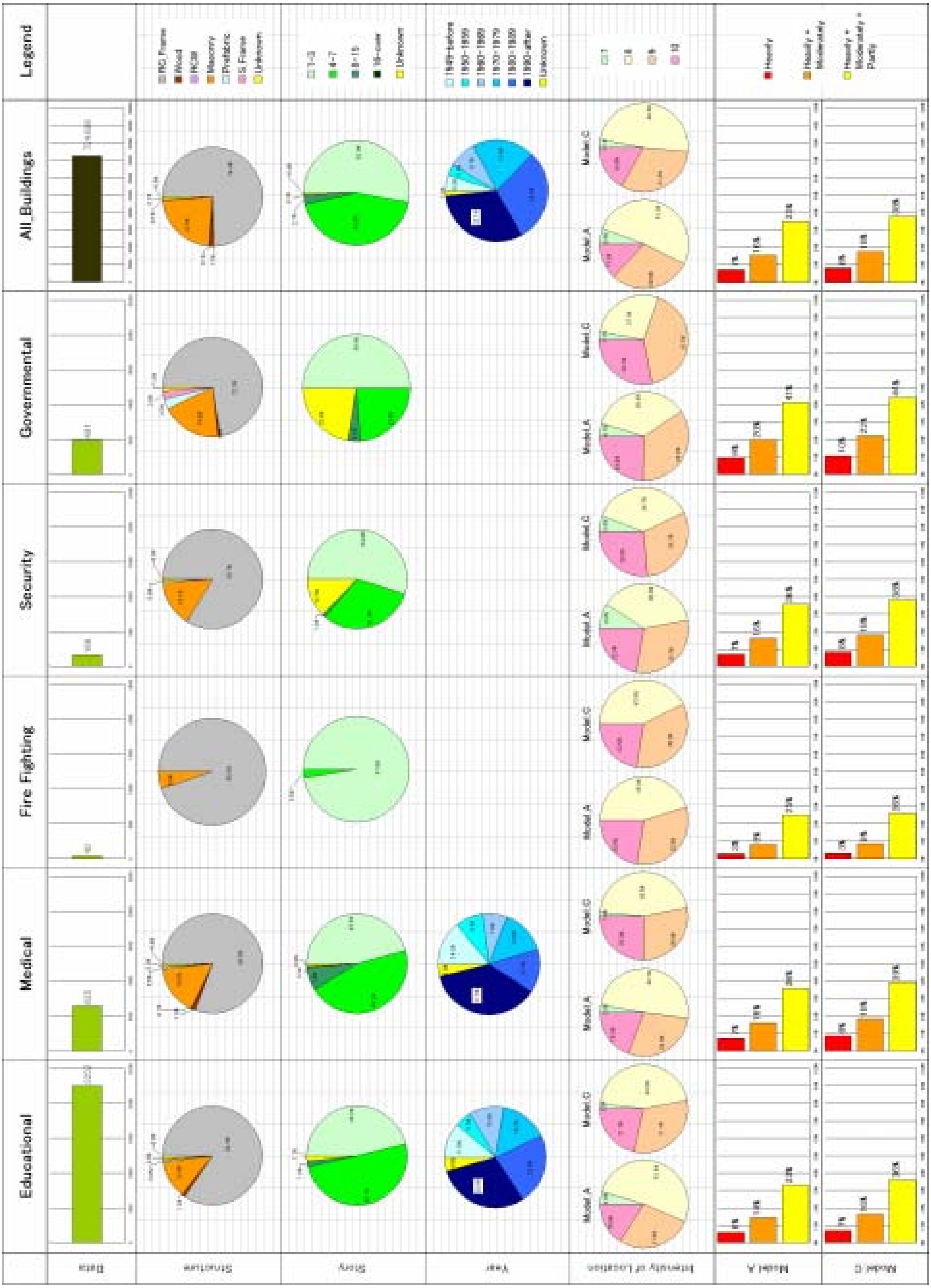


Figure 9.2.1 Characteristics of the Facilities and Results of the Damage Estimation

(2) Story

Table 9.2.3 shows the ratios of 1 to 3 story-buildings and of 4 to 7 story-buildings for the public facilities and all the buildings.

Table 9.2.3 Numbers of floors and facility type

Facility	1 – 3 Story building	4 – 7 Story building
Educational Primary and High School	46.2% (- 6.7%)	50.1% (+ 6.2%)
Medical Hospital and Policlinic	45.8% (- 7.1%)	45.2% (+ 1.3%)
Fire Fighting	97.5% (+44.6%)	2.5% (-41.4%)
Security Police and Gendarme	54.8% (+ 1.9%)	31.3% (-12.6%)
Governmental Ministry, Province and Municipality	49.9% (- 3.0%)	23.6% (-20.3%)
All Buildings	52.9%	43.9%

Note: ( ): Facilities(%) - All Buildings(%)

More than 70% of the public facilities are lower than 7 stories building. Among those the ratios of 1-3 story educational facilities and of 1-3 story medical facilities to the total number of buildings are slightly lower than that of all the 1-3 story buildings. The ratios of the same facilities built with 4-7 stories are slightly higher than that of the all buildings. Most of the fire fighting station / department facilities are 1-3 story building. Numbers of stories were not reported for more than 10% of the security and the governmental buildings. However, our visual investigation confirmed that most of these buildings are lower than 7 stories. Therefore, it can be said that the ratios of the security building to and the governmental building to total number of buildings are similar to the case of all the buildings.

(3) Construction Year

Table 9.2.4 Educational and Medical facilities: before, in, and after 1980

Facility	1979 and Before	1980 and After
Educational Primary and High School	43.2% (+ 6.0%)	52.4% (- 9.1%)
Medical Hospital and Policlinic	45.4% (+ 8.2%)	50.7% (-10.8%)
All Buildings	37.2%	61.5%

Note: ( ): Each facilities(%) - All Buildings(%)

More educational and medical facilities have been built by 1979 than all other buildings (also refer to Figure 9.2.1). This indicates that the educational and medical facilities are relatively older than all the buildings.

(4) Seismic Intensity at the Location of the Facilities

In Section 8.1.4, seismic intensity is estimated in each Mahalle based on the estimated damage of the buildings. The seismic intensity by the scenario earthquake at the location of each public facility is found and summarized in Table 9.2.5.

Table 9.2.5 Ratios of facilities whose intensity is greater than or equal to 9

Facility	Model A	Model C
	Intensity >= 9	Intensity >= 9
Educational Primary and High School	43.6% (+ 0.8%)	53.1% (+ 4.6%)
Medical Hospital and Policlinic	48.0% (+ 5.2%)	53.0% (+ 4.5%)
Fire Fighting	55.0% (+12.2%)	57.5% (+ 9.0%)
Security Police and Gendarme	53.0% (+10.2%)	57.2% (+ 8.7%)
Governmental Ministry, Province and Municipality	59.4% (+16.6%)	69.6% (+21.1%)
All Buildings	42.8%	48.5%

Note: ( ): each Facilities(%) - All Buildings(%)

More than 50% of all the facilities in the table resulted in the intensity greater than 9 by the Model C. Almost 70% of the governmental facility is distributed within the range. Also, the percentage on the public facilities whose intensities were greater than 9 is relatively higher than the case of all the buildings. The above results indicate that the public facilities could be located close to the earthquake center or/and on soft ground such as Quaternary Deposit.

9.2.3. Results of the Damage Estimation

(1) Educational Facilities

The degree of actual damages could be lower than the estimated one because:

Some schools were built with earthquake resistant technologies according to the new construction standard of 1998.

The fragility function was determined based on all the buildings and did not consider floor area-height ratio.

We tried to find an effect of school structure. In this particular case, the earthquake resistant structured schools were 287 which is merely less than 10% of the total numbers of schools: "Heavily + Moderately + Partly" damaged, "Heavily + Moderately" damaged, "Heavily" damaged schools were 32%, 14%, and 6% respectively. The damage ratios of the educational facilities are not so different in comparison with that of all the buildings. Therefore, prior to considering schools for emergency shelters reliability / strength / earthquake resistibility of the buildings must be thoroughly examined and evaluated. Moreover, new earthquake resistant structured schools shall be built taking into account of a practical emergency response management plan, proximity of shelters, and foundation/ground type.

(2) Medical Facilities

The damage estimation resulted in that the medical facilities would get damaged as much as all the buildings would. The results indicate that the medical facilities are not strong anymore than any other ordinary buildings. Hence, in order to keep the medical facilities functioning in the event of earthquake, they should be strengthened /retrofitted according to a plan taking into account precise numbers and locations of earthquake resistant medical facilities already exist.

(3) Fire Fighting Facilities

The damage rate of the fire fighting facilities is 4% to 12% lower than that of all the buildings. It could be because the buildings are RC structured and lower than or equal to 3 stories. However, a fire fighter station inherits weak structure against earthquake: the first floor of the building as garage has only 3 walls and the rest is open to the street and the walls are made of bricks. The stations need to be evaluated for earthquake resistibility and strengthen.

(4) Security Facilities

The damage estimation resulted in that the security facilities would get damaged as much as all the buildings would. It sounds reasonable because the structures of the facilities are similar to residential buildings. Since the security facilities have to function as the center of the emergency response measures, they must be evaluated for earthquake resistibility and strengthen the structure.

(5) Governmental Facilities

The damage estimation resulted in that the governmental facilities would get damaged more than the case of all the buildings. It sounds reasonable because the structures of the facilities are similar to residential buildings and such facilities tend to be located on the sites where seismic intensity is relatively high. Although some of the facilities are already earthquake resistant, since the governmental facilities would be the center of the emergency response measures, they must be evaluated for earthquake resistibility and strengthen the structure.

9.3. Fire

Istanbul has suffered from great fires repeatedly since its ancient days. The fire of 1782 reduced almost half of the city to ashes. The last great fires of Istanbul were the Hocapasa fire of 1865, the Beyoğlu fire of 1870, and the Laleli fire of 1912. After these fires, a fire-fighting organization was established and further construction of wooden buildings in the city was prevented. This enforcement seems successful, and no great fire has affected the Study Area after 1912. The wooden buildings in the Study Area are very few now, only 1.6% in total, and they exist in a limited area.

Figure 9.3.1 shows the number of fire outbreaks from 1996 to 2000 by 20 fire-fighting districts. Because data in some districts are missing, the total number of fire outbreaks in 12 districts is shown with a black line for comparison. The total number of fire outbreaks in one year is around 9000 in these 12 districts and is showing gradual decrease. This may be the result of switching from coal to natural gas for cooking and heating during the winter and progress made in transferring factories to suburban areas.

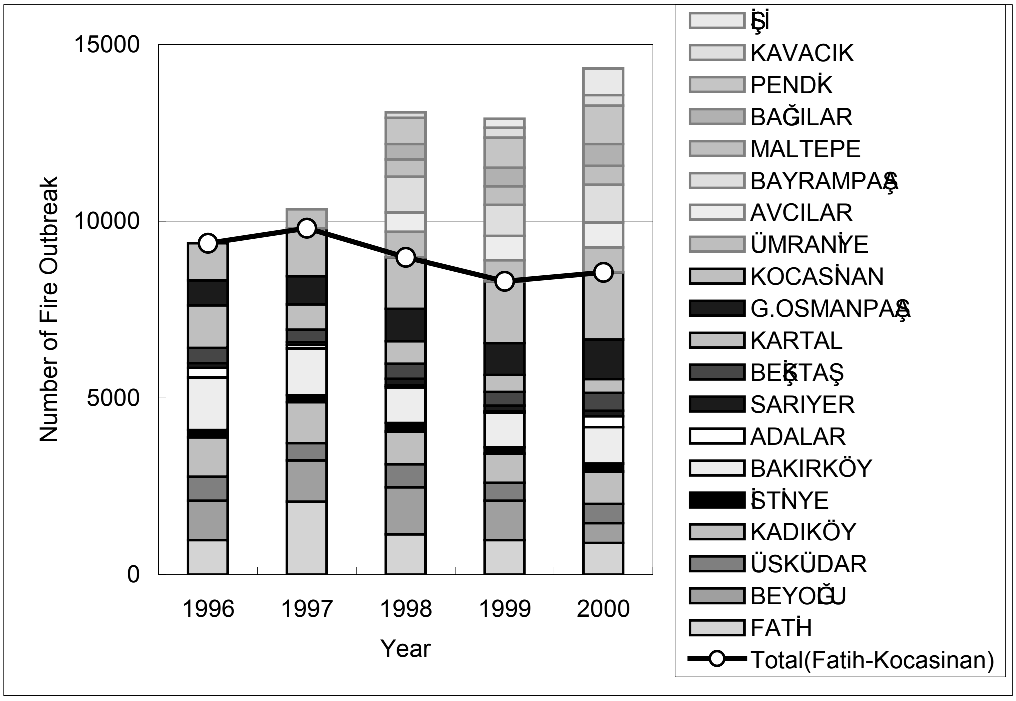


Figure 9.3.1 Number of Fire Outbreaks from 1996 to 2000

Source: Fire Brigade Department

Figure 9.3.2 shows the origin of fires in Istanbul. The most cases were due to the careless handling of the cigarettes, about 40% of all cases, and the second highest number of incidents were due to electric leakage or short circuits. It is notable that fires due to chimneys or sparks are diminishing. This may be also be the resulted of the switch from coal to natural gas for heating during the winter.

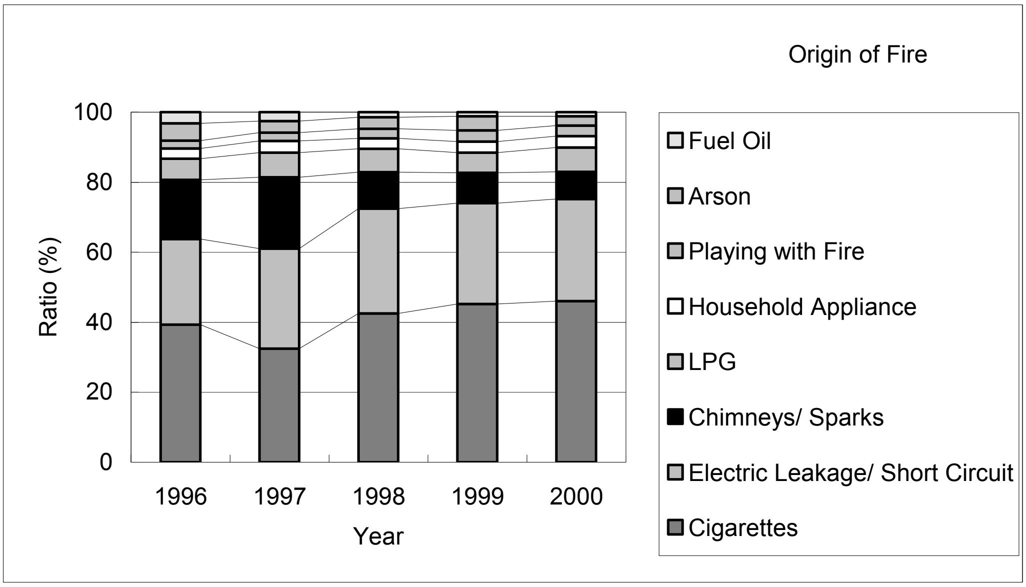


Figure 9.3.2 Origin of Fire from 1996 to 2000

Source: Fire Brigade Department

9.3.1. Fire Outbreak after Earthquake

After an earthquake, fire outbreaks from many facilities and buildings may occur. If the earthquake occurs during mealtimes, cooking stoves may become the main sources of fire outbreaks. Electric leakage or short circuits will also be significant sources of outbreaks. Over 100 fire outbreaks were reported in the Avcılar area due to the 1999 Izmit Earthquake, and it is estimated that most of them occurred due to electric leakage. It is also reported that no fires spread to other buildings.

The fire potential of building dwellings is strongly affected by the local situation, namely, the fuel used for the cooking stove, the structure of the kitchen, the heating system, etc. Therefore, it is necessary to statistically analyse fire outbreaks during past earthquakes and develop a vulnerability function for the local area, but this type of data is not available in Istanbul.

Therefore, the potential of fire outbreaks from facilities where flammable liquids or gas materials are handled is estimated in this study. These facilities are classified as follows:

1) Big LPG Storage

2) Factory of Paint/ Polish Products

3) Warehouse of Chemical Products

4) LPG Filling Station

5) Fuel Filling Station

The concepts of the estimation are as follows:

1) The offices of the facilities suffer damages caused by earthquake motion and the damage is estimated by the same procedure to the buildings as shown in the paragraph 8.1.

2) The damage grade of facilities is supposed to be same to that of the offices of facilities.

3) Inflammable liquids or gases will leak from the pipes and storage tanks of facilities that are heavily damaged.

4) The leaking liquids or gases will ignite to fire according to the following probability:

−	Big LPG Storage, LPG Filling Station	57.9%
−	Factory of Paint/ Polish Products, Warehouse of Chemical Products	3.66%
−	Fuel Filling Station	2.55%

(after Kanagawa Prefecture 1986)

5) The above values are estimated based on Japanese experience. No information on fire occurrences in Turkey is available. Consequently, the results show only a relative possibility of fire occurrence.

6) The number of fire outbreaks is summed for each mahalle and then expressed as a rating of fire from hazardous facilities.

Distribution of the vulnerability rating for mahalle is shown in Figure 9.3.3 and Figure 9.3.4.

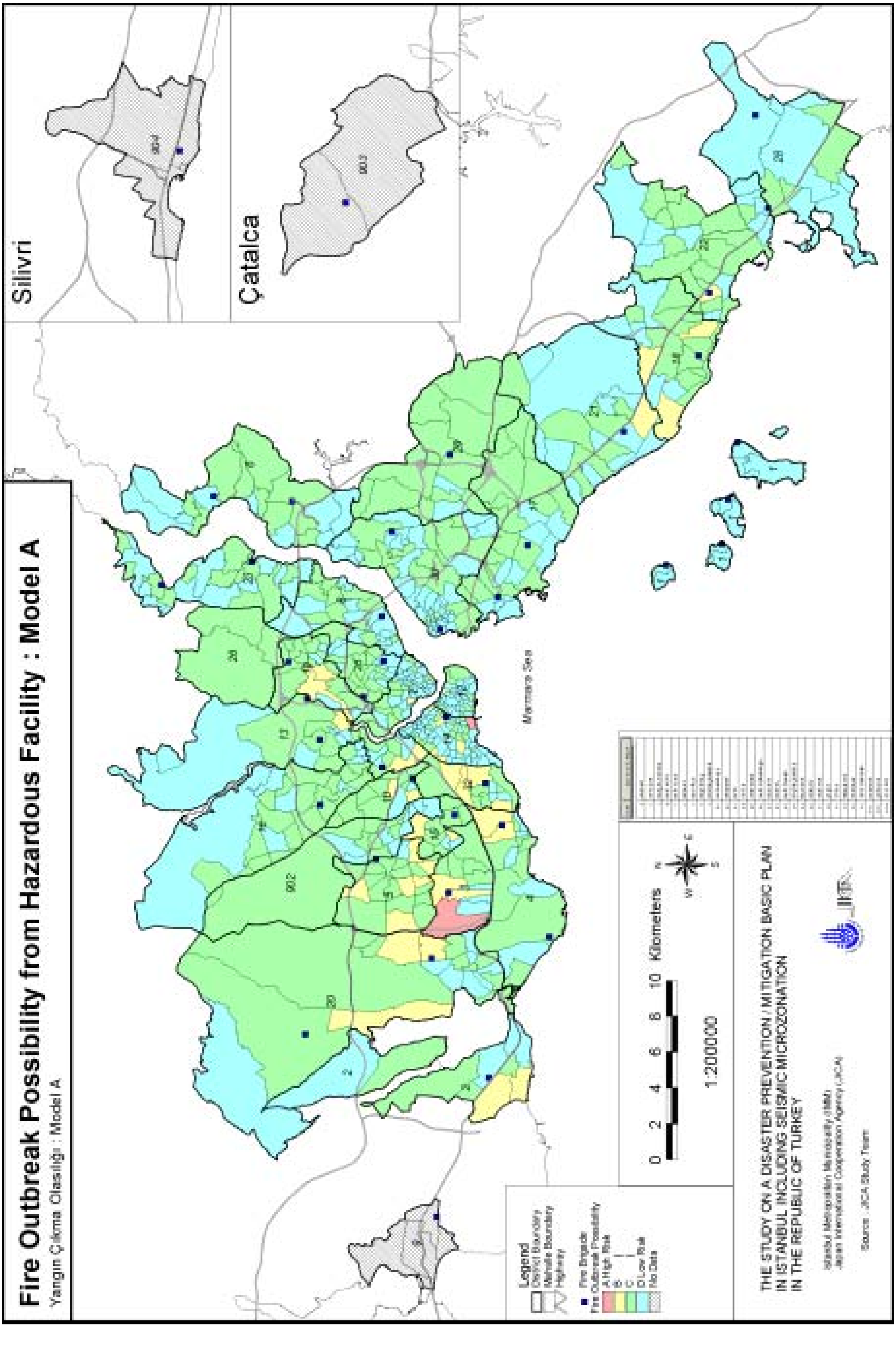


Figure 9.3.3 Fire Outbreak Possibility from Hazardous Facilities : Model A

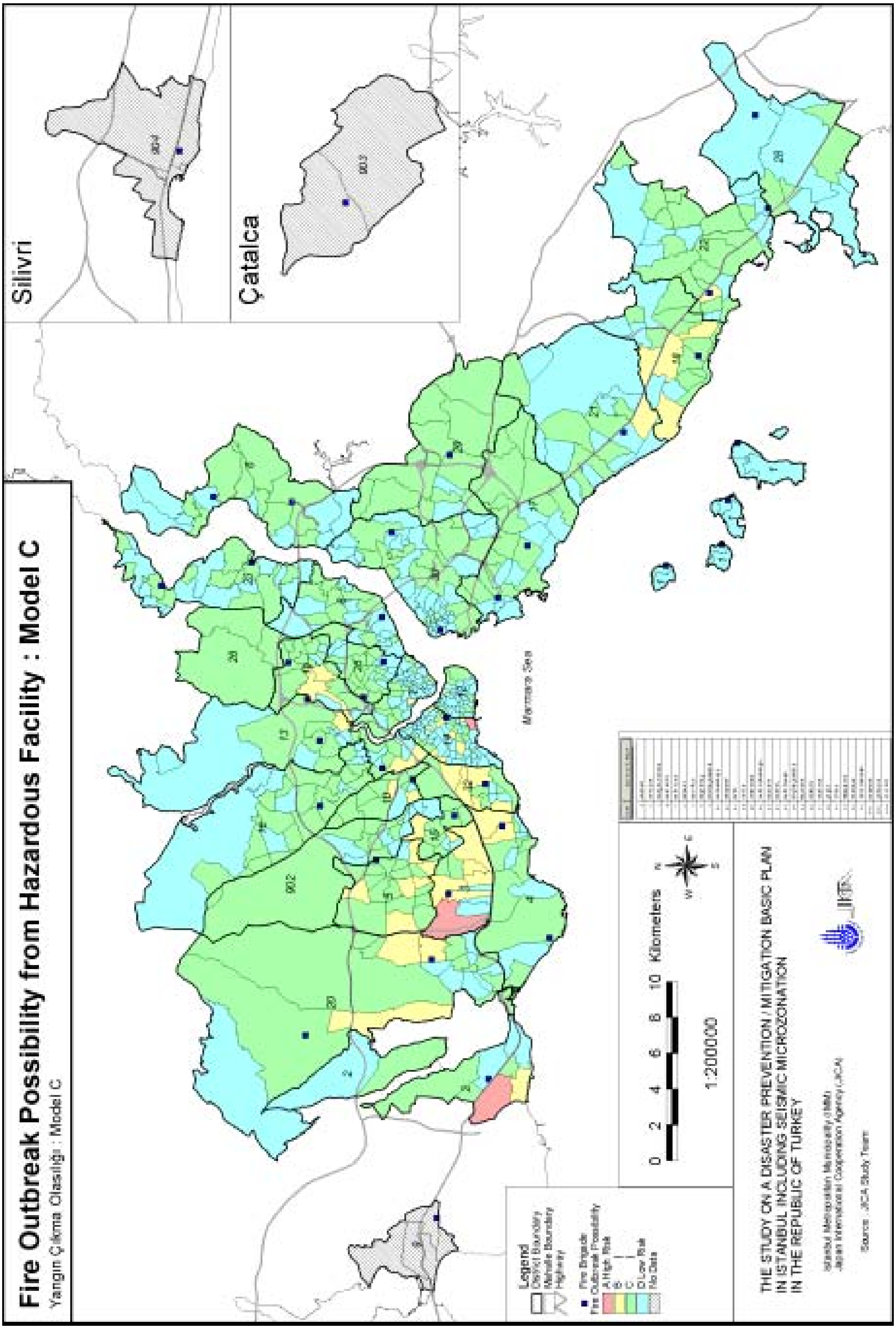


Figure 9.3.4 Fire Outbreak Possibiltiy from Hazardous Facilities : Model C

9.3.2. Fire Spread Possibility

If there are many wooden buildings in the area and if the space between buildings is limited, fire can more easily spread from one building to another. There are many wooden buildings in the city of Japan; therefore, the spread of fire in the city is well studied by Japanese researchers.

Figure 9.3.5 shows the result of the numerical simulation on the relation between "burnt area ratio" and the "wooden building coverage area ratio" by the Japanese Ministry of Construction (1982). The definition is as follows:

$$\text{Burnt Area Ratio} = \frac{\text{Burnt Floor Area}}{\text{Total Area}}$$

$$\text{Wooden Building Coverage Area Ratio} = \frac{\text{Wooden Building Coverage Area}}{\text{Total Area}}$$

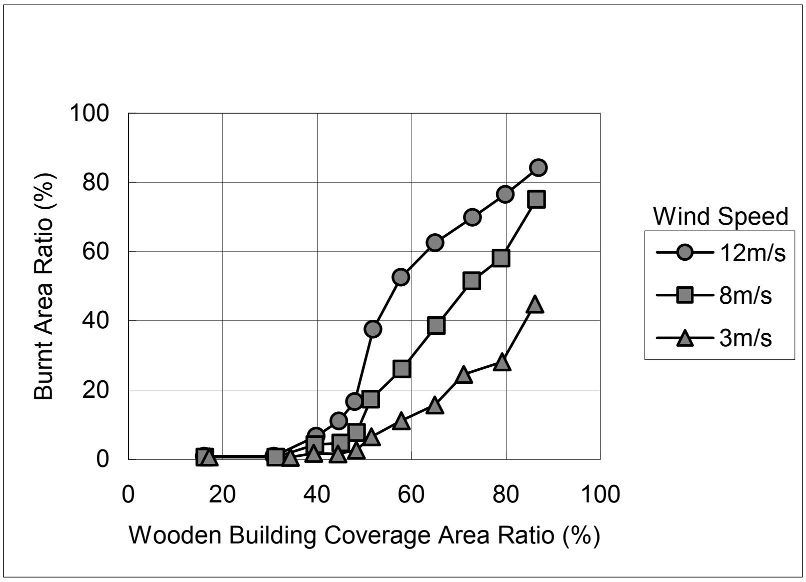


Figure 9.3.5 The Relation between Burnt Area Ratio and Wooden Building Coverage Area Ratio

From this figure, it is concluded that fire will never spread if the wooden building coverage area ratio is under 30%. The wooden building coverage area ratio of each mahalle is shown in Figure 9.3.6 and all the mahalle show a ratio of less than 10%. This means no fire spreading is estimated in the study area.

In conclusion, there exists a small possibility of a great fire occuring because most buildings are constructed with concrete and bricks. However, it should be kept in mind that many fires occur immediately after an earthquake and, due to blockage of the roads by debris, much time can pass until a fire-fighting team reaches and can attend to the fire.

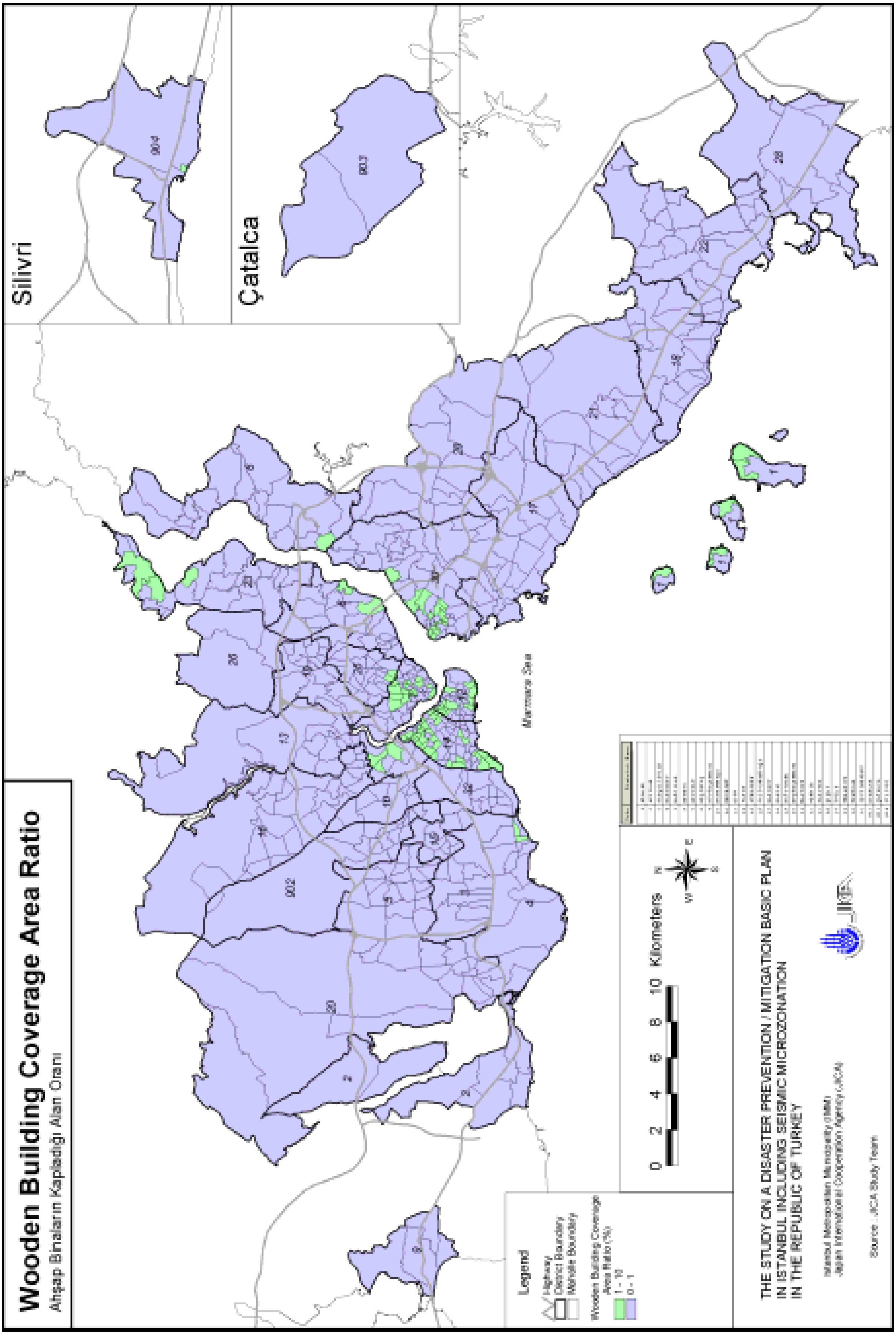


Figure 9.3.6 Wood Building Coverage Area Ratio

References to Section 9.3

Kanagawa Prefecture, 1986, Investigation Study Report on Earthquake Damage Estimation, Fire Outbreak and Hazardous Materials. (in Japanese)

Ministry of Construction, 1982, Report on the Development of Fire Prevention Measures in the City. (in Japanese)

9.4. Lifelines

In a broad sense of the word "lifeline" includes not only the water or electricity supply facilities but also road and transportation systems. In this report, the damage of bridges is described in section 9.5 and transportation facilities are described in section 9.6.

Citizens living in the city who enjoy their modernized and comfortable urban life strongly rely on lifeline facilities. Even if their homes are not severely damaged during an earthquake, it is impossible to live in the house if water and electricity service is cut off. Therefore, the information on seismic damage to lifelines is very important for the preparation of a seismic disaster management plan.

The following 5 types of lifelines are considered in this section:

1) Water Supply Pipeline

2) Sewage Pipeline

3) Gas Pipeline and Service Box

4) Electric Power Supply Cable

5) Telecommunication Cable

Lifeline facilities are to be classified into two major categories, nodes and links. Nodes include facilities such as substations and purification plants. Links include facilities such as pipes or cables for supply and distribution purposes. A statistical approach for damage estimation of links, i.e., distribution pipes and lines, is applied in this study

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

The 3 districts of Silivri, Çatalca, and Büyükçekmece are not included in the lifeline damage estimation because enough information was not available or not contributed.

9.4.1. Water Supply Pipeline

(1) Damage Estimation Method

Several researchers have proposed a correlation between pipeline damage and seismic parameters such as peak ground acceleration (PGA) or peak ground velocity (PGV). Kubo and Katayama (1975) reported one of the first studies that correlated water supply pipeline damage ratio with PGA from experiences in Japan, USA, and Nicaragua. The damage of water pipes in Kobe city in the 1995 Kobe Earthquake is one of the most well known examples, and the damage distribution and seismic motion in Kobe and the surrounding area are well studied. Isoyama *et al*. (1998) studied the correlation between the damage of pipes and several parameters, such as seismic motion, ground condition, pipe material, etc. They used PGA and PGV as seismic parameters and PGV showed a slightly better correlation based on their analysis. The Japan Waterworks Association (1998) published a report entitled, "Seismic Damage Estimation Procedure for Water Pipes" based on their study.

Toprak (1998) studied the 1994 Northridge Earthquake very precisely. He used PGA, PGV, and several other seismic parameters to evaluate their correlation with the damage ratio. He concluded that PGV showed the best correlation and PGA showed the next best.

Based on these studies, PGV was selected as the seismic parameter used to evaluate the damage of pipes in this study.

Figure 9.4.1 shows the damage function developed by the Japan Waterworks Association (1998) and Toprak (1998) for buried cast iron (CI) water pipes. This figure also shows the damage function that is used in HAZUS99 (FEMA, 1999).

The quantitative studies on seismic damage for pipelines in Turkey are very few. Sarıkaya and Koyuncu (1999) reported the damage of water pipelines in the town of Sapanca due to the Izmit Earthquake. According to Sarıkaya and Koyuncu (1999), there were about 90km of water pipelines in Sapanca Town before the earthquake and 400 damage points were reported -- namely, 4.4 damages/km. They also pointed out that the material of almost all of the pipes is asbestos cement. It is well known that asbestos cement piping is fragile compared to CI or PVC piping. It is estimated that the damage ratio of asbestos cement pipes is 1 to 4 times larger than CI pipes in Japan. The earthquake motion in Sapanca Town is not observed unfortunately. Kudo (2001) estimated the seismic motion during the Izmit Earthquake in the city centre of Adapazari to have measured 108 to 127 kine (cm/sec). The seismic motion in Sapanca Town is estimated not to have been very different. The damage ratio in Sapanca Town due to the Izmit Earthquake, which is estimated from above mentioned analysis, is shown in Figure 9.4.1. The damage ratio in Sapanca Town is shown to fall between the damage functions by HAZUS99 and Japan Waterworks Association.

The damage function of HAZUS99 estimates a much higher damage ratio than the other damage functions, including that of the Japan Waterworks Association. The damage function of HAZUS99 is based on work by O'Rourke and Ayala (1993). Toprak (1998) pointed out that their work is based on the damages due to the 1985 Michoacan, Mexico Earthquake, which has an extremely long duration; therefore, the damage ratio is high.

The damage function by Toprak (1998) shows a lower value than that of HAZUS99. Toprak broke up Los Angeles City into many isoseismal areas, which were interpolated from strong motion records without considering ground conditions, and only the areas that contained over 150km of pipelines were used in the analysis to reduce the bias of corroded or defected pipes. This may be a reason for the low value. Toprak says in his paper that this approach represents the large system-wide response.

The magnitude of the Kobe Earthquake (M=7.4) is comparable to the magnitudes of the scenario earthquake (M=7.5, 7.7). Isoyama *et al*. (1998) used the damage of pipes within 2km from strong motion stations for analysis. This approach can reflect the contributions of ground conditions to damage more precisely.

From the above considerations, the damage function developed by the Japan Waterworks Association (1998) is selected for use in the damage estimation in this analysis.

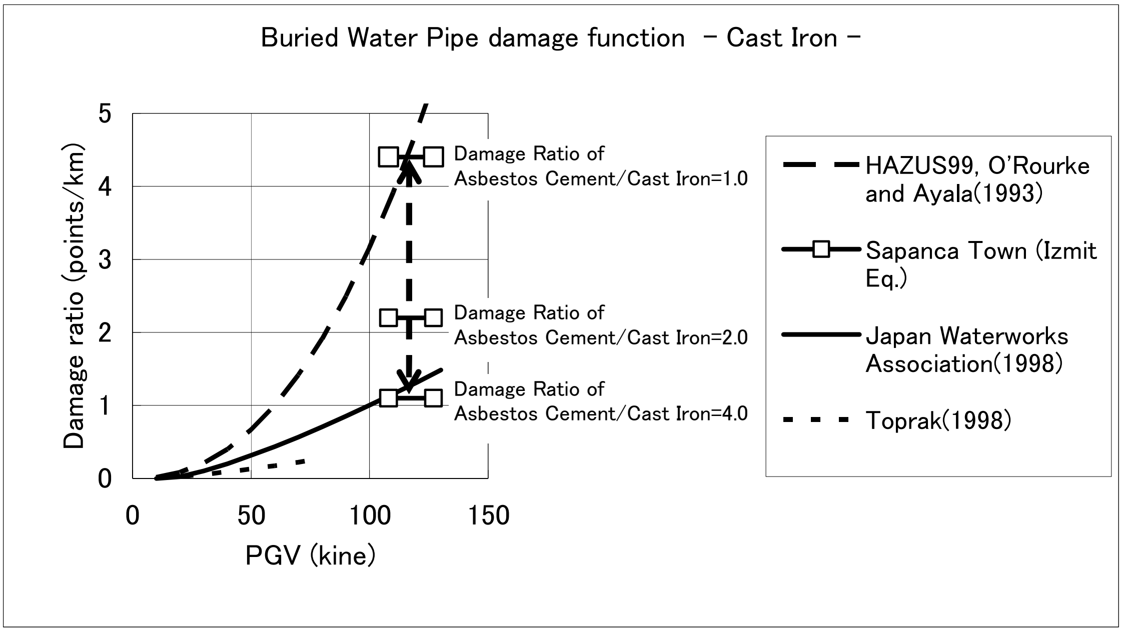


Figure 9.4.1 Relation between Cast Iron Water Pipe Damage Ratio and PGV

The damage function for Istanbul, based on damage functions of the Japan Waterworks Association (1998), is formulated as follows:

$Rm(PGV) = R(PGV) \times Cp \times Cd \times Cg \times Cl$

where

Rm(PGV): damage ratio (points/km)

PGV: Peak Ground Velocity (kine = cm/sec)

$R(PGV) = 3.11 \times 10^{-3} \times (PGV-15)^{1.3}$

Cp: pipeline material coefficient

1.0 for Concrete
0.3 for Steel
0.3 for Ductile Iron
1.0 for Galvanized Iron
0.1 for Polyethylene
0.0 for High Density Polyethylene

Cd: pipeline diameter coefficient

1.6 for less than 90mm
1.0 for 100 to 175mm
0.8 for 200 to 450mm
0.5 for over 500mm

Cg: ground condition coefficient

1.5 for Yd, Sd, Ym
1.0 for Qal, Ksf, Oa, Q
0.4 for others

Cl: liquefaction coefficient

2.0 for Ym, Yd, Sd, Qal, Ksf, Oa, Q
1.0 for others

(2) Estimated Damage

The damage estimation definition is shown in Table 9.4.1.

Table 9.4.1 Definition of Water Pipeline Damage Estimation

Object	Distribution, Service Pipes
Content of Damage	Break of pipes or joints Pull out of joints
Amount of Damage	Number of damage points

The damage in each 500m grid is calculated and shown in Figure 9.4.2 to Figure 9.4.3. The damage is added up by district and shown in Table 9.4.2

About 1,400 and 1,600 points of damage are estimated for Model A and Model C respectively. The damage is concentrated in the pipeline network on the European side. The highest damage ratio was found in Fatih and Güngören.

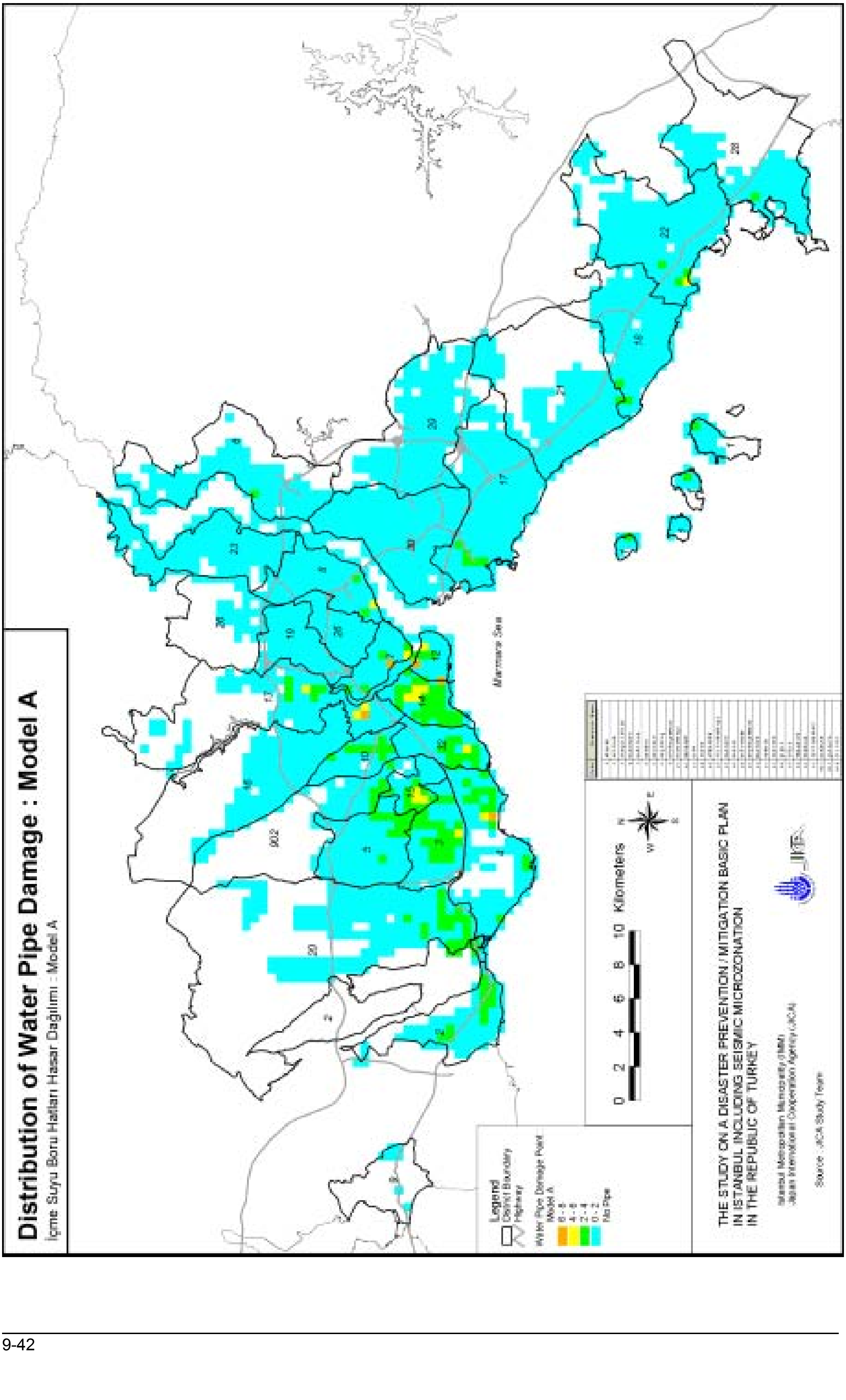


Figure 9.4.2 Distribution of Water Pipe Damage : Model A

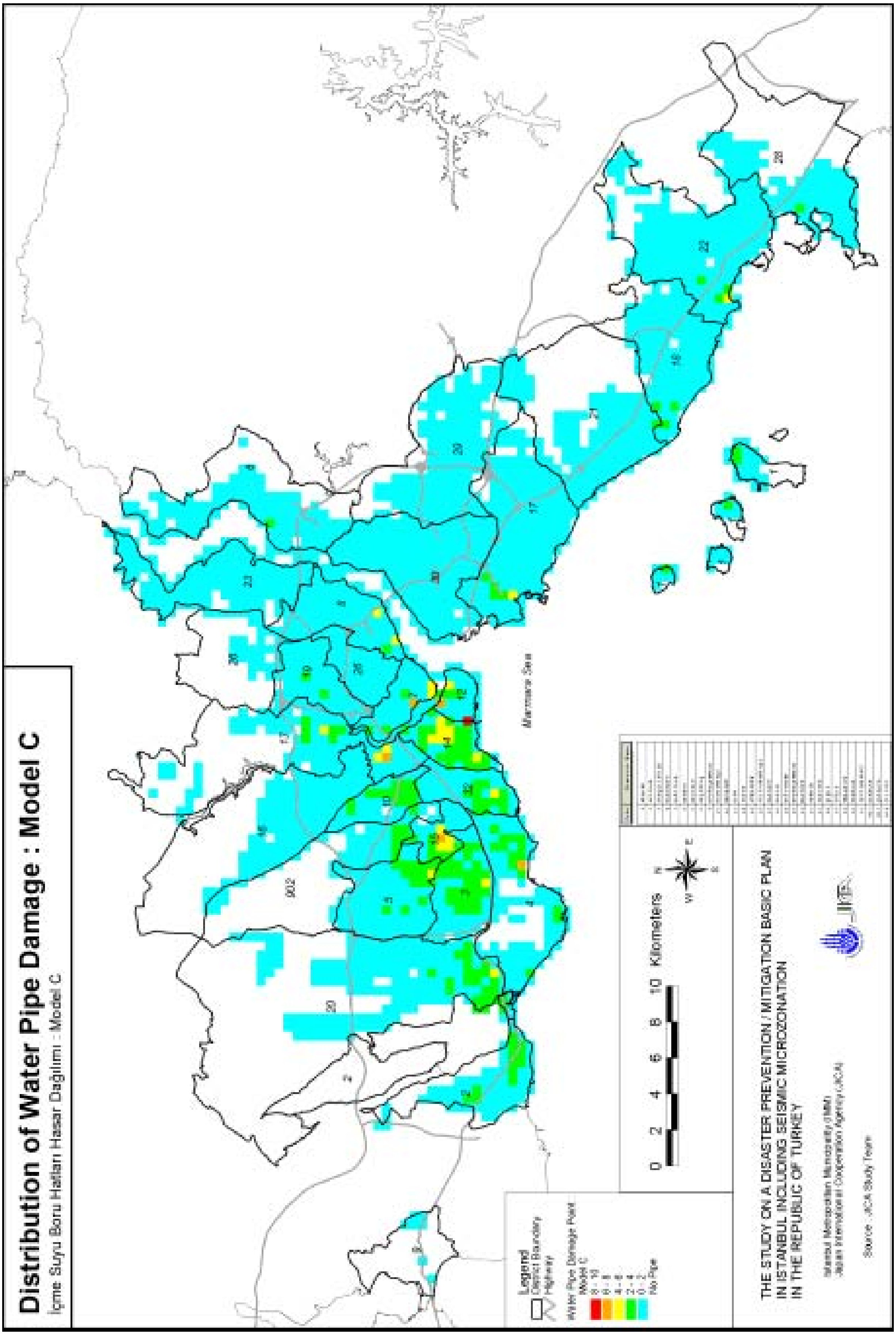


Figure 9.4.3 Distribution of Water Pipe Damage : Model C

Table 9.4.2 Damage to Water Pipeline

ID	District Name	Pipe Length (km)	Damage Points	
			Model A	Model C
1	Adalar	59	20	21
2	Avcılar	187	65	66
3	Bahçelievler	321	107	115
4	Bakırköy	207	98	97
5	Bağcılar	391	87	98
6	Beykoz	189	16	21
7	Beyoğlu	220	46	54
8	Beşiktaş	234	24	31
10	Bayrampaşa	207	48	55
12	Eminönü	126	37	41
13	Eyüp	262	60	69
14	Fatih	321	110	122
15	Güngören	169	64	70
16	Gaziosmanpaşa	372	23	30
17	Kadıköy	527	71	85
18	Kartal	394	62	71
19	Kağıthane	264	21	27
20	Küçükçekmece	523	130	142
21	Maltepe	352	48	56
22	Pendik	432	59	69
23	Sarıyer	276	13	19
26	Şişli	247	15	21
28	Tuzla	138	29	32
29	Ümraniye	293	14	19
30	Üsküdar	471	32	42
32	Zeytinburnu	180	66	70
902	Esenler	205	31	36
Total		7,568	1,395	1,577