9.4.2. Sewage Pipeline

(1) Damage Estimation Method

The evaluation formula for sewage pipelines is the same as that of the water supply pipelines. The following values were used for each factor based on figures that are currently used in Japan.

Cp: pipeline material coefficient

0.5 no information is available for the material
estimated to be Hume Pipe (Concrete)

Cd: pipeline diameter coefficient

0.6 no information is available for the diameter
estimated to be 150 to 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 9.4.3.

Table 9.4.3 Definition of Sewage Pipeline Damage Estimation

Object	All 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 9.4.4 and Figure 9.4.5. The damage is added up by district and shown in Table 9.4.4. Several districts are not included in this table because enough information was unavailable.

About 1,200 and 1,300 points of damage are estimated for Model A and Model C respectively. These numbers do not include the damage in several districts, where enough information was unavailable.

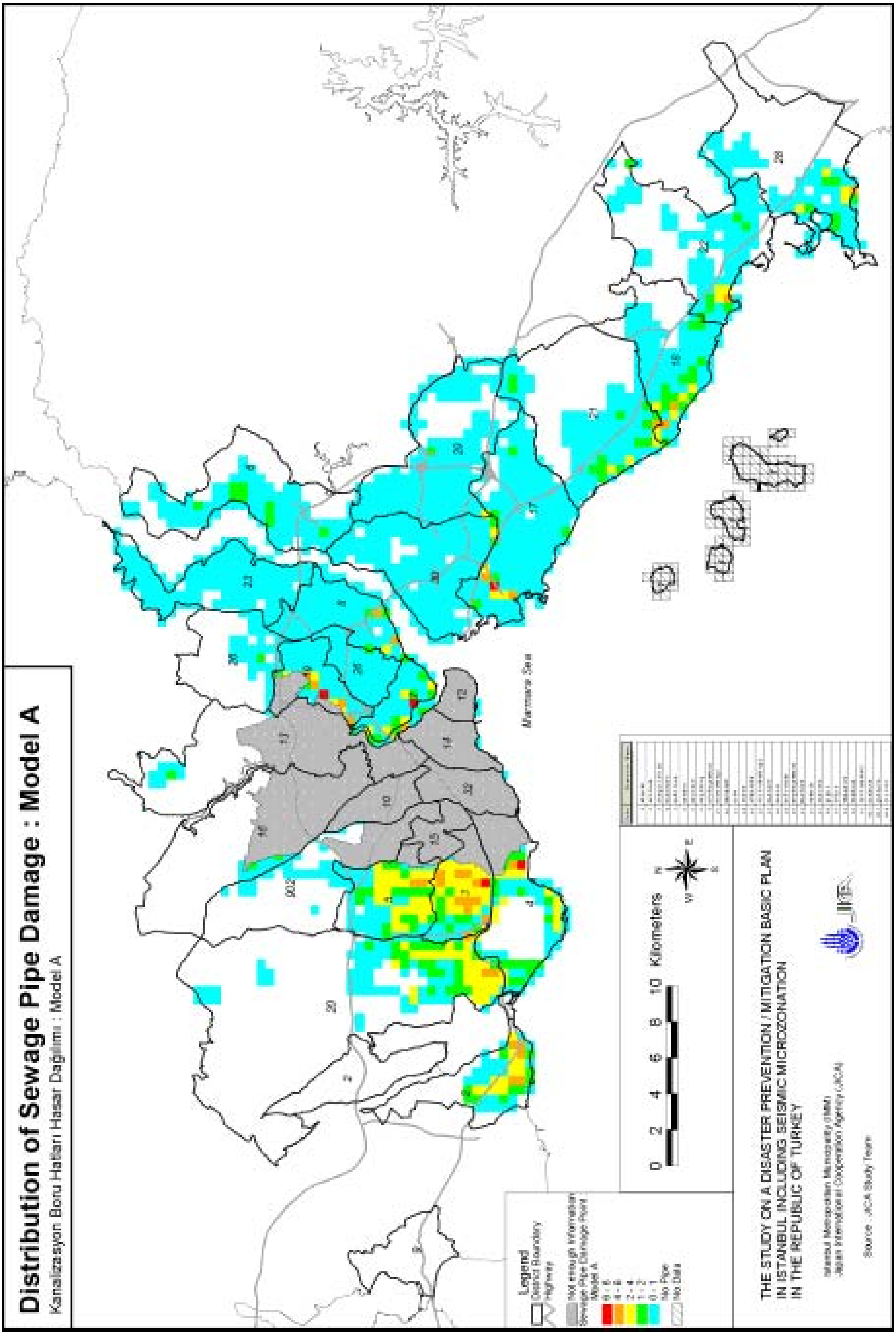

Figure 9.4.4 Distribution of Sewage Pipe Damage : Model A

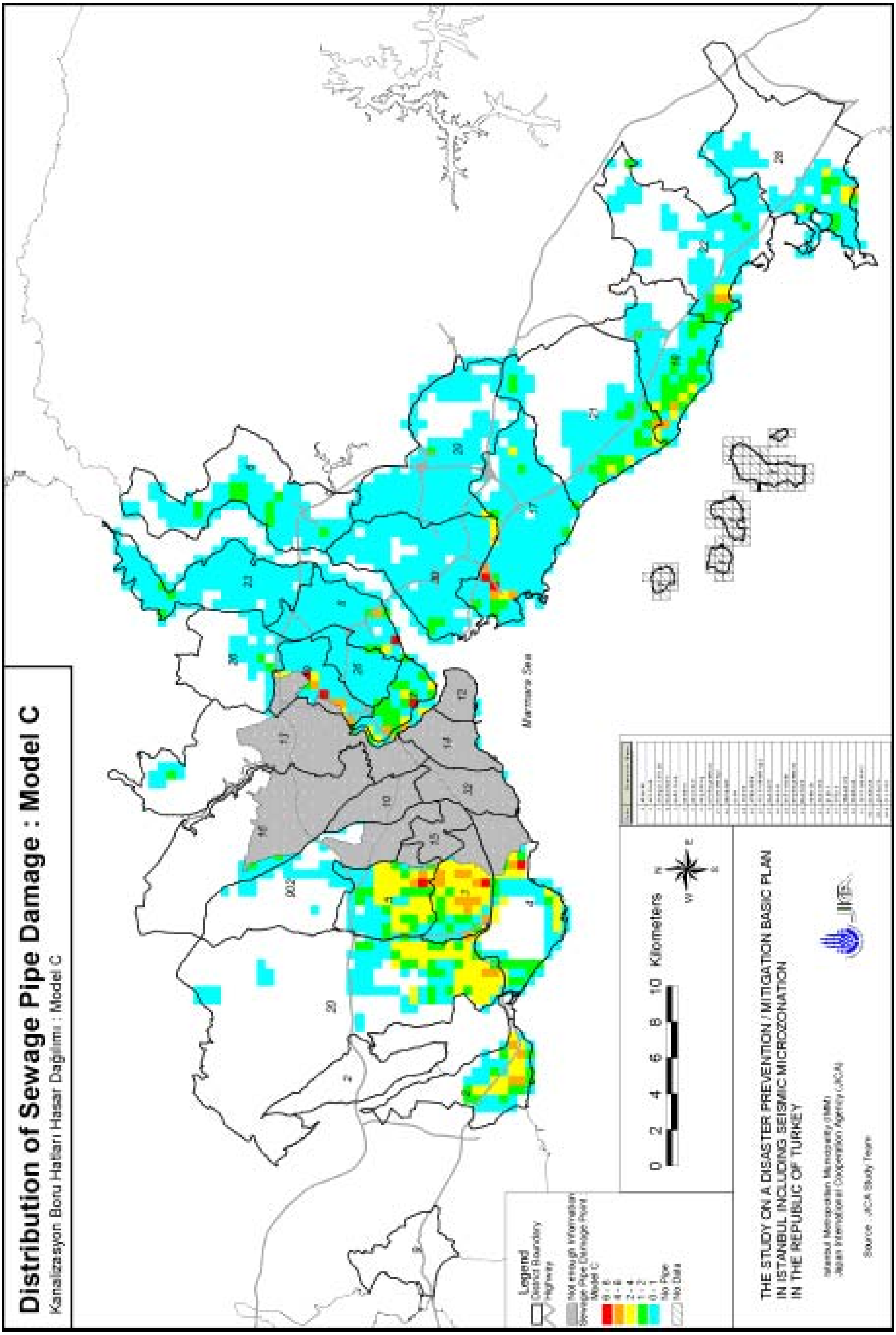

Figure 9.4.5 Distribution of Sewage Pipe Damage : Model C

Table 9.4.4 Damage to Sewage Pipeline

ID	District Name	Pipe Length (km)	Damage Points	
			Model A	Model C
2	Avcılar	229	85	85
3	Bahçelievler	422	152	162
4	Bakırköy	183	93	91
5	Bağcılar	474	121	136
6	Beykoz	318	20	28
7	Beyoğlu	271	48	57
8	Beşiktaş	286	28	36
10	Bayrampaşa	Enough information is not available		
12	Eminönü			
13	Eyüp			
14	Fatih			
15	Güngören			
16	Gaziosmanpaşa			
17	Kadıköy	613	87	103
18	Kartal	398	71	81
19	Kağıthane	289	57	70
20	Küçükçekmece	525	152	165
21	Maltepe	402	63	73
22	Pendik	245	44	51
23	Sarıyer	307	12	18
26	Şişli	261	17	23
28	Tuzla	145	44	47
29	Ümraniye	343	21	28
30	Üsküdar	463	36	46
32	Zeytinburnu	Enough information is not available		
902	Esenler			
Total		6,174	1,152	1,299

9.4.3. Gas Pipeline and Service Box

(1) Damage Estimation Method

a. Pipeline

Figure 9.4.6 shows the damage function - used in the earthquake damage estimation study by the Disaster Prevention Council of the Tokyo Metropolitan Area (1997) for welded steel gas pipes. This damage function was derived from the damage in Kobe City due to the 1995 Kobe Earthquake. Polyethylene pipes are treated as suffering no damage.

The damage of gas pipes due to the Izmit Earthquake is reported in some papers. *Tohma et al.* (2001) reported that there was no damage to gas distribution pipelines in the Avcılar area, which has polyethylene pipes, in spite of the heavy building damage. Kudo *et al.* (2002) estimated the PGV in the Avcılar area during the Izmit Earthquake to be about 35 kine.

O'Rourke *et al.* (2000) reported the damage in Izmit City. There were 367km middle density polyethylene (MDPE) pipes and 38km steel pipes in Izmit City and no damage were found. There is a strong motion seismometer in Izmit and the record shows 40 kine in PGV, but the station is located at a stiff rock site, so the PGV in the city area might have been higher.

Based on the damage function by Disaster Prevention Council of the Tokyo Metropolitan Area (1997), the damage to the pipeline in Izmit is estimated to be 0.14 points for steel pipes. This corresponds to the result of "no damage" in Izmit. If steel pipes experience one break in Izmit, the damage ratio becomes 0.026 point/km. Therefore "no damage" should be interpreted between 0.0 and 0.026 points/km from a statistical point of view.

From the above consideration, the damage function by the Disaster Prevention Council of the Tokyo Metropolitan Area (1997) is selected for use in the damage estimation in this analysis.

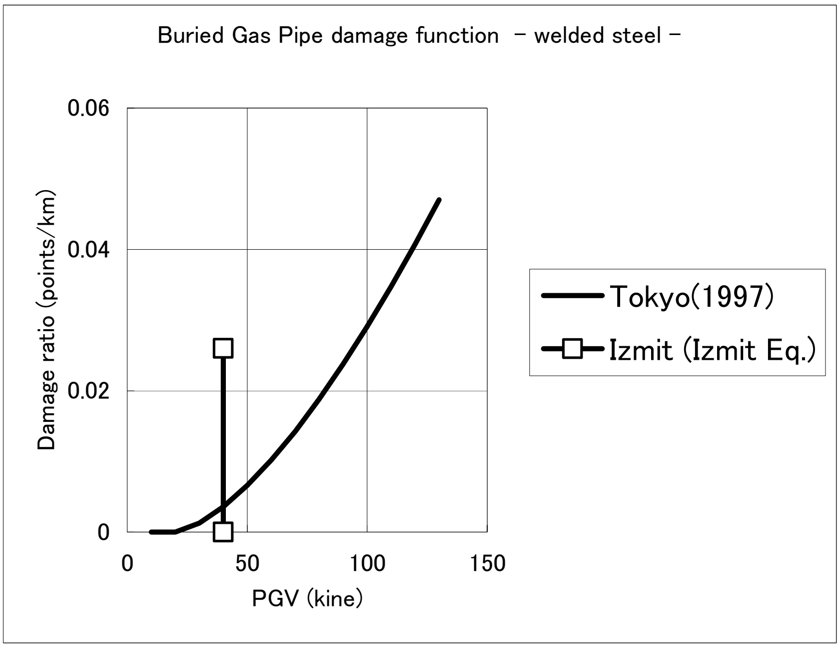

Figure 9.4.6 Relation between Damage Ratio of Welded Steel Gas Pipe and PGV

The damage function for Istanbul, based on Disaster Prevention Council of the Tokyo Metropolitan Area (1997), is formulated as follows:

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

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

0.01 for Steel

0.00 for Polyethylene

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

b. Service Box

The SIS census data has information on natural gas installations. In total, about 186,000 buildings (= 25.6%) have natural gas systems installed.

The gas service box is installed on the ground floor of the buildings or on the outer wall. If the building will collapse, the gas box will be damaged. Even if the gas pipeline is not damaged, gas leakage can occur from the service box, which may cause an explosion. In this study, it is assumed that all of the service boxes in heavily damaged buildings and half of those in moderately damaged buildings will be damaged. The following considerations support this assumption:

According to O'Rourke *et al.* (2000), there were 26,000 gas users in the city of Izmit before the Izmit Earthquake, and 860 service boxes were damaged. The mean number of housing units in one building in Izmit is assumed to be the same as in Istanbul-- namely, 4.2 housing units/building. Therefore, it is assumed that about 6,190 buildings have service boxes in them. Building damage estimates for Izmit are not available; therefore, the damage ratio in Izmit is assumed to be half of that of Gölcük and Değırmendere. Kabeyasawa *et al*. (2001) reported 16% of buildings heavily damaged and 18% of buildings moderately damaged in these areas. According to these assumptions, it is estimated that 774 gas boxes were damaged in Izmit.

(2) Estimated Damage

The damage estimation definition is shown in Table 9.4.5.

Table 9.4.5 Definition of Gas Pipeline Damage Estimation

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

The damage in each 500m grid is calculated and shown in Figure 9.4.7 to Figure 9.4.10. The damage is added up by district and shown in Table 9.4.6.

The damage of the gas pipeline system is slight. The main reason is that the gas pipeline in Istanbul wasrecently installed and IGDAŞ used polyethylene pipes, which have high flexibility and earthquake-resisting capacity, in accordance with the experience in past earthquake damage. However, the damage to service boxes amounts to over 25,000 because of the poor building structures.

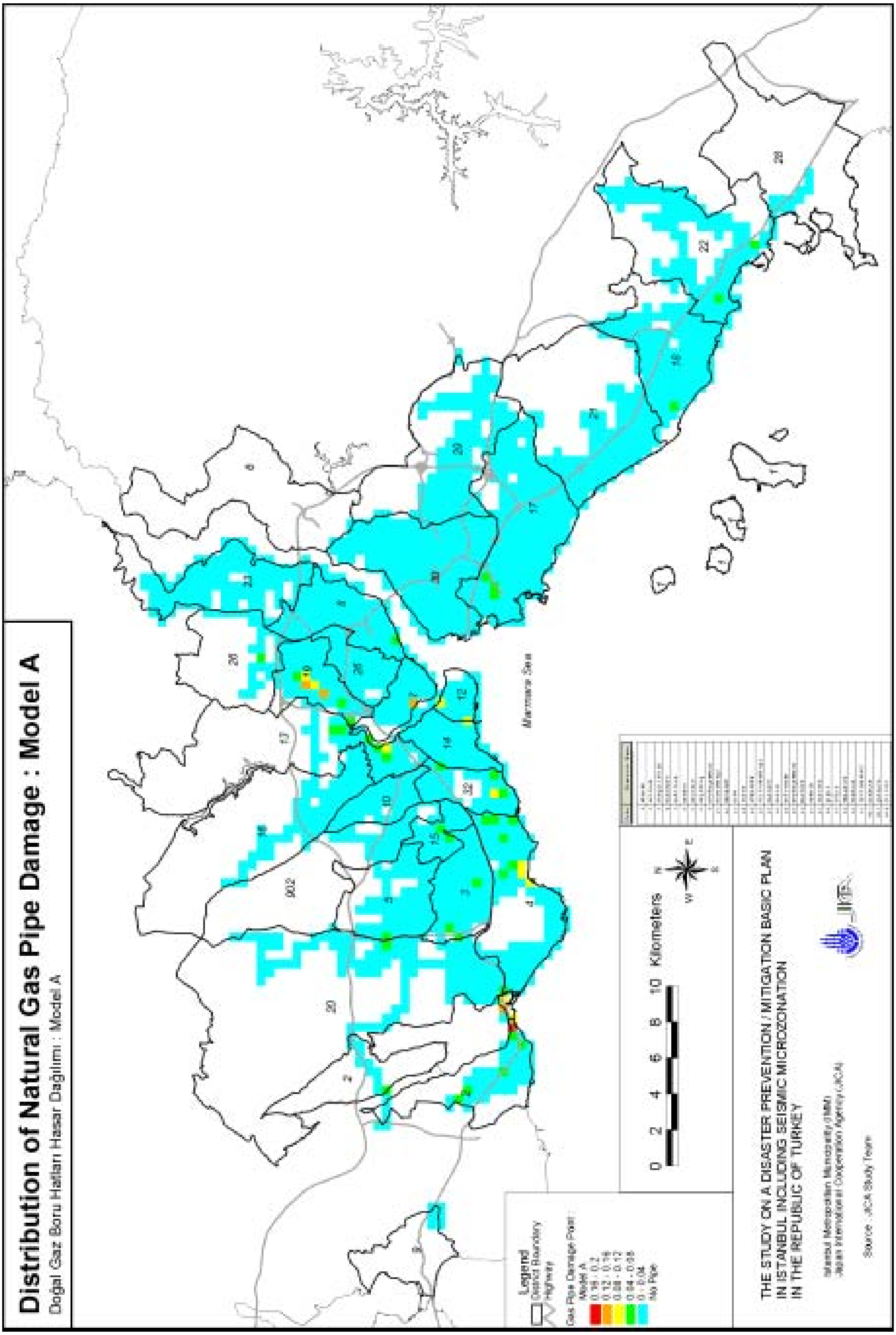

Figure 9.4.7 Distribution of Natural Gas Pipe Damage : Model A

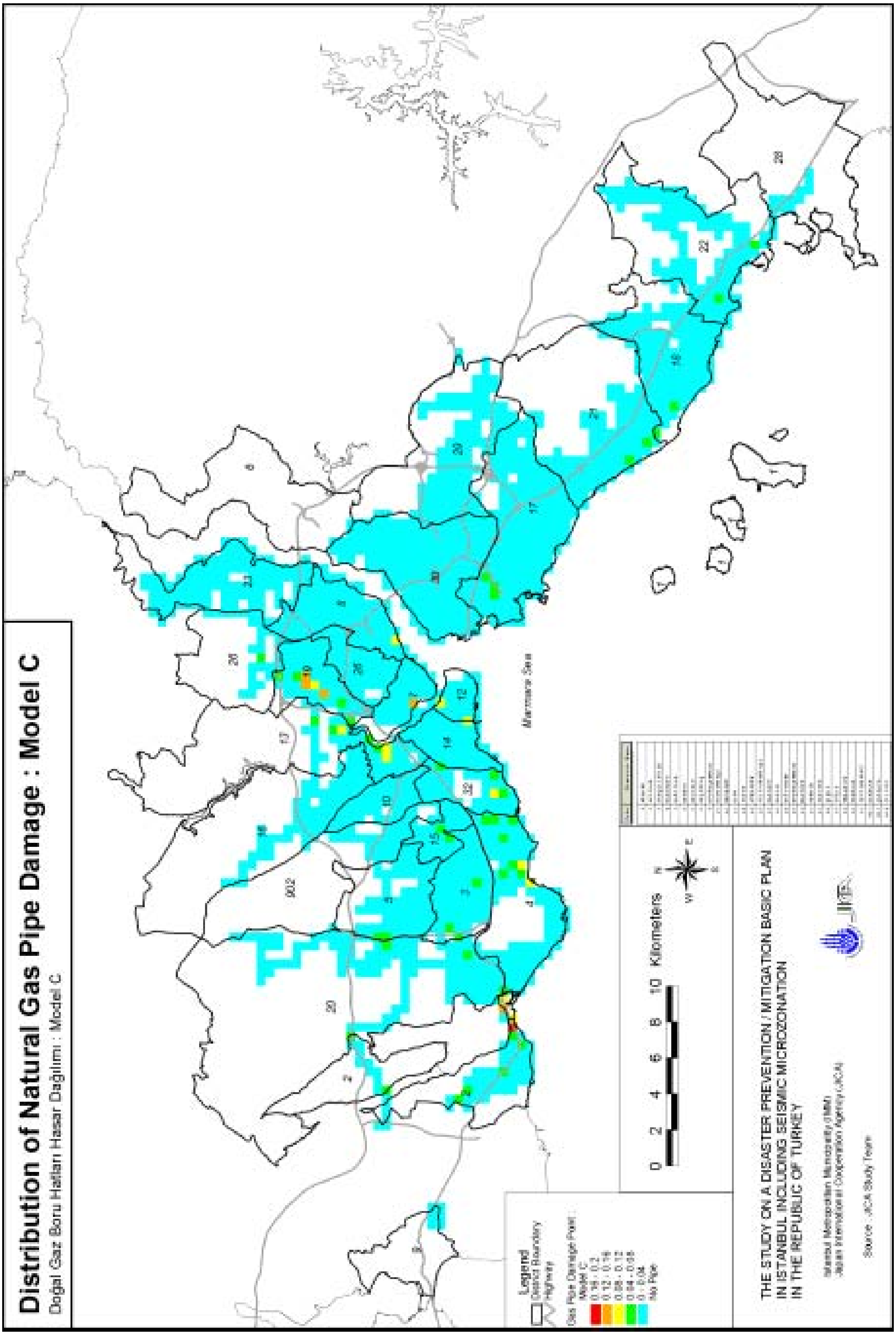

Figure 9.4.8 Distribution of Natural Gas Pipe Damage : Model C

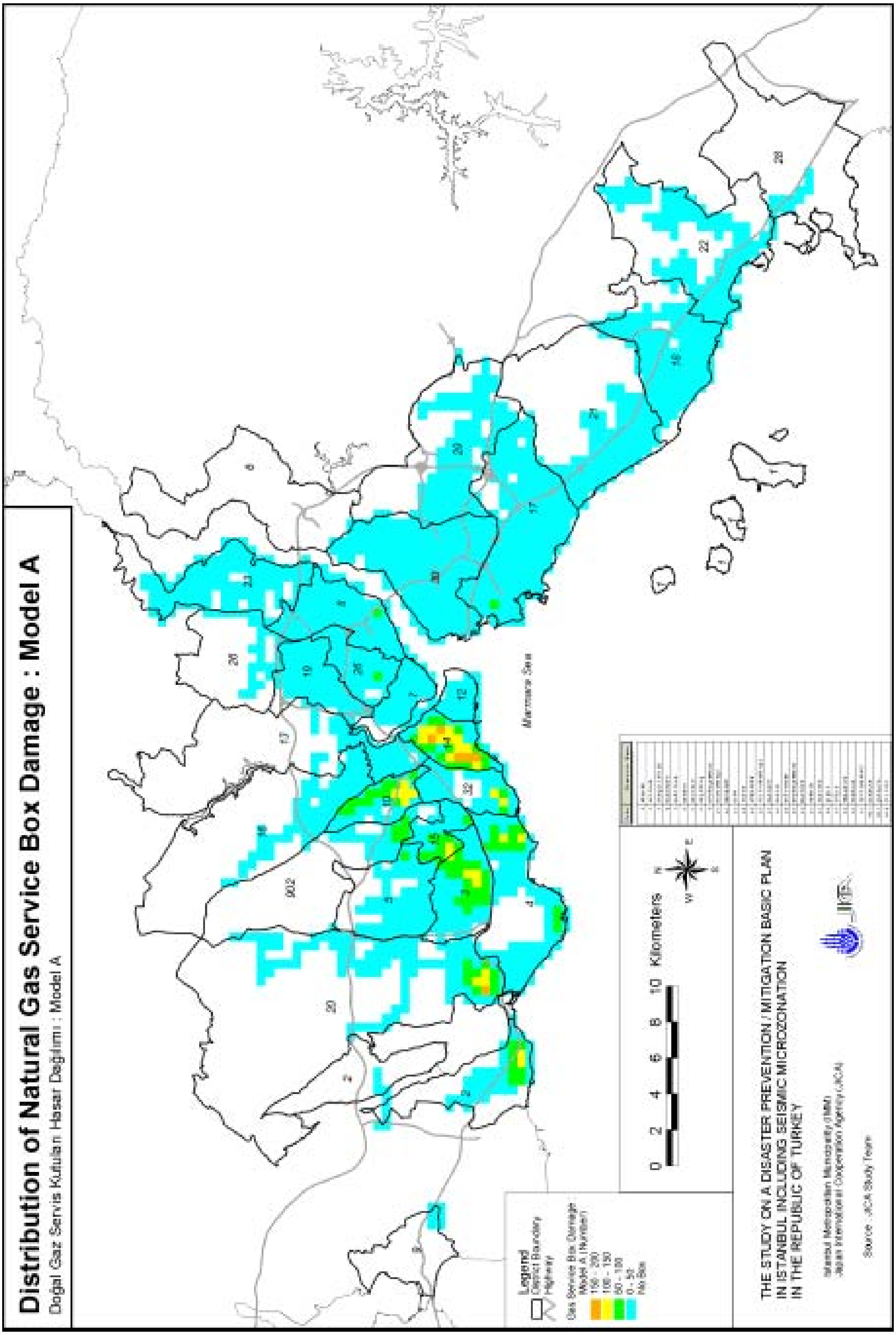

Figure 9.4.9 Distribution of Gas Service Box Damage : Model A

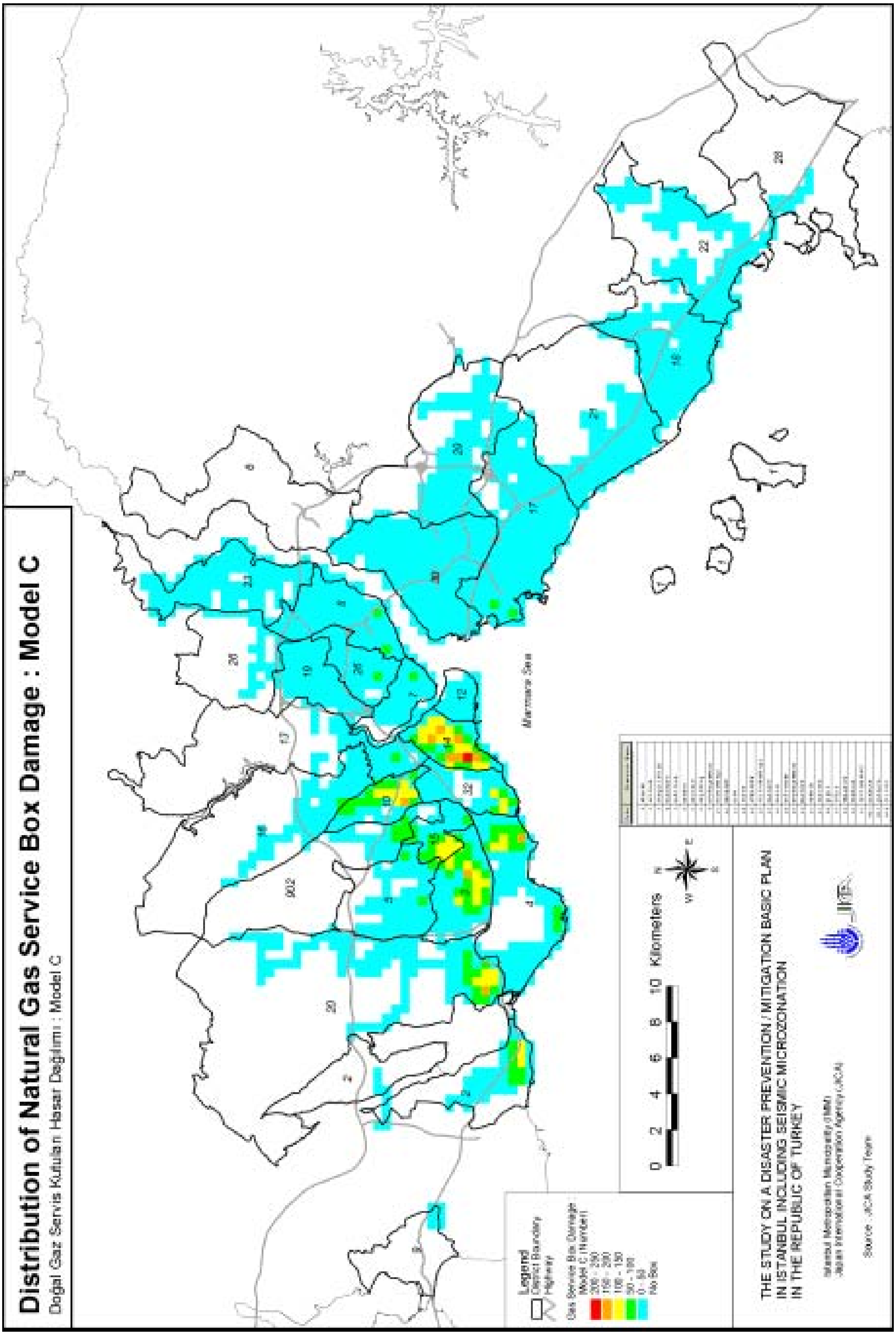

Figure 9.4.10 Distribution of Gas Service Box Damage : Model C

Table 9.4.6 Damage to Gas Pipeline and Service Box

ID	District Name	Pipe Length (km)	Damage Points		Service Box number	Damaged Box			
			Model A	Model C		Model A		Model C	
2	Avcılar	119	1	1	4,263	1,254	29%	1,426	33%
3	Bahçelievler	240	1	1	11,305	2,457	22%	2,866	25%
4	Bakırköy	194	1	1	7,978	2,208	28%	2,490	31%
5	Bağcılar	171	1	1	4,841	679	14%	807	17%
7	Beyoğlu	101	0	0	3,776	449	12%	510	14%
8	Beşiktaş	217	0	0	9,290	551	6%	656	7%
10	Bayrampaşa	163	0	0	11,866	1,981	17%	2,246	19%
12	Eminönü	39	0	0	511	90	18%	100	20%
13	Eyüp	86	1	1	3,167	456	14%	498	16%
14	Fatih	214	1	1	15,243	3,620	24%	4,033	26%
15	Güngören	150	0	0	7,211	1,374	19%	1,653	23%
16	Gaziosmanpaşa	182	0	0	7,886	544	7%	631	8%
17	Kadıköy	462	1	1	17,963	1,532	9%	1,868	10%
18	Kartal	295	0	1	7,959	1,145	14%	1,272	16%
19	Kağıthane	111	1	1	1,924	114	6%	133	7%
20	Küçükçekmece	252	1	1	8,260	1,811	22%	2,023	24%
21	Maltepe	251	0	1	8,038	944	12%	1,096	14%
22	Pendik	186	1	1	3,940	649	16%	725	18%
23	Sarıyer	171	0	0	6,281	130	2%	151	2%
26	Şişli	173	0	0	8,088	466	6%	574	7%
28	Tuzla	5	0	0	146	26	18%	28	19%
29	Ümraniye	207	0	0	6,576	275	4%	330	5%
30	Üsküdar	520	0	0	22,726	1,121	5%	1,325	6%
32	Zeytinburnu	88	1	1	2,146	620	29%	700	33%
902	Esenler	75	0	0	3,572	491	14%	589	16%
Total		4,670	11	13	184,956	24,985	14%	28,729	16%

9.4.4. Electric Power Supply Cables

For high voltage electricity supply lines, hard copy maps of the network have been converted to GIS data. However, for the middle and low voltage line networks, only a statistical table, which was prepared by their distribution company, is available. The length of cable in each 500m-grid cell is estimated based on the building distribution map on a 1/1,000 scale.

(1) Damage Estimation Method

O'Rourke *et al*. (2000) reported on the damage to electricity distribution systems due to the Izmit Earthquake. They pointed out that the physical damage to generation, transmission, and distribution equipment was consistent with the experiences in past earthquakes in California, Japan, and elsewhere. Some observations include the following:

- Generation plants are usually resistant to significant damage in earthquakes, provided their foundations do not undergo large deformations.
- Transmission towers and cables are highly resistant to earthquake damage, even when displaced by surface fault rupture.
- Underground cables are prone to damage where they connect to surface electrical supplies or buildings and due to subsequent degradation in cable insulation due to physical or electrical effects.

They provide statistics of damage length and pre-earthquake total length of cables and other facilities for the five primary provinces. The damage ratio of overhead and underground cables are shown in Figure 9.4.11 and Figure 9.4.12. The seismic intensity of each province is read from the isoseismal map by ERD and converted to PGA using Trifunac and Brady (1975).

The damage of overhead cables in Erzincan due to 1992 Erzincan Earthquake is also plotted in Figure 9.4.11 and Figure 9.4.12. Kawakami *et al.* (1993) reported that 4.0 km of 50 km overhead cable and 1.8 km of 32 km underground cable needed repair. One strong motion seismometer was installed in Erzincan and recorded a PGA equal to 480gal.

In the 1995 Kobe Earthquake, no electricity poles were damaged in areas of seismic intensity (MMI) less than 8, while 0.55% of poles and 0.3% of underground cables were damaged in areas of seismic intensity (MMI) 9 and over. This damage and the damage function in ATC-13 and HAZUS99 are also shown in Figure 9.4.11 and Figure 9.4.12.

For overhead cables, the damage in Turkey does not show differ greatly from that in the USA except for the damage in Yalova. On the contrary, the damage to underground cables due to the Izmit Earthquake shows a much higher damage ratio than HAZUS99. If the underground cable is properly laid, namely in pipes or conduits, the damage ratio is usually less than that of overhead cable, as seen in the case of Kobe. O'Rourke *et al.* (2000) said that direct-buried cables are used primarily in urban areas in Turkey, and they were damaged by ground failure, foundation failure of buildings, and from being pulled during post-earthquake building rescue and demolition activities. Therefore, the underground cable damage due to the Izmit Earthquake in Figure 9.4.12 includes post-earthquake damage.

Based on the damage observed in Turkey and existing damage functions, a new damage function for overhead cables is proposed, shown in Figure 9.4.11, and is used for the damage analysis. For underground cable damage, the damage function of HAZUS99 is used based on the damage in Erzincan. High voltage transmission lines are assumed to suffer no damage based on the past earthquake experiences.

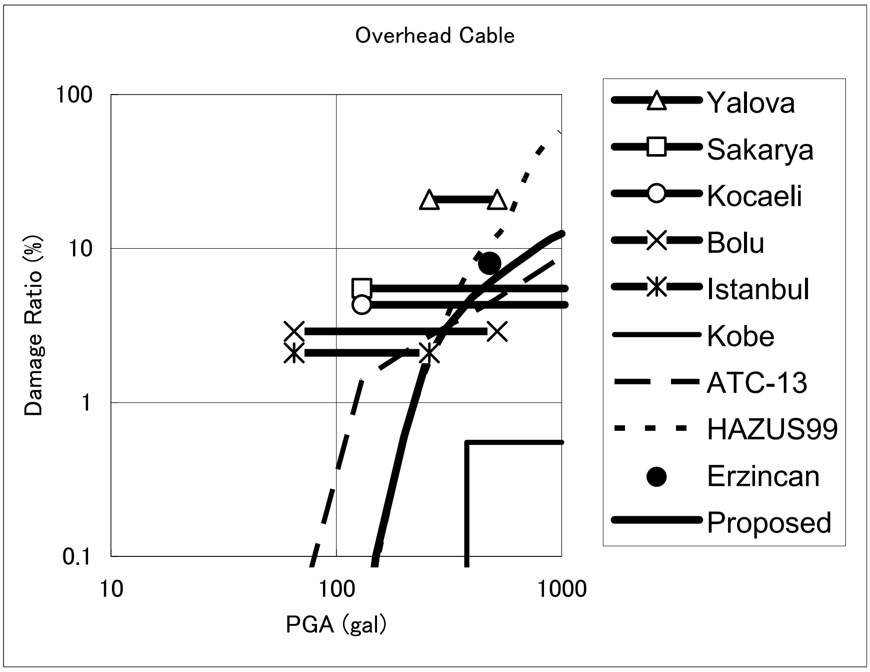

Figure 9.4.11 Relation between Damage Ratio of Overhead Electricity Cable and PGA

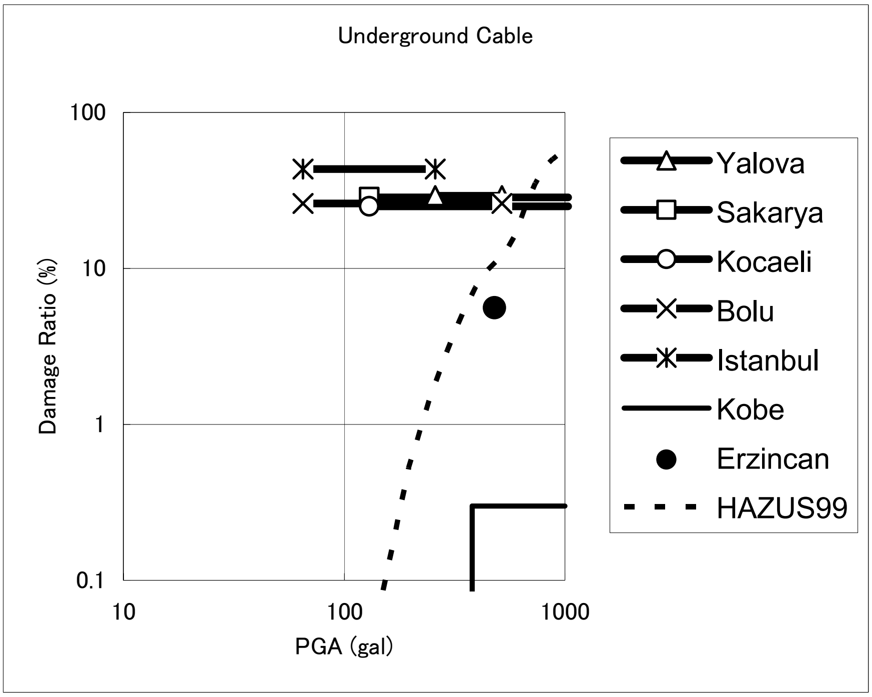

Figure 9.4.12 Relation between Damage Ratio of Underground Electricity Cable and PGA

(2) Estimated Damage

The damage estimation definition is shown in Table 9.4.7.

Table 9.4.7 Definition of Electricity Cable Damage Estimation

Object	Distribution line (Low and Middle Voltage)
Content of Damage	Cut of cables
Amount of Damage	Length of cables to be replaced

The damage in each 500m grid cell is calculated and shown in Figure 9.4.13 to Figure 9.4.14. The damage is added up by district and shown in Table 9.4.8.

About 800 and 1,100 km of damage are estimated for Model A and Model C respectively. The damage is concentrated on the European side. The most severe damage is found in Zeitinburnu, Güngören, and Bahçelievler.

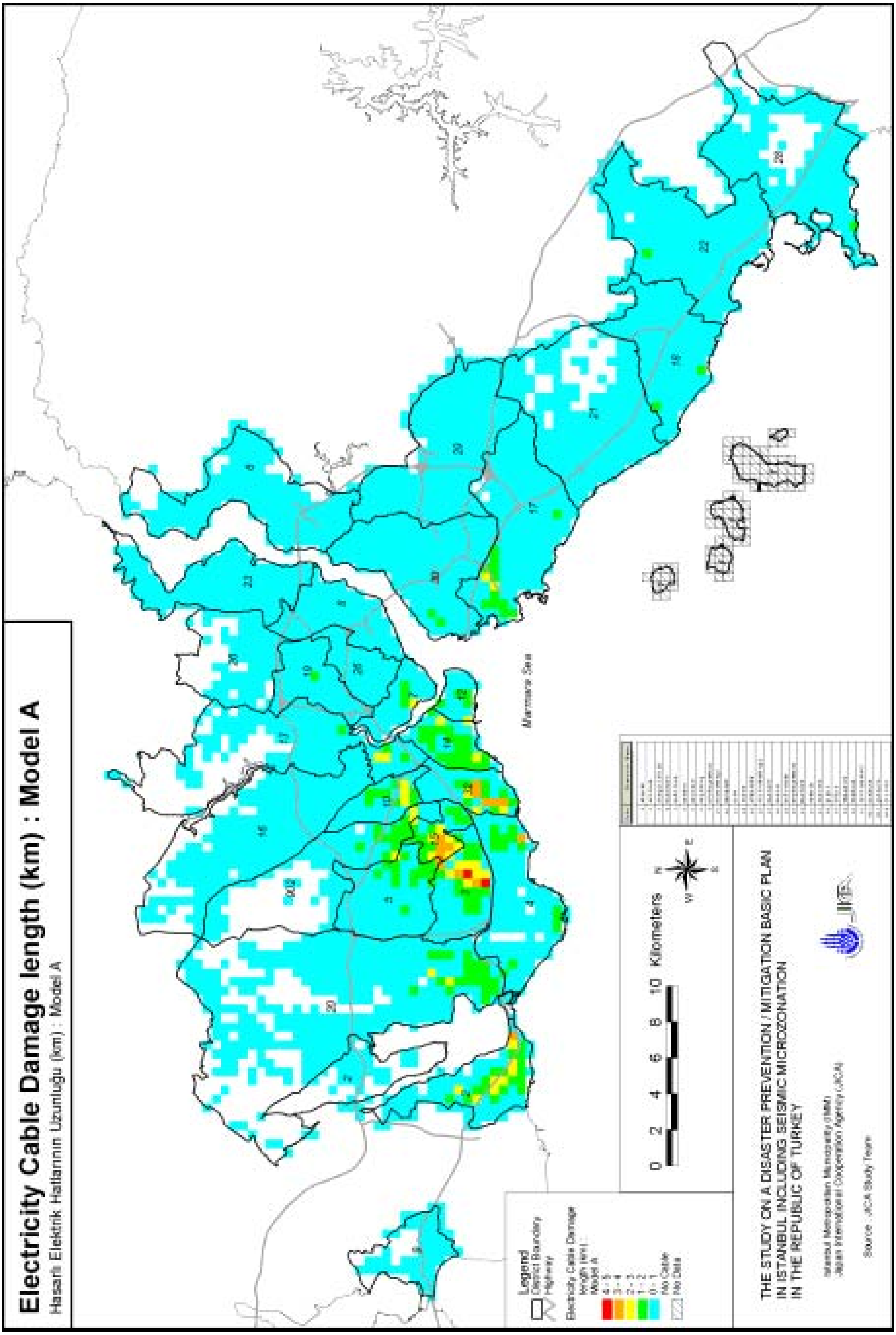

Figure 9.4.13 Electricity Cable Damage Length (km) : Model A

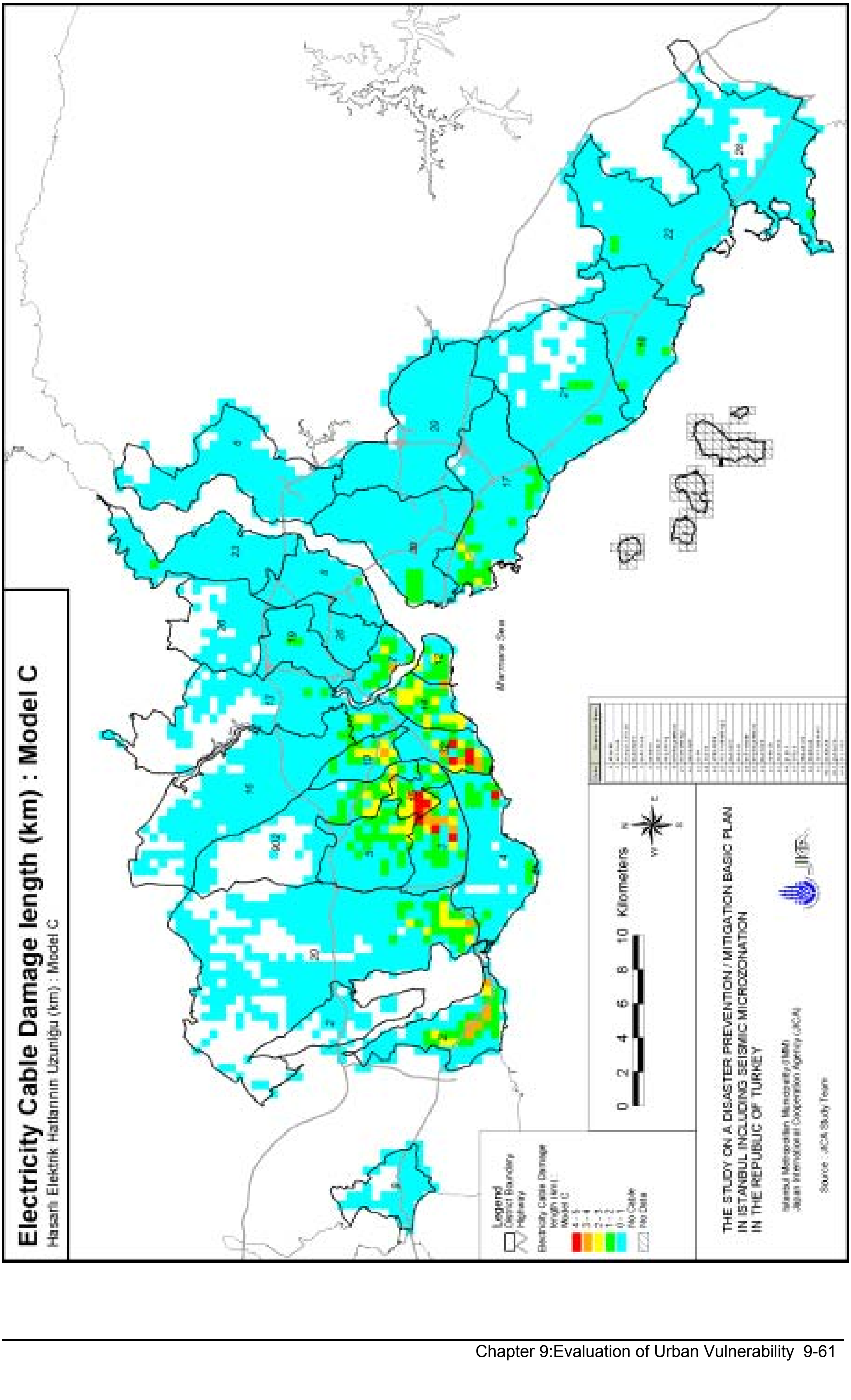

Figure 9.4.14 Electricity Cable Damage Length (km) : Model C

Table 9.4.8 Damage to Electricity Cable

ID	District Name	Cable Length			Damaged Cable											
					Model A						Model C					
					Overhead		Under-ground		Total		Overhead		Under-ground		Total	
		Overhead (km)	Underground (km)	Total (km)	Length (km)	(%)	Length (km)	(%)	Length (km)	(%)	Length (km)	(%)	Length (km)	(%)	Length (km)	(%)
2	Avcılar	875	368	1,243	39	4.5	25	6.9	64	5.2	44	5.1	31	8.4	75	6.1
3	Bahçelievler	300	965	1,265	11	3.8	59	6.1	70	5.6	11	3.6	58	6.0	68	5.4
4	Bakırköy	195	408	604	9	4.9	34	8.3	43	7.2	9	4.9	36	8.7	45	7.5
5	Bağcılar	618	923	1,540	17	2.8	32	3.4	49	3.2	22	3.6	47	5.1	69	4.5
6	Beykoz	349	421	770	2	0.5	2	0.5	4	0.5	3	0.9	4	0.9	7	0.9
7	Beyoğlu	390	850	1,240	7	1.8	16	1.9	23	1.8	9	2.4	23	2.7	32	2.6
8	Beşiktaş	169	336	506	2	1.0	4	1.1	6	1.1	2	1.2	4	1.3	6	1.2
10	Bayrampaşa	556	474	1,030	13	2.3	14	2.9	27	2.6	18	3.3	22	4.6	40	3.9
12	Eminönü	23	397	419	1	2.9	14	3.6	15	3.5	1	3.3	18	4.6	19	4.5
13	Eyüp	659	529	1,188	12	1.8	12	2.3	24	2.0	16	2.4	17	3.2	33	2.8
14	Fatih	57	943	1,000	2	3.5	46	4.8	48	4.8	2	3.9	56	6.0	59	5.9
15	Güngören	181	706	887	7	3.9	41	5.8	48	5.4	8	4.4	51	7.2	59	6.7
16	Gaziosmanpaşa	1,152	761	1,913	11	1.0	7	0.9	18	1.0	18	1.6	12	1.6	30	1.6
17	Kadıköy	1,490	1,794	3,284	29	1.9	35	2.0	64	2.0	38	2.5	52	2.9	89	2.7
18	Kartal	433	522	955	12	2.8	17	3.2	29	3.0	14	3.3	23	4.3	37	3.8
19	Kağıthane	465	498	963	5	1.0	6	1.3	11	1.2	7	1.6	9	1.8	16	1.7
20	Küçükçekmece	691	1,084	1,775	17	2.5	44	4.1	61	3.5	23	3.4	65	6.0	88	5.0
21	Maltepe	610	735	1,345	14	2.3	18	2.5	32	2.4	18	3.0	27	3.7	45	3.4
22	Pendik	600	723	1,324	13	2.1	16	2.2	29	2.2	16	2.7	23	3.2	40	3.0
23	Sarıyer	1,505	1,212	2,717	6	0.4	4	0.4	10	0.4	9	0.6	7	0.6	17	0.6
26	Şişli	500	648	1,149	4	0.8	5	0.8	9	0.8	6	1.2	8	1.3	14	1.2
28	Tuzla	205	247	452	7	3.2	10	4.2	17	3.8	8	3.7	14	5.6	21	4.7
29	Ümraniye	601	724	1,325	5	0.8	6	0.8	10	0.8	8	1.3	9	1.2	17	1.3
30	Üsküdar	928	1,118	2,046	11	1.2	12	1.1	23	1.1	17	1.8	19	1.7	36	1.8
32	Zeytinburnu	310	603	912	12	3.7	37	6.1	48	5.3	15	4.7	51	8.4	65	7.1
902	Esenler	630	562	1,192	16	2.5	18	3.2	34	2.8	20	3.2	25	4.5	45	3.8
Total		14,492	18,551	33,044	282	1.9	535	2.9	817	2.5	364	2.5	711	3.8	1,075	3.3

9.4.5. Telecommunication Cables

With regards to telecommunication cables, only GIS data on the main fiber optic cable system is available. Other data on trunk and branch copper cable, not even their total length in the Study Area, could not be collected.

Generally, the fragility of fiber optic cable in earthquakes is not well known. Quantitative damage statistics based on past earthquakes are indispensable in developing the fragility function for the damage estimation, but experience with damage to fiber optic cable is scarce not only in Turkey but also in other countries. The only available information in Turkey is the damage at the fault crossing to the east of Izmit during the Izmit Earthquake (Erdik, Online).

Therefore, it is impossible to estimate the damage of fiber optic cable quantitatively, but it can be pointed out that it is more vulnerable if the earthquake motion is larger or if liquefaction will occur.

Figure 9.4.15 shows the location of fiber optic cable with PGA distribution for Model C and the liquefaction potential area. The relatively vulnerable section can be seen in this map. In Figure 9.4.16 and Figure 9.4.17, the cable length distribution by PGA rank and liquefaction potential is shown.

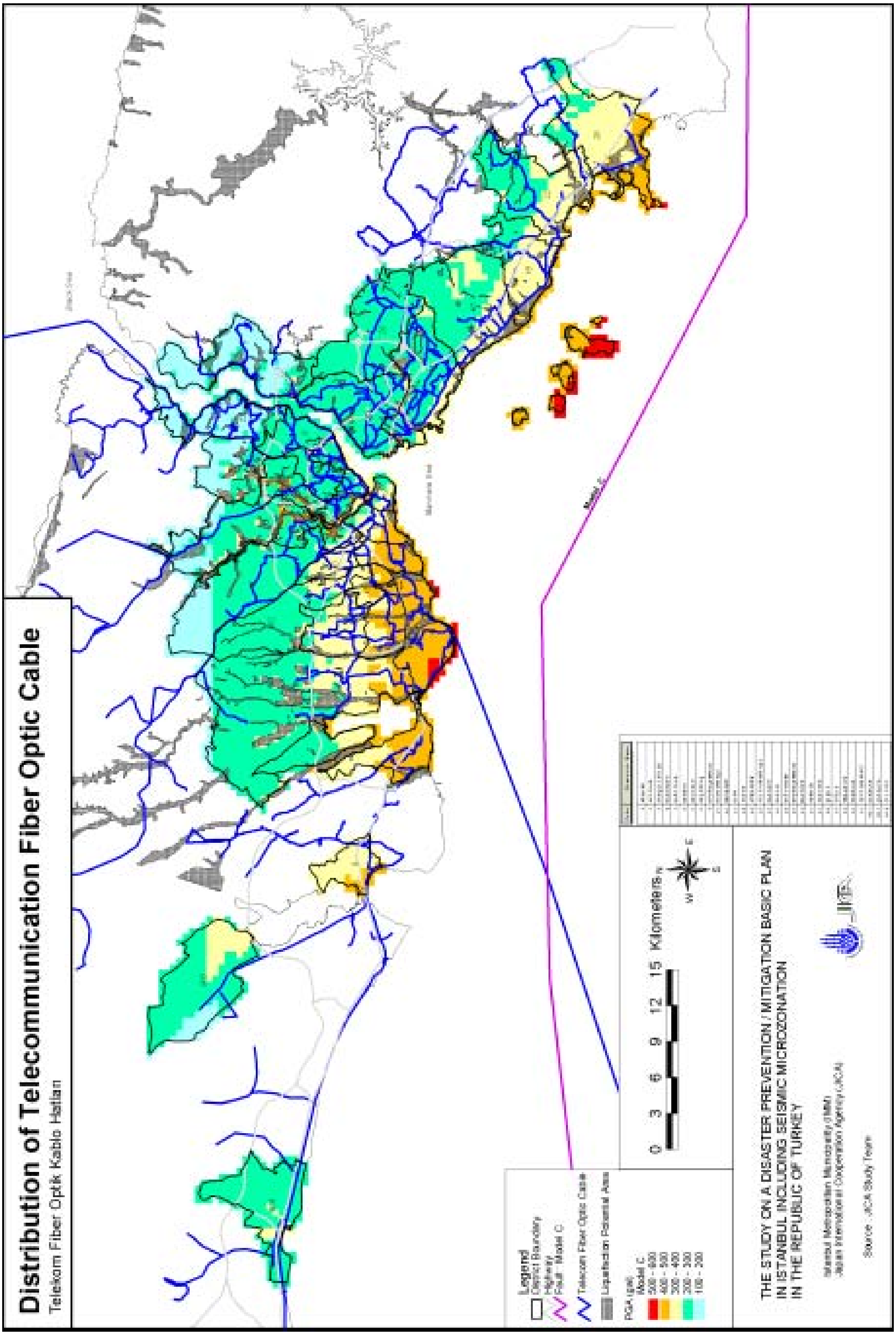

Figure 9.4.15 Distribution of Telecommunication Fiber Optic Cable

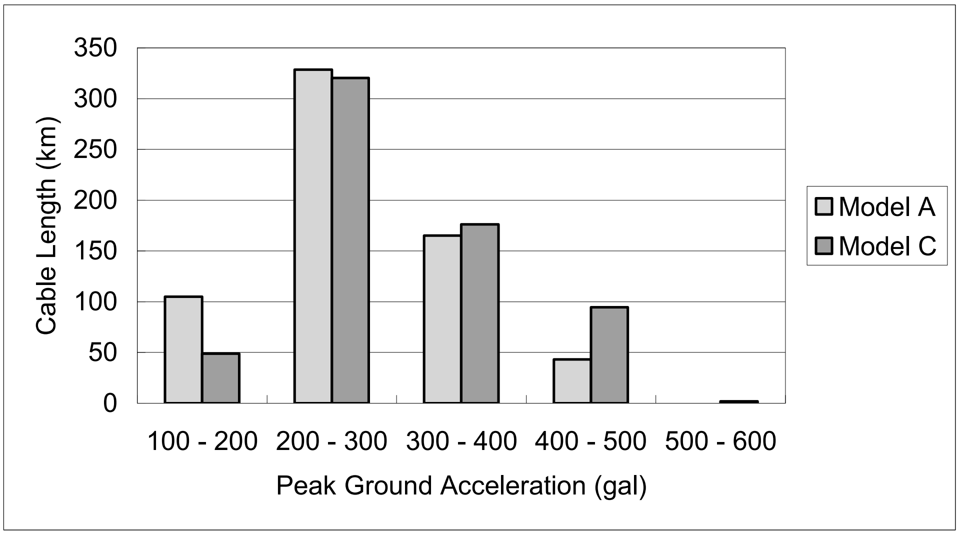

Figure 9.4.16 Summary of PGA along Fiber Optic Cable

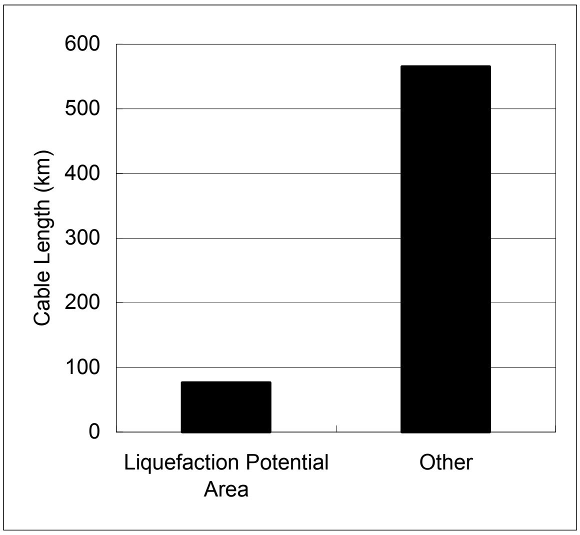

Figure 9.4.17 Summary of Liquefaction Potential area along Fiber Optic Cable

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Trifunac, M. D. and A. G. Brady, 1975, On the correlation of seismic intensity scales with the peaks of recorded strong ground motion, Bull. Seism. Soc. Am., Vol. 65, No. 1.

9.5. Bridge

9.5.1. Present aspect of bridge design and construction

(1) Earthquake resistant code

In Turkey, the 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.

However, this code defines only the inertia force for structures other than building type. There is no specific design code for bridge structure.

Foreign design code is made reference to, because there are many necessary rules for designing bridge in practice as shown in Table 9.5.1.

Table 9.5.1 Applied specification

Location of Bridges	Construction Year	Specifications used in Project
bridges on 1st highway (E5)	between 1973-1987	Technical Specifications for Bridges French Spec.
bridges on 2nd highway (TEM)	after 1987	AASHTO

(2) Earthquake resistance of existing briges

Failure of bridge structure can give an extensive malfunction even though each failure is limited to particular point in line of road system. Contribution of road system in reconstruction term of the city is very large when the bridges are safe, but if some of the bridges of road are destructed, repairing of bridge need very long term. This is the reason why the destruction of the bridges should be prevented as much as possible.

Purpose of this section is to point out specific bridges that should be noticed in order to mitigate malfunction. This is so called "First screening".

Considering that, the falling-off of the girder can give the most serious effect to the road system. Therefore, a methodology that is proposed by Kubo/Katayama (hereafter reffered to as Katayama's method) is selected in this study because that methodology is very effective for evaluate the bridges on the viewpoint of falling-off of the girder. Schema of this evaluation system is shown in Figure 9.5.1.

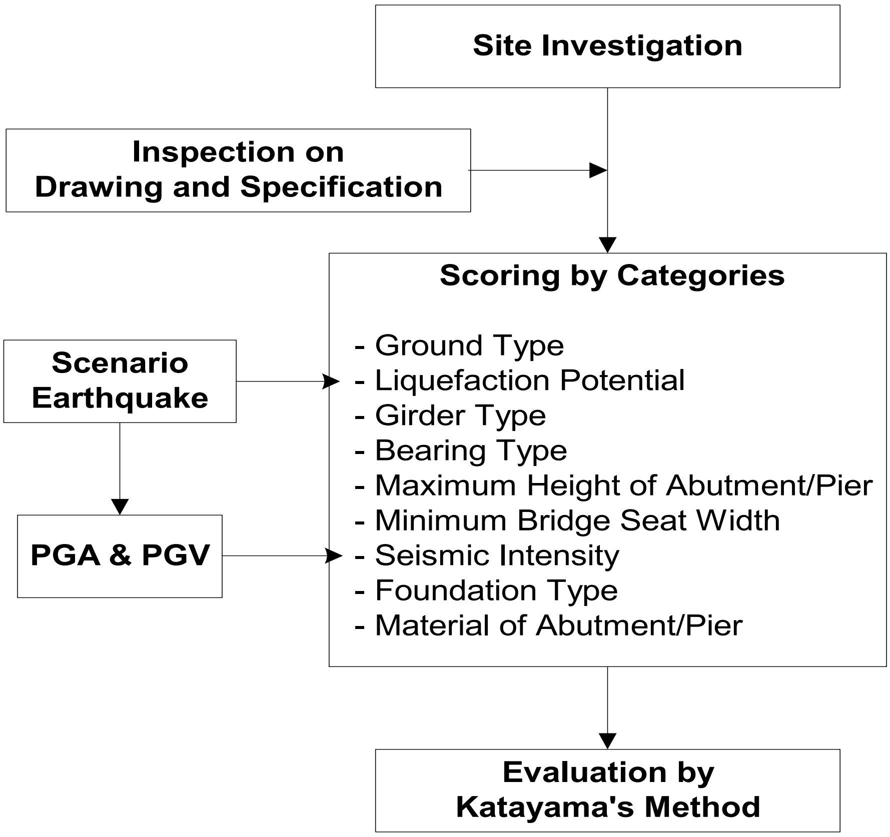


Figure 9.5.1 Schematic Drawing of Methodorogy

As shown in Figure 9.5.1, almost necessary data can be obtained by observing the bridges in site except a few exceptions. The foundation can be identified by the general drawing, the earthquake intensity, and probability of liquefaction, must be discussed by another way.

In Katayama's method, 10 items which are likely to affect the falling–off probability of the girder are studied. Each items consist of a few categories, they can be selected without complex calculations. The items, categories and category-score are shown in Table 9.5.2. The category-score is given to each category as a weighting factor. The category-score, which is modified by taking account of bridges in Istanbul is shown in this table.

Table 9.5.2 Items, Categories and Category-score

Item	Category		Category Score
Ground type	Stiff		0.5
	Medium		1.0
	Soft		1.5
	Very Soft		1.8
Probability of Liquifaction	Nothing		1.0
	Fear		1.5
	Having		2.0
Girder Type	1span	Arch or Rigid Frame	1.0
		Simple Beam	3.0
	2 or more span	Simple Beam	5.25
		Single Continues Girder	3.5
		more than one Continuous Girder	4.2
		Combination Of Continuous & Simple	6.3
Type of Bearing	with Specific Device (prevent falling-off of the girder)		0.6
	Bearing (with clear design concept)		1.0
	exist two bearing that can move axial deirection		1.15
Max. Height of Abut./Pier	less than 5 m		1.0
	5 to 10 m		1.35
	more than 10m		1.7
Min.Bridge Seat Width	Wide		0.8
	Narrow		1.2
JMA seismic intensity scale	5 (4.5 to less than 5.0)		1.0
	5.5 (5.0 to less than 5.5)		1.7
	6.0 (5.5 to less than 6.0)		2.4
	6.5 (6.0 to less than 6.5)		3.0
	7.0 (6.5 and more than 6.5)		3.5
Foundation Type	Spread		1.0
	Pile		0.9
Material of Abut./Pier	Masonry		1.4
	Reinforced Concrete		1.0

the evaluated result can be given by substituting the data to Eq. (9.2.1)

$$y_i = \prod_{j=1}^{N} \prod_{k=1}^{M_j} X_{jk}^{\delta_j(jk)} \qquad (9.2.1)$$

where,

y_i : Predictors of damage degrees of i -th bridges

N : Number of all items

M_j : Number of categories of j -th item

$\delta_i(jk)$: dummy variable

$\delta_i(jk)=1$: when the characteristics of the i -th bridge correspond to the category k in the item

$\delta_i(jk)=0$: otherwise

X_{jk} : category-score for k-th category of the j-th item

$\prod_{j=1}^{N}\cdot$: multiplication sign from j-th value to N-th value

If practical expression is needed, above mentioned procedure means followings;

"Select the value of particular category for each item, and multiply the scores one another".

The seismic intensity scale in this context means the scale that is defined by JMA "the seismological observatory Japan", not correspond to MMI. The JMA intensity is selected because Katayama's method is based on this scale originally.

The analysis that is based on 30 sample of damaged bridges that are observed at 3 earthquake (1923 Kanto, 1948 Fukui, 1964 Niigata) results following critical value.

- The fall-off samples and the not falling-off samples were differentiated in the grade point value of 30～35.
- All samples of falling-off and samples on the edge of fall-off differentiated in the grade point value of 26.

Therefore, the boundary value of Predictors of damage degrees for this study was set as follows;

	Class of damage degree	boundary value of *Predictors of damage degrees*
(A)	Large probability of falling-off	30 and more than 30
(B)	Modelate probability	26 to less than 30
(C)	Less probability	less than 26

480 bridges were investigated in this sudy. The distribution of *Predictors of damage degrees* are shown in Figure 7.4.2. 21 samples of *Modelate proberbility* and 4 samples of *Large proberbility of falling-off* were identified. A lot of samples were centered on the degree of 10.

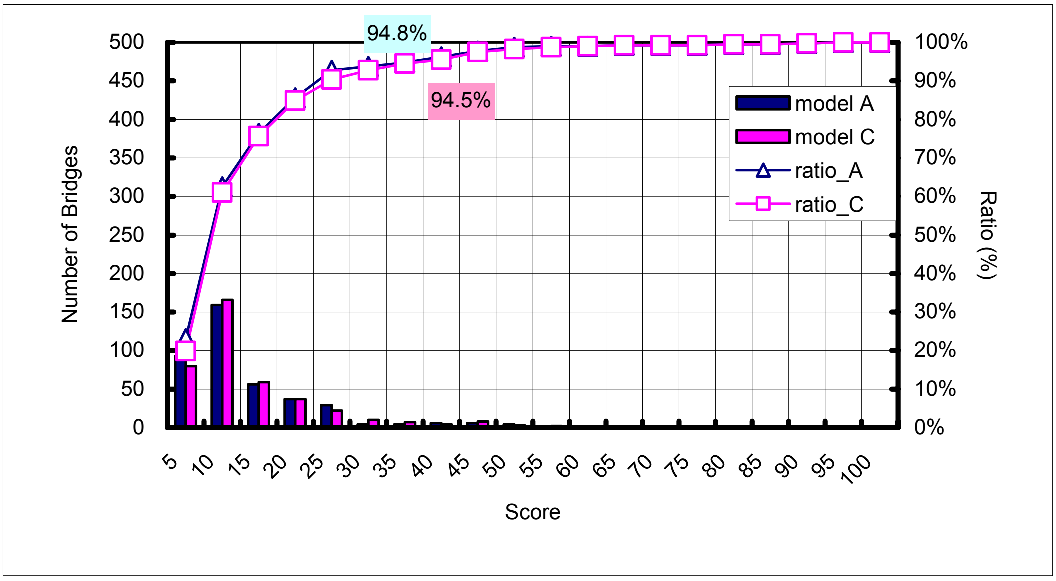


Figure 9.5.2 Distribution of *Predictors of Damage Degrees*

The list of the bridges that were evaluated as class (A) or (B) is shown in Table 9.5.3.

The two samples that does not belong class (A) or (B) is shown in Table 9.5.4., these two bridges are under following condition;

- Peak Ground Acceleration of the site is more than 300gal
- Height of pier is more than 10 m

The bridges shown in Table 9.5.3 and Table. Table 9.5.4 need to be done the next step detail investigation and reasonable earthquake resistant strengthening if necessary.

Table 9.5.3 Bridges that were evaluated as class (A) or (B)

BRIDGE No.	SOURCE	Ground type: Stiff	Ground type: Medium	Ground type: Soft	Ground type: Very Soft	Probability of Liquifaction: Nothing	Probability of Liquifaction: Fear	Probability of Liquifaction: Having	Girder Type, 1 Span: Arch or Rigid Frame	Girder Type, 1 Span: Simple Beam	Girder Type, 2 or more span: Simple Beam	Girder Type, 2 or more span: Single Continues Girder	Girder Type, 2 or more span: more than one Continuous Girder	Girder Type, 2 or more span: Combination Of Continuous Simple	Type of Bearing: with Specific Device	Type of Bearing: Bearing (with clear design concept)	Type of Bearing: exist two bearing that can move axial direction	Max. Height of Abut./Pier: less than 5 m	Max. Height of Abut./Pier: 5 to 10 m	Max. Height of Abut./Pier: more than 10m	Min. Bridge Seat Width: Wide	Min. Bridge Seat Width: Narrow	Foundation Type: Spread	Foundation Type: Pile	Material of Abut./Pier: Masonry	Material of Abut./Pier: Reinforced Concrete	REMARKS	JMA seismic: Model A	JMA seismic: Model C	Predictors of damage: Model A	Predictors of damage: Model C	Class of damage: Model A	Class of damage: Model C
52	17_region	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	1	0	1		6.0	6.1	93.7	93.7	A	A
188	17_region	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	1	0	1		6.0	6.1	89.8	89.8	A	A
89	17_region	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1		6.0	6.0	79.2	79.2	A	A
T5	TCDD	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1		6.1	6.1	62.0	62.0	A	A
57	17_region	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	0	1		5.9	6.0	47.9	59.9	A	A
AK5	IBB-Infra.coord Dpt	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	1	0	1		6.0	6.0	52.8	52.8	A	A
MT110	JICA	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	L	5.5	5.6	47.5	47.5	A	A
MT112	JICA	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	L	5.5	5.6	47.5	47.5	A	A
MT94	JICA	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	L	5.8	5.8	47.5	47.5	A	A
MT86	JICA	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	G,L	5.9	6.0	35.2	44.0	A	A
MT87	JICA	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	L	5.9	6.0	35.2	44.0	A	A
MT88	JICA	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	L	5.9	6.0	35.2	44.0	A	A
T4	TCDD	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	G,L	5.8	5.8	41.3	41.3	A	A
58	17_region	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	G,L	5.9	6.0	31.9	39.9	A	A
T28A	TCDD	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	G,L	5.8	5.9	35.2	35.2	A	A
T28B	TCDD	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	G,L	5.8	5.9	35.2	35.2	A	A
190	17_region	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	L	5.5	5.6	31.7	31.7	A	A
T33	TCDD	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	1	0	1	L	5.5	5.5	30.6	30.6	A	A
AK3	IBB-Infra.coord Dpt	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	1	G	5.9	6.0	24.1	30.2	C	A
AK4	IBB-Infra.coord Dpt	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	1	G,L	5.9	6.0	24.1	30.2	C	A
1	17_region	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	G	5.6	5.7	26.6	26.6	B	B
55	17_region	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	L	5.5	5.6	26.6	26.6	B	B
UAS17	IBB METRO	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	L	5.9	6.0	21.1	26.4	C	B
T30	TCDD	0	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	1		6.0	6.1	26.2	26.2	B	B

Table 9.5.4 Bridges (Peak Ground Acceleration of the site is more than 300gal, Height of pier is more than 10 m)

BRIDGE No.	SOURCE	JMA seismic intensity scale		Predictors of damage degrees		Class of damage degree	
		Model A	Model C	Model A	Model C	Model A	Model C
M1-3-A	IMM Mantanance	5.3	5.4	7.0	7.0	C	C
YIM5	IMM-construction	5.7	5.7	9.9	9.9	C	C

As mentioned above, Katayama's method can evaluate vulnerability reflecting both qualitative characteristics and quantitative characteristics of the bridges. For instance "configuration of girder type", "bearing", "foundation", and "material of pier abutment" represent qualitative characteristics.

It is reported that "configuration of girder type" can be effective factor to find the begining point of falling–off of the girder in the report of many earthquake disaster especialy "Kobe Earthquake".

As mentioned above the main purpose of Katayama's method is to differenciate the probability that the girder of the bridge fall-off. Another types of damage must be discussed using another method. i.e. damage of expansion joint failure of the girder and the crack of the pier

However it is effective to point out the bridges that have high risk, using this method as a first screening.

The statistical analysis of this method does not include the sample damaged by the ground surface displacement under the condition of faulting or land slide caused by faulting. Another discussion must be carried out if obvious evidence that indicate the possibility of faulting.

9.5.2. Indication of a controversial point

The number of the bridges that is evaluated as "Large proberbility of falling-off: more than 30 point" is 20. However detail explanation for each bridges is needed, and specific condition of Istanbul's bridges must be explained. Therefore each of them will be descrived as follws even though it is for 5 examples.

(1) No.52 (Score; 93.7)





The evaluated result of this bridge shows the highest score 93.7, but some explanation is needed for this example. The reason why this bridge possesses the highest value is "there are a combination of single span of the girder and continuous girder" and "the pier is very high". Some possibility of collision between continuous girder that has very large mass and single span of girder that has comparatively light mass. The girder that has lagrer mass compared with single span of the girder can give a large impact to the single span of the girder. Therefore careful discussion is needed considering collision. The falling-off prevention device can be effective for this situation as mentioned later.

(2) No.188 (Score; 89.8))

The evaluated result of this bridge is 89.8. The reason why this bridge possesses the high value is that this bridge is composed of simple beam of the girder and that pier is comparatively high. The collision between each girder can cause contingent boost of displacement and falling-off of the girder.

(3) No.89 (Score; 79.2)

The evaluated result of this bridge is 79.2. The reason why this bridge possesses the high value is that this bridge is composed of simple beam of the girder and that pier is comparatively high.

(4) T5 (Score; 62.0)

The evaluated result of this bridge is 62.0. The reason why this bridge possesses the high value is that this bridge is composed of simple beam of the girder. In addition two bearings on the pier allow relative displacement of the girder face to face. This kind of bearing condition can cause very large relative displacement, because neighboring pier may have two bearings, which do not allow relative displacement of the girder face to face. These two kinds of structure parts have very different natural period, so there can be large relative displacement of the girder.

However the neighboring under parts of structure are abutment which is bonded on the earth, so the natural period of the abutment can not be so long. This is a few exception which is assessed excessively severe in Ktayama's method, but this kind of bearing condition must be cautioned.

(5) No.57 (Score; 59.9)

However the void between the girder end and the face of abutment is comparatively large, so there may not be a collision in this part.

The void between each girder end on the pier could not be identified in this study. If that void is kept reasonably the problem of collision can be prevented. Regarding the Minimum Seat Width, if the width is kept reasonably the problem of falling-off of the girder can be prevented.

Enyhow some kind of falling-off prevention device that bind neighboring girder is needed to discussed on this bridge.

9.5.3. Recommendation on earthquake resistant strengthening

(1) Basic point

There can be some practical difference between the bridge design and building design even though basic principle of them are the same. The reason of difference are;

1) All of the bridges are public facilities in contrast that most of the building are owned by each person.

2) Very high level of function is required for the bridged at the rescue operations and reconstruction of the city.

3) The earthquake resistance of the bridges have to be guaranteed obviously by design.

Taking in account of above points counter・measure that is different from the one for building design is needed.

Regarding the intensity of earthquake to be targeted; it is same as the one for building design.

1) The intensity of earthquake in Istanbul caused by the 1999 Izmit Earthquake.

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) Basically keep the structure as operational.

If some incidental damage occur it has to be repaired rapidly (within 1 or 2 days).

Elastic design method may be applied.

c) Damage must be controlled for preventing excessive reduction of the bridge.

Sufficient ductility must be retained even though some yielding allowed at some part of the structure. This type of design method is called "Capacity Design". In that method some plastic hinge is set in the structure model, then stability of whole structure and displacement is discussed.

Some reasonable correspondence between *intensity of earthquake* and *counter measure* is selected in Table 9.5.5.

Table 9.5.5 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 Occasional Eartquake		Linear Design	
③ Very Rare Earthquake			Capacity Design

If bridge is designed taking into accout of the earthquake, which is showed in Table 9.5.5 as "(3) Very Rare Earthquake", it is not so effective to get strength solely. There can be some case in which seismic isolation or dynamic structure control give effective solution. However some discussion regarding the cost performance must be needed because of their high-priced device. An example of seismic isolation device named "Lead rubber bearing" is shown in Figure 9.5.3.

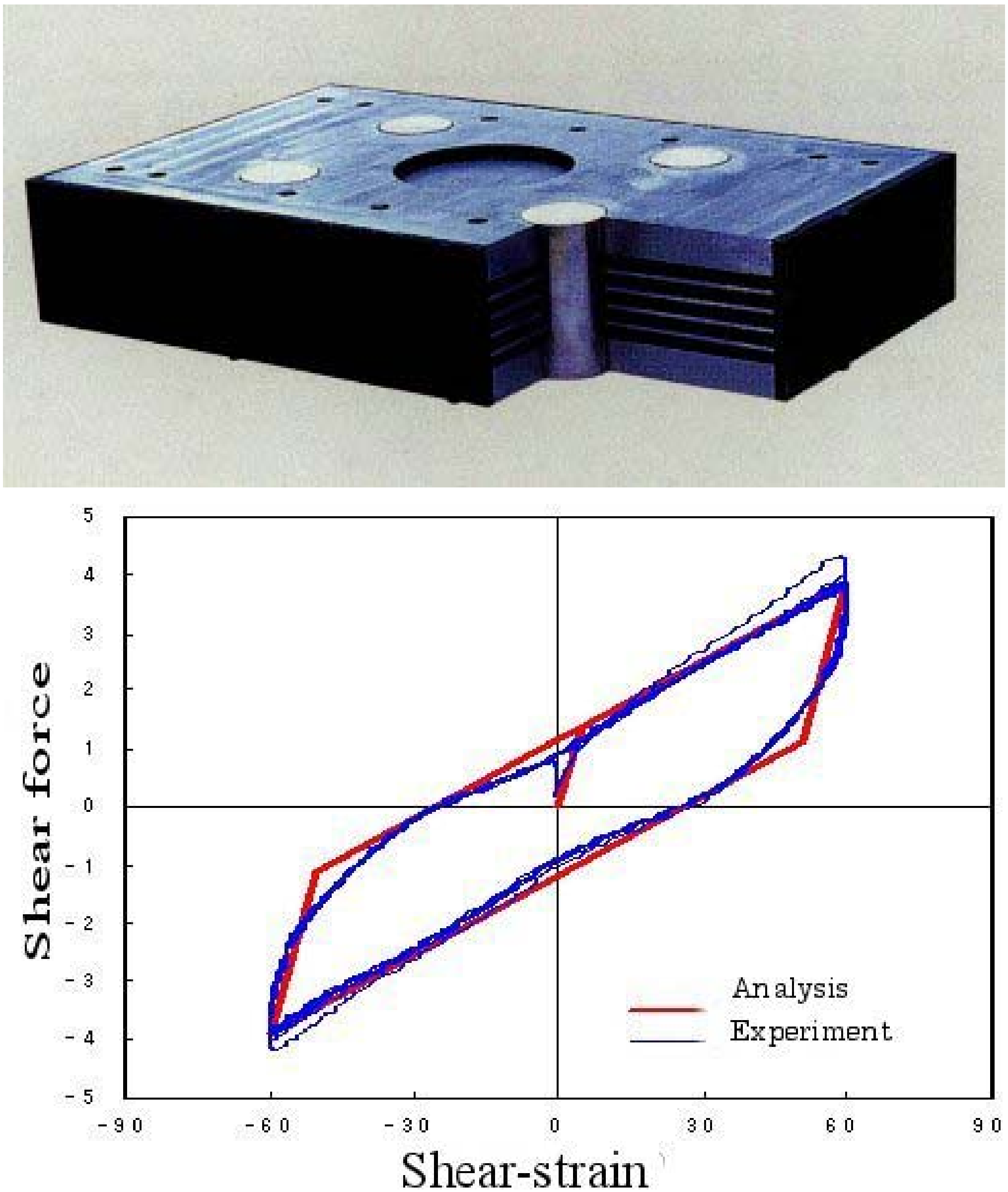


Figure 9.5.3 An Example of Seismic Isolation Device (Lead Rubber Bearing)

(2) Countermeasure on designing

Basically, the drawings and specifications of every bridge must be kept by Competent Authority, and that must follow the present earthquake resistant design code of bridges. For this purpose appropriate design code for bridges must be discussed and established, because there is not the code, which contain practical design rule of bridge yet in Turkey. The failure at detail design can cause severe damage as shown in many previous disaster reports.

The design earthquake criterion that is defined in "Specification for Structures to be Built in Disaster Areas (PART III - EARTHQUAKE DISASTER PREVENTION)" give realistic suggestion, but further detail discussion is needed regarding *Structural Behavior Factors*, (**R**).

This factor is prepared in order that linear analysis can be applied as a simplified method even if the design earthquake criterion is so large that non-linear analysis is needed.

However this kind of simplified method cannot give sufficiently certain guaranty for severe earthquake, because the earthquake motion probable in Istanbul is larger than the design earthquake that is defined in present code.

Applying the capacity design method should be discussed in order to make safety of the bridges under ultimate limit state certain, taking into account the important role of the bridges under severe earthquake. When the design earthquake for this discussion is required the earthquake motion that is assumed in this study as a scenario earthquake can give effective suggestion.

(3) Urgent countermeasure

The important points for strengthening the bridges are certain design method and execution management. Considerably long term is needed to improve the design method and execution management, because sufficient discussion and corroboration of experiment is required. On the other hand, there can be some effective measure that can be done urgently as follows;

a. Bridge inventory

It is needed to make the bridge inventory written in certain form, and that must include entire information, which is effective for discussion about earthquake resistant and daily maintenance.

When there are some old bridges that enough information can not be found necessary investigation has tobe carried out.

b. In case effective measure is possible without difficult discussion

In case effective measure is possible without difficult discussion quick construction of retrofit should be done. Case in point may be found in "Falling-off prevention system" defined by Specifications for highway bridges in Japan in Japan. "Falling-off prevention system" is composed of following three components

1) Extension of seat width on pier cap

2) Control of relative displacement between girder and pier/abutment

3) Control of relative displacement between girder and ajoining girder

The worst situation of bridge damage is the falling-off of the girder. The bridge can resume urgent service if the falling-off of the girder is prevented.

Urgent service can be maintained by covering the void between the girder and ajoining girder with steel plate and asphalt even if the edge of the girder was destructed by excessive displacement under earthquake motion.

Even if the serious crack is generated on the pier and the load carrying capacity is reduced supporting the girder with sadndle can give the next best solution for urgent use.

Following is the schematic drawing of "Falling-off prevention system" in Japan. Figure 9.5.4 shows some typical sample of that device.

Figure 9.5.5 explains the effect at each stage of the earthquake intensity. Figure 9.5.6 shows an example, in which relative displacement between the girder and ajoining girder is controlled by damper with specially equipped viscous material.

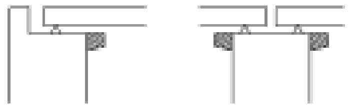
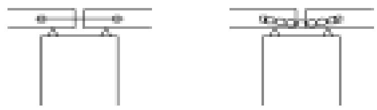
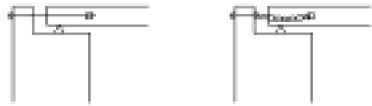
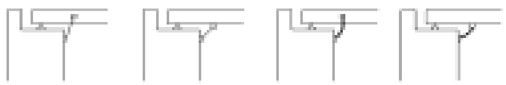
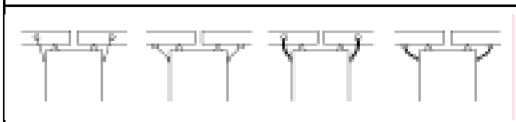
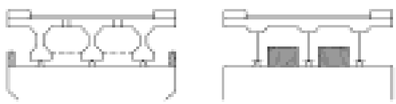
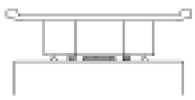
					Material	Schematic Configration	Remark
Regarding longitadinal direction	Widening of Seat width				R/C or Steel plate		Adding Bracket
Regarding longitadinal direction	Fall-off prevention device	Connecting device between girder and adjoining girder			P/C Strand or Steel chain		
Regarding longitadinal direction	Fall–off prevention device and Relative displacement control	Connecting girder and substructure	Abutment	Connecting girder and parapet	P/C Strand or Steel chain		
Regarding longitadinal direction	Fall–off prevention device and Relative displacement control	Connecting girder and substructure	Abutment	Connecting girder and Substructure	P/C Strand or Steel chain		Attach to girder side or under surface
Regarding longitadinal direction	Fall–off prevention device and Relative displacement control	Connecting girder and substructure	Pier	Connecting girder and Substructure	P/C Strand or Steel chain		Attach to girder side or under surface
Regarding longitadinal direction	Fall–off prevention device and Relative displacement control	Bulge	Bulge on substructare		R/C or Steel plate		
Regarding longitadinal direction	Fall–off prevention device and Relative displacement control	Bulge	Conbination of bulge		R/C or Steel plate		
Transrerse direction	Fall–off prevention device and Relative displacement control	Bulge	Bulge on substructure		R/C or Steel plate		Outside or inside of girder
Transrerse direction	Fall–off prevention device and Relative displacement control	Bulge	Conbination of bulge		R/C or Steel plate		
Adding of landing space		Landing space on substructure			R/C or Steel plate		

Figure 9.5.4 Typial Sample of “Falling-off Prevention System”

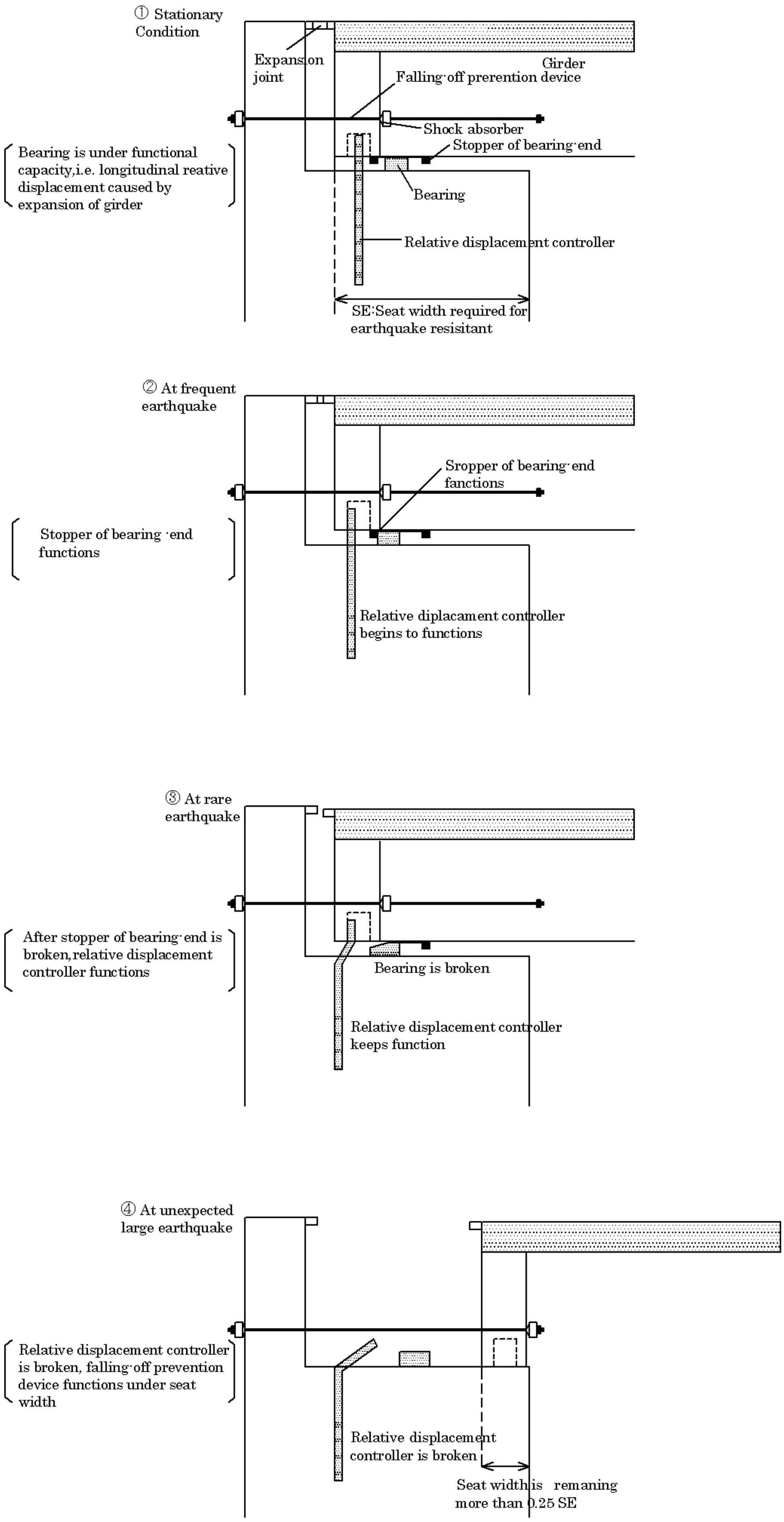


Figure 9.5.5 Explanation of the Effect at Each Stage of the Earthquake Intensity

Figure 9.5.6 An Example of Displacement Controlling by Damper