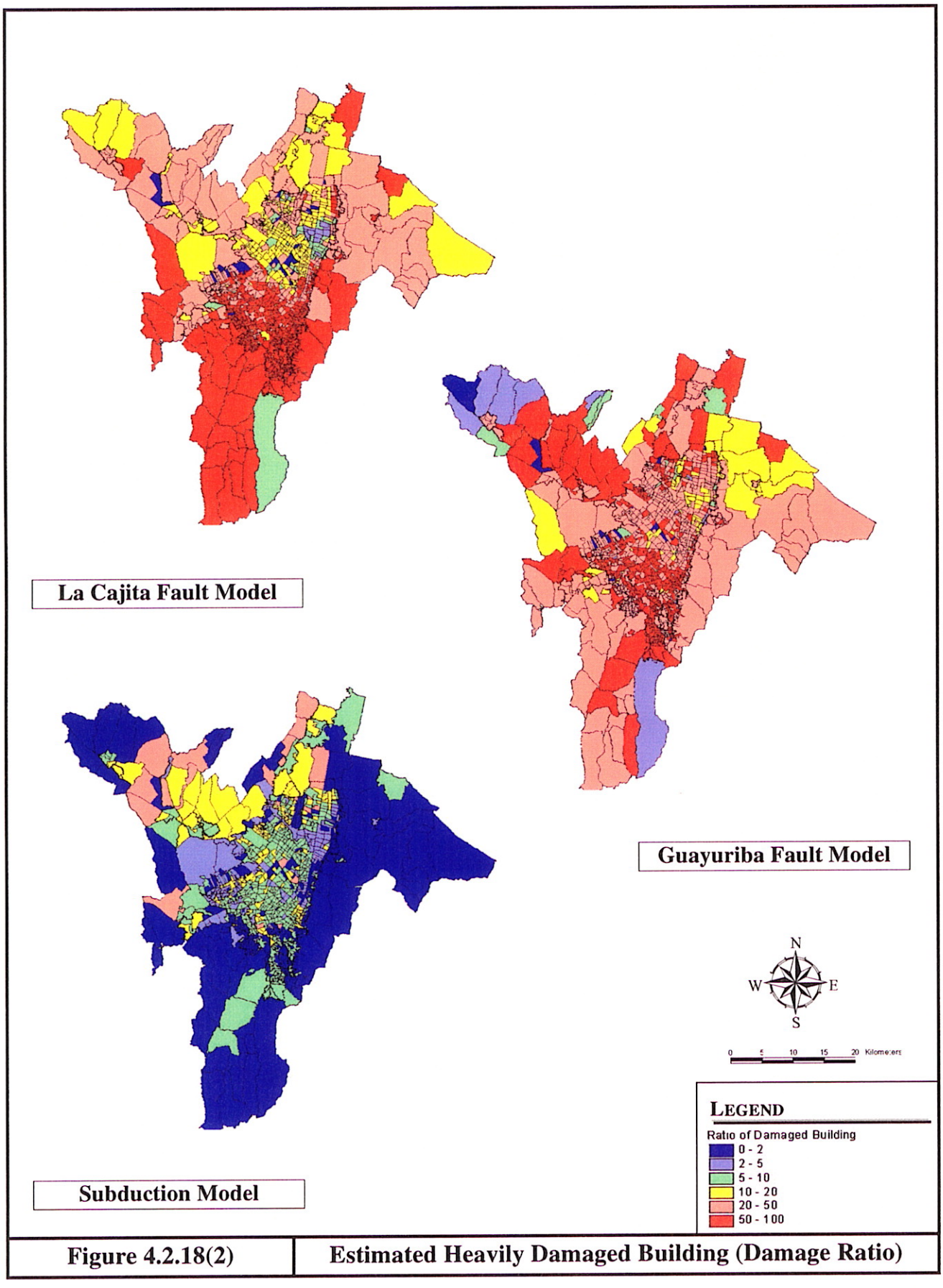


Figure 4.2.18(2) | **Estimated Heavily Damaged Building (Damage Ratio)**

Table 4.2.16 Summary of Building Damage

		Case 1		Case 2		Case 3	
		Heavily Damaged Building		Heavily Damaged Building		Heavily Damaged Building	
	Locality or Municipality	Number (nos)	Ratio (%)	Number (nos)	Ratio (%)	Number (nos)	Ratio (%)
Bogotá	Usaquén	11,070	2.8%	14,697	3.5%	2,404	3.9%
	Chapinero	5,771	1.4%	5,158	1.2%	481	0.8%
	Santa Fe	10,418	2.6%	8,232	2.0%	1,035	1.7%
	San Cristobal	43,281	10.8%	30,561	7.2%	2,506	4.1%
	Usme	33,740	8.4%	27,135	6.4%	2,305	3.7%
	Tunjuelito	13,959	3.5%	12,995	3.1%	2,144	3.5%
	Bosa	25,666	6.4%	28,442	6.7%	3,466	5.6%
	Kennedy	46,229	11.6%	49,964	11.8%	7,387	11.9%
	Fontibón	4,153	1.0%	11,269	2.7%	2,217	3.6%
	Engativá	11,873	3.0%	35,197	8.3%	6,796	11.0%
	Suba	16,786	4.2%	37,336	8.8%	7,628	12.3%
	Barrios Unidos	4,854	1.2%	13,242	3.1%	2,642	4.3%
	Teusaquillo	4,089	1.0%	7,365	1.7%	1,144	1.9%
	Mártires	7,500	1.9%	7,285	1.7%	937	1.5%
	Antonio Nariño	7,273	1.8%	7,153	1.7%	932	1.5%
	Puente Aranda	18,575	4.7%	18,697	4.4%	2,493	4.0%
	La_Candelaria	2,122	0.5%	1,925	0.5%	287	0.5%
	Rafael Uribe	38,244	9.6%	29,062	6.9%	3,066	5.0%
	Ciudad Bolívar	55,569	13.9%	31,870	7.6%	2,038	3.3%
	Sub Total	**362,072**	**90.7%**	**377,585**	**89.5%**	**51,908**	**84.0%**
Cundinamarca	Chia	3,725	0.9%	8,014	1.9%	2,370	3.8%
	Cota	1,460	0.4%	2,447	0.6%	722	1.2%
	Facatativa	5,078	1.3%	5,325	1.3%	1,372	2.2%
	Funza	1,555	0.4%	3,329	0.8%	897	1.5%
	La Calera	1,746	0.4%	1,435	0.3%	71	0.1%
	Madrid	2,089	0.5%	4,069	1.0%	1,240	2.0%
	Mosquera	1,329	0.3%	2,436	0.6%	486	0.8%
	Soacha	20,330	5.1%	17,349	4.1%	2,763	4.5%
	Sub Total	**37,312**	**9.3%**	**44,404**	**10.5%**	**9,921**	**16.0%**
	Total	**399,384**	**100.0%**	**421,989**	**100.0%**	**61,829**	**100.0%**

D. Discussion

a) Heavily damaged buildings

Due to the estimated damages, the ratios of the heavily damaged buildings are between 45% and 48% in the case of near and medium distance earthquakes, of which the building damage ratio is much higher than the results of the previous study.

In the case of near earthquake, the damage ratio is rather high in the southern part of the Bogotá City Area. These are both attributed to the higher earthquake intensity and lower seismic performance defined in this Study than those by the previous study.

(2) Human casualty

A. Collected data

As mentioned in (4) collected data for estimation, human casualties have been calculated based on the building data and population data.

B. Methods and procedure

a) Procedure

The human casualties are estimated based on the flowchart shown in Figure 4.2.19.

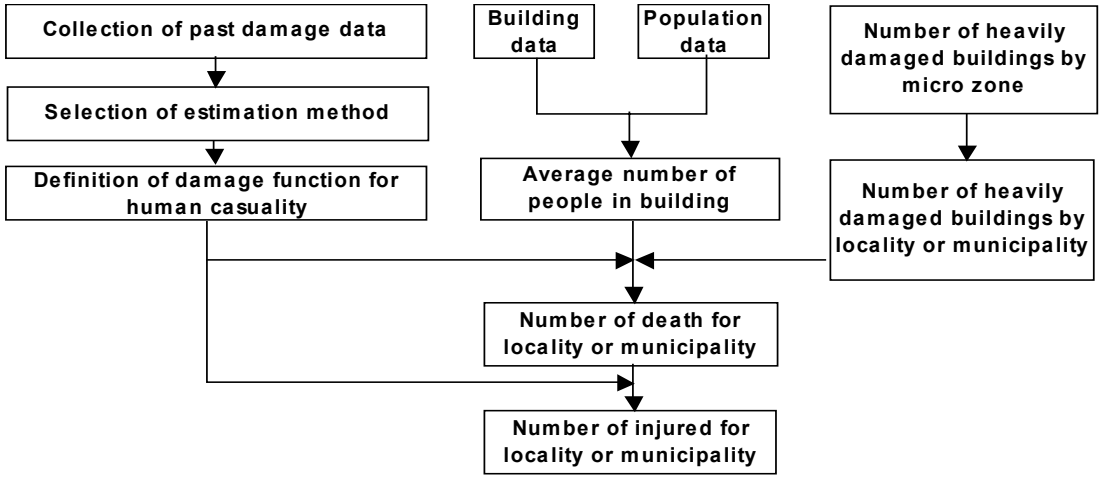


Figure 4.2.19 Flowchart of Human Casualty Estimation

b) Human deaths

This Study defines human deaths in an earthquake as number of victims by building damages.

The relation between the number of deaths and the number of heavily damaged buildings is based on the study by DANE on the 1999 Quindio earthquake. These numbers are in good correlation as shown in Figure 4.2.20. Therefore, following equation is proposed to estimate the human deaths due to the building damages in the Study Area.

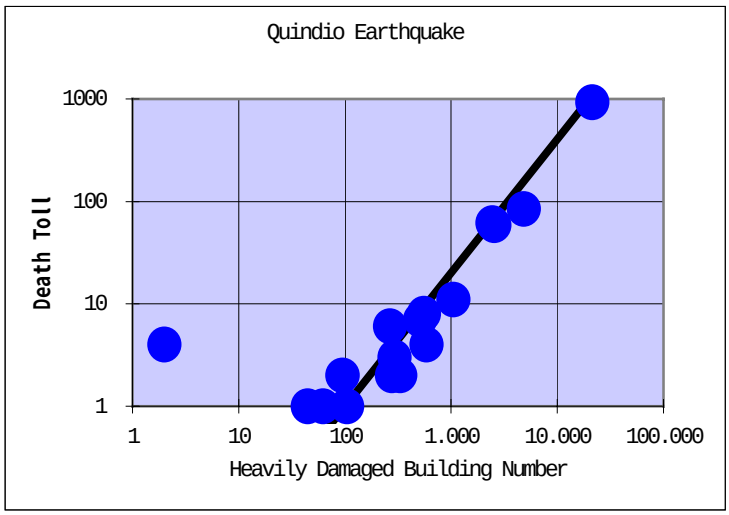


Figure 4.2.20 Heavily Damaged Buildings and Death Toll Relationship

Log Y = 1.3029 log X – 2.6039.

Where Y: Number of Deaths.

X: Number of Heavily Damaged Buildings.

c) Humans Injured

The relationship between number of Deaths and Injured is also obtained from Figure 4.2.20, and expressed in the Figure 4.2.21. Referring to the figure, the relationship between deaths and casualties is formulated by the following equation:

Log Y = 0.9824 log X + 0.9031.

Where Y: Number of Injured.

X: Number of Deaths by heavily damaged buildings.

In this study, the relationship above is adopted for estimation of the number of human casualties due to the building damages.

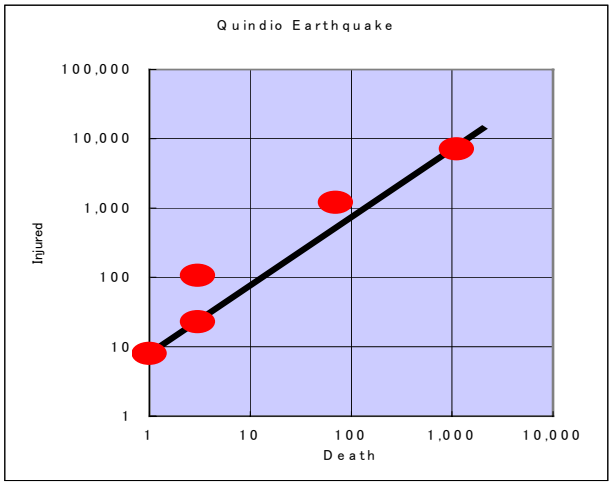


Figure 4.2.21 Relationship between Number of Deaths and Injured

C. Results of estimation

Following table and figure shows the results of estimation.

Table 4.2.17 Results of Estimation

		Case 1				Case 2				Case 3			
		Human Death		Human Injury		Human Death		Human Injury		Human Death		Human Injury	
	Locarity or Municipality	Number (persons)	Ratio (%)	Number (persons)	Ratio (%)	Number (persons)	Ratio (%)	Number (persons)	Ratio (%)	Number (persons)	Ratio (%)	Number (persons)	Ratio (%)
Bogota	Usaquen	1,081	2.8%	7,651	2.8%	1,564	3.9%	10,996	3.9%	148	4.5%	1,083	4.4%
	Chapinero	336	0.9%	2,426	0.9%	290	0.7%	2,101	0.7%	13	0.4%	101	0.4%
	Santa Fe	642	1.6%	4,580	1.7%	472	1.2%	3,388	1.2%	32	1.0%	238	1.0%
	San Cristobal	5,104	13.0%	35,136	12.9%	3,243	8.0%	22,507	8.0%	125	3.8%	916	3.8%
	Usme	3,027	7.7%	21,028	7.7%	2,279	5.6%	15,911	5.7%	92	2.8%	678	2.8%
	Tunjuelito	1,544	3.9%	10,854	4.0%	1,406	3.5%	9,904	3.5%	134	4.1%	987	4.1%
	Bosa	2,529	6.4%	17,629	6.5%	2,892	7.2%	20,106	7.1%	186	5.7%	1,359	5.6%
	Kennedy	6,564	16.7%	44,985	16.5%	7,263	18.0%	49,688	17.6%	602	18.4%	4,302	17.7%
	Fontibón	299	0.8%	2,162	0.8%	1,097	2.7%	7,757	2.8%	132	4.0%	968	4.0%
	Engativá	1,014	2.6%	7,181	2.6%	4,177	10.3%	28,859	10.2%	490	15.0%	3,516	14.4%
	Suba	1,460	3.7%	10,273	3.8%	4,134	10.2%	28,582	10.2%	522	16.0%	3,743	15.4%
	Barrios Unidos	213	0.5%	1,552	0.6%	788	1.9%	5,608	2.0%	97	3.0%	713	2.9%
	Teusaquillo	269	0.7%	1,947	0.7%	446	1.1%	3,205	1.1%	39	1.2%	296	1.2%
	Mártires	378	1.0%	2,727	1.0%	364	0.9%	2,627	0.9%	25	0.8%	190	0.8%
	Antonio Nariño	428	1.1%	3,076	1.1%	419	1.0%	3,011	1.1%	29	0.9%	222	0.9%
	Puente Aranda	1,497	3.8%	10,529	3.9%	1,510	3.7%	10,617	3.8%	109	3.3%	805	3.3%
	La Candelaria	115	0.3%	843	0.3%	101	0.2%	744	0.3%	8	0.3%	65	0.3%
	Rafael Uribe	3,848	9.8%	26,622	9.8%	2,691	6.7%	18,733	6.7%	144	4.4%	1,053	4.3%
	Ciudad Bolivar	7,280	18.5%	49,806	18.3%	3,528	8.7%	24,448	8.7%	98	3.0%	724	3.0%
	Sub Total	**37,627**	**95.9%**	**261,005**	**95.7%**	**38,667**	**95.6%**	**268,792**	**95.5%**	**3,026**	**92.7%**	**21,959**	**90.2%**
Cundinamarca	Chia	85	0.2%	628	0.2%	230	0.6%	1,674	0.6%	47	1.4%	352	1.4%
	Cota	23	0.1%	177	0.1%	46	0.1%	343	0.1%	9	0.3%	72	0.3%
	Facatativá	227	0.6%	1,650	0.6%	241	0.6%	1,753	0.6%	41	1.3%	309	1.3%
	Funza	45	0.1%	334	0.1%	120	0.3%	885	0.3%	22	0.7%	165	0.7%
	La Calera	47	0.1%	349	0.1%	36	0.1%	272	0.1%	1	0.0%	6	0.0%
	Madrid	60	0.2%	443	0.2%	142	0.4%	1,040	0.4%	30	0.9%	227	0.9%
	Mosquera	23	0.1%	175	0.1%	51	0.1%	381	0.1%	6	0.2%	48	0.2%
	Soacha	1,112	2.8%	7,865	2.9%	905	2.2%	6,420	2.3%	83	2.5%	611	2.5%
	Sub Total	**1,622**	**4.1%**	**11,621**	**4.3%**	**1,771**	**4.4%**	**12,768**	**4.5%**	**239**	**7.3%**	**1,790**	**7.4%**
	Total	**39,249**	**100.0%**	**272,626**	**100.0%**	**40,438**	**100.0%**	**281,560**	**100.0%**	**3,265**	**100.0%**	**24,349**	**100.0%**

D. Discussion

Approximately forty thousand would be killed by the heavy damage of the buildings in the cases of near and medium distance earthquakes. In the case of near earthquake, high death percentages are in the southern localities.

However, in the case of medium distance earthquake, the casualties are distributed in the whole Study Area, that necessitates urgent countermeasures against earthquake disasters.

(3) Lifeline

The following 4 types of lifelines are to be estimated:

- Water supply pipelines.
- Gas pipelines.
- Electric power supply cables.
- Telecommunications cables.

The lifeline facilities are to be classified into two major categories, namely, nodes and links. Nodes include facilities such as purification plants and substations. Links include facilities such as pipes or lines for supply and distribution purposes.

A. Water supply pipeline

a) Collected data

Water pipeline GIS or CAD data for the whole area in Bogotá and urban area in the eight municipalities in Cundinamarca are provided from EAAB. Rural area in Cundinamarca was not studied because the data was not available.

Provided data includes information on service network, mostly including pipe diameter between 1 and 78 inches, and pipe material. However, the data excludes pipelines to individual buildings.

The collected data is classified by material as shown in Table 4.2.18, and by diameter as shown in Table 4.2.19. Details of the data compilation procedure are described in Appendix 4.2.6.

Note that proportion of pipe material type is different between Bogotá and municipalities in Cundinamarca. This difference would come from the pipeline installation age, because Cundinamarca has installed later than Bogotá.

Table 4.2.18 Distribution of Water Pipeline by Material

	Locarity or Municipality	Asbest-cement pipe (ACP)	Cast Iron (CIP)	Galvanized iron (SP)	Polyvinyl-chloride pipe (VP)	Reinforced Concrete (ACP)	Steel (SP)	Steel Iron (SP)	Unknown	Sum (m)	Sum (%)
Bogota	Usaquen	369,002	2,209	377	75,457	11,008	5,224	0	24,977	488,253	7.2
	Chapinero	159,138	6,623	25,257	47,119	1,557	4,482	1,780	7,648	253,606	3.7
	Santa Fe	134,311	1,245	9,866	5,566	28,998	407	0	3,511	183,903	2.7
	San Cristobal	278,913	3,670	15,463	64,001	26,501	418	619	4,758	394,344	5.8
	Usme	126,166	227	168	29,536	5,481	0	1,932	919	164,430	2.4
	Tuenjuelito	145,691	1,431	4,173	6,134	6,974	0	3,596	41	168,040	2.5
	Bosa	198,614	0	802	46,226	13,995	0	0	1,019	260,657	3.8
	Kennedy	510,429	580	2,127	115,990	34,077	0	2,499	3,020	668,722	9.8
	Fontibón	233,865	1,196	6,378	15,979	19,435	0	0	3,570	280,423	4.1
	Engativá	509,134	1,894	8,693	61,036	27,984	0	0	6,919	615,661	9.1
	Suba	357,034	17	524	301,663	21,966	5,820	0	29,889	716,915	10.6
	Barrios Unidos	192,104	8,211	34,615	27,986	3,907	3,619	13	2,062	272,517	4.0
	Teusaquillo	181,891	7,465	32,110	17,084	17,409	939	205	12,714	269,816	4.0
	Mártires	140,094	4,535	34,341	478	9,223	299	0	395	189,365	2.8
	Antonio Nariño	95,520	5,066	20,829	5,565	5,658	0	2,374	291	135,302	2.0
	Puente Aranda	345,323	9,098	15,980	23,727	21,969	0	11	1,902	418,009	6.2
	La Candelaria	42,089	142	2,703	399	8,852	15	0	1,431	55,631	0.8
	Rafael Uribe	233,398	4,962	34,195	40,226	10,676	0	9,715	518	333,689	4.9
	Ciudad Bolivar	293,808	0	3,842	61,351	16,669	0	689	7,803	384,162	5.7
	Sub-total (m)	4,546,525	58,571	252,443	945,522	292,340	21,222	23,432	113,388	6,253,444	92.1
	(%)	72.7	0.9	4.0	15.1	4.7	0.3	0.4	1.8	100.0	
Cundinamarca	Chia	0	0	0	141,785	0	0	0	576	142,361	2.1
	Cota	0	0	0	0	0	0	0	15,903	15,903	0.2
	Facatativá	0	0	0	0	0	0	0	25,697	25,697	0.4
	Funza	26,736	172	0	38,614	0	0	0	1,436	66,958	1.0
	La Calera	0	0	0	18,661	0	0	0	0	18,661	0.3
	Madrid	31,438	244	0	17,564	0	0	0	623	49,869	0.7
	Mosquera	16,559	0	0	22,406	1,723	0	0	2,830	43,519	0.6
	Soacha	119,580	0	7,478	33,505	11,234	0	0	1,282	173,080	2.5
	Sub-total (m)	194,314	415	7,478	272,535	12,957	0	0	48,349	536,048	7.9
	(%)	36.2	0.1	1.4	50.8	2.4	0.0	0.0	9.0	100.0	
	Total (m)	4,740,839	58,987	259,921	1,218,057	305,296	21,222	23,432	161,736	6,789,491	100.0
	(%)	69.8	0.9	3.8	17.9	4.5	0.3	0.3	2.4	100.0	

Source: EAAB

Table 4.2.19 Distribution of Water Pipeline by Diameter

	Locarity or Municipality	D is bigger than 500mm	D is 200 - 500mm	D is 100 - 200mm	D is samller than 100mm	Sum (m)	Sum (%)
Bogota	Usaquén	42,264	58,205	189,153	198,632	488,253	7.2
	Chapinero	10,341	45,813	128,944	68,508	253,606	3.7
	Santa Fe	25,220	34,762	64,126	59,795	183,903	2.7
	San Cristobal	28,343	56,720	90,834	218,447	394,344	5.8
	Usme	10,015	9,340	42,237	102,838	164,430	2.4
	Tunjuelito	6,577	21,796	52,390	87,277	168,040	2.5
	Bosa	11,666	21,715	78,534	148,741	260,657	3.8
	Kennedy	23,227	79,513	215,692	350,290	668,722	9.8
	Fontibón	15,423	50,962	101,517	112,521	280,423	4.1
	Engativá	25,328	91,809	237,891	260,632	615,661	9.1
	Suba	46,249	114,783	261,025	295,108	717,165	10.6
	Barrios Unidos	12,138	32,640	108,317	119,421	272,517	4.0
	Teusaquillo	19,745	34,947	123,246	91,878	269,816	4.0
	Mártires	7,023	28,746	64,545	89,051	189,365	2.8
	Antonio Nariño	5,093	20,849	40,878	68,482	135,302	2.0
	Puente Aranda	20,721	72,159	163,084	162,045	418,009	6.2
	La Candelaria	6,598	13,803	23,129	12,101	55,631	0.8
	Rafael Uribe	10,708	37,804	114,064	171,114	333,689	4.9
	Ciudad Bolivar	21,362	47,111	112,504	203,185	384,162	5.7
	Sub-total (m)	348,041	873,475	2,212,110	2,820,066	6,253,693	92.1
	(%)	5.6	14.0	35.4	45.1	100.0	
Cundinamarca	Chía	963	10,775	31,482	99,141	142,361	2.1
	Cota	0	0	822	15,081	15,903	0.2
	Facatativá	0	13,453	10,753	1,492	25,697	0.4
	Funza	1,436	8,139	13,497	43,885	66,958	1.0
	La Calera	0	554	2,907	15,201	18,661	0.3
	Madrid	623	6,814	15,047	27,384	49,869	0.7
	Mosquera	4,553	3,779	11,425	23,762	43,519	0.6
	Soacha	8,964	18,213	55,208	90,695	173,080	2.5
	Sub-total (m)	16,540	61,727	141,140	316,640	536,048	7.9
	(%)	3.1	11.5	26.3	59.1	100.0	
	Total (m)	364,581	935,202	2,353,251	3,136,706	6,789,741	100.0
	(%)	5.4	13.8	34.7	46.2	100.0	

Source: EAAB

b) Methods and procedures

Assumptions

Following are the basic assumptions applied for estimation of water supply pipelines and gas pipelines.

A statistical approach for damage estimation of links, i.e. distribution pipes and lines, is applicable only when information on their structures and lengths is available in any given area. This approach was used in the Study.

- Node facilities are not included for damage estimation, such as water purification plant, gas tank, electric power generator, transformer station, telephone station. Individual diagnosis should be made on such node facilities to evaluate safety against earthquakes.
- Damage due to the direct result of ground motion is estimated, such as breakage or disjoint of pipelines. Secondary damages such as the damages caused by landslides or building collapses are not included.
- Results are considered as a statistical representation in a given area.
- Damage estimation method is in principle based on the past damage experiences.
- In cases when proper data is not available, input data are set based on reasonable assumptions. Thus precision of the results is dependent on the quality of the input data.

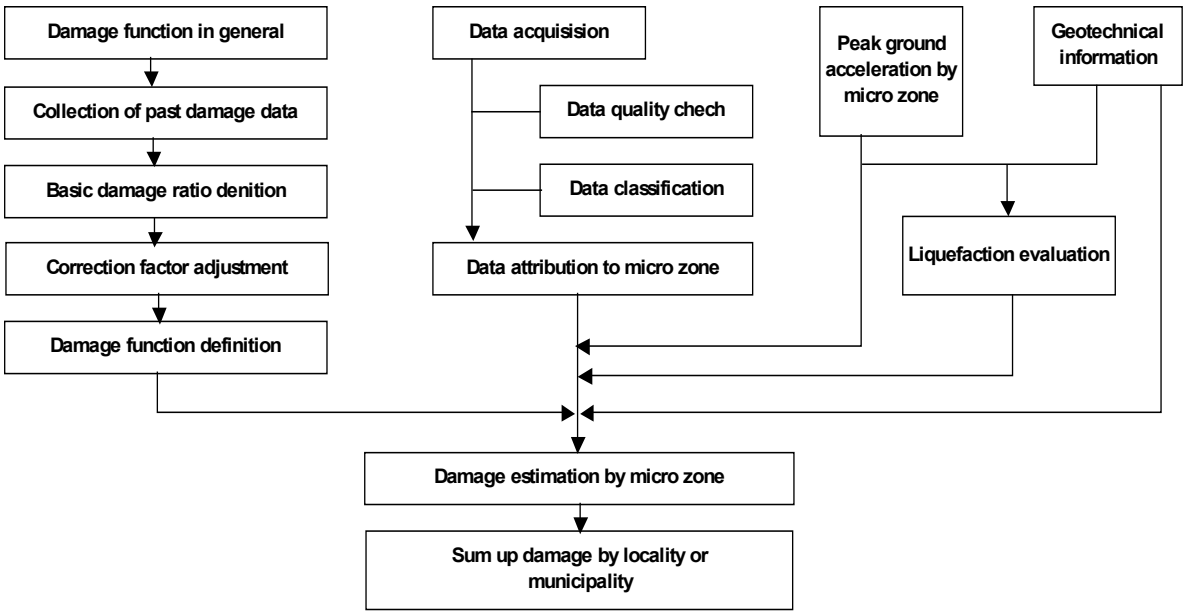


Figure 4.2.22 Flowchart of Damage Estimation for Water and Gas Pipelines

c) Damage function

Except for a few quantitative studies, no quantitative studies on seismic damages for lifeline facilities were available in the Study Area.

The characteristics of water supply networks and pipeline structures are considered similar to those of Japan. Although the strength of the pipeline materials is not much different from that of Japan, it is considered that the quality of construction of the joints always leads to problems. Therefore, an analysis method for the damage estimation of water pipelines as well as gas pipelines proposed by Japan Waterworks Association, which is widely used in Japan, was applied to the Study, taking account of the experience in Armenia earthquakes. However, it is considered that the damages will be more serious than those estimated.

In Japan, the standard damage ratio R(a) for water pipeline proposed by Kubo and Katayama (1975)[4-2-1] has been commonly used to evaluate seismic damages of water pipelines. The damage ratio for pipeline $R_m(a)$ is defined as follows:

$$R_m(a) = C_p \times C_d \times C_g \times C_l \times R(a).$$

Where,

R(a) : standard damage ratio (damaged points/km).

Cp : correction factor for pipe material.

Cd : correction factor for pipe diameter.

Cg : correction factor for topography and ground.

Cl : correction factor for liquefaction.

A : peak ground acceleration (gal).

Japan Waterworks Association[4-2-2] (1996) compiled relationship between damage ratio of pipelines and PGA value based upon actual observation of damage for the 1995 Kobe earthquake. They applied average damage ratio, especially in cases of larger PGA. There is a significant difference in damage ratio between the above two procedures, especially for the case of acceleration range from 300gal to 800gal.

Kawakami's (1996)[4-2-3], study shows that 1) service interruption rate after two days from the main shock is about 60%, and 2) service interruption rate is 87% in the case of 2 damaged points/km.

[4-2-1] Japan Water works Association (Nov. 1998 Damage estimation of water supply pipeline due to earthquake).

[4-2-2] K. Kubo & T. Katayama (1975 Damage estimation of underground water supply pipeline).

[42-3] E. KAWAKAMI (1996 Relation between shape of road traffic system and establishment of connection)

According to the damage study on the 1999 Quindío earthquake, the situations are noted as follows:

- In Armenia, recorded PGA was 589 gal, and almost no service was available after two days from the main shock.
- In Pereira, recorded PGA was 291 gal, and almost all services were available after two days from the main shock.

Standard Damage Ratio Proposed for this Study

If PGA of 589 gal in Armenia earthquake is applied to Japan Waterworks Association's damage curve, damage ratio is estimated at about 0.6 points/km. However, almost all service interruption after two days indicates that damage ratio would be higher than 0.6 points/km based on Kawakami's work. In addition, it is noted that installation situation is different than that in Japan from the site observation.

Therefore, a higher damage ratio than Japan Waterworks Association's damage curve is proposed and this is shown in Figure 4.2.23.

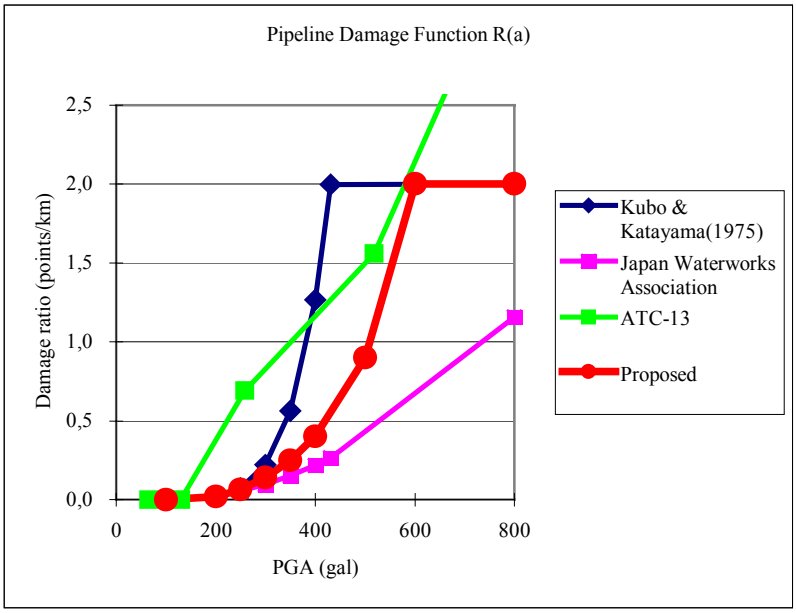


Figure 4.2.23 Standard Damage Ratio for Pipelines

In the method of Kubo and Katayama, various correction factors are included such as pipe material, pipe diameter, ground, and liquefaction. In this study, these values are maintained, while classifications of pipe materials, pipe diameters, and ground conditions are adjusted to Colombian situation. They are shown in Table 4.2.20 to Table 4.2.23.

Table 4.2.20 Correction Factor for Pipe Materials (Cp)

Pipe material	Correction factor Cp
Asbest-cement, Reinforced concrete〔ACP〕	1.2
Cast iron〔CIP〕	1
Polyvinyl-chloride〔VP〕	1
Steel, Steel Iron , Galvanized iron〔SP〕	0.3
Unknown	1

Table 4.2.21 Correction Factor for Pipe Diameters (Cd)

Diameter	Correction factor Cd
ϕ 100mm or smaller	1.6
ϕ 100mm - 200mm	1
ϕ 200mm - 500mm	0.8
ϕ 500 or bigger	0.5

Table 4.2.22 Correction Factor for Ground Conditions (Cg)

Ground	Correction factor Cg
Geotechnical Zone 1,2: good ground	0.4
Geotechnical Zone 3,4: good ground	1.1
Geotechnical Zone 5: alluvial plane	1
Geotechnical Zone 6: soft soil	1
Geotechnical Zone 7,8: other than above	1

Table 4.2.23 Correction Factor for Liquefaction (Cc)

Liquefaction potential	Correction factor Cl
None	1
Possible	2
Probable	2.4

d) Results of Estimation

Case 1: La Cajita

The results of damage estimation by the scenario earthquakes are shown in Table 4.2.24 and in Figure 4.2.24. Damages are concentrated in the southern part of the Study Area, due to the high ground acceleration and liquefaction phenomena, which would enhance the extent of damages. In Bogotá, damage ratio in Usme and Ciudad Bolivar exceeds 2.0 points per km. During the 1999 Quindío earthquake, water service was totally out of service immediately after the earthquake in

the area where damage ratio exceeded 2.0 points per km. The damage ratio in San Cristobal and Soacha is also as high as 1.3 points per km and 1.4 points per km respectively.

Case 2: Guayuriba

The results are shown in Table 4.2.24 and in Figure 4.2.24. The damaged area spreads widely in the Bogotá City Area, though total amount of damage is smaller than that of Case 1. The damage extends in liquefied areas. The area with a high damage ratio is at Tunjuelito, where the value is 0.5 points per km. Total disruption of water service in this case is not likely in any locality in Bogotá or municipality in Cundinamarca.

Case 3: Subduction

The results are shown in Table 4.2.24 and in Figure 4.2.24. Almost no damage is estimated for this case.

Remarks

- Damage will be extensive due to the liquefaction areas, where the localities of Kennedy, Puente Aranda, Rafael Uribe and Ciudad Bolivar are located.
- Regarding the pipe material, asbestos cement suffers most, because of the fragility of the material and also the widespread use of the material, whose proportion is about 70%.

Table 4.2.24 Estimated Damage of Water Pipelines (Cases 1, 2, and 3)

(Case 1)

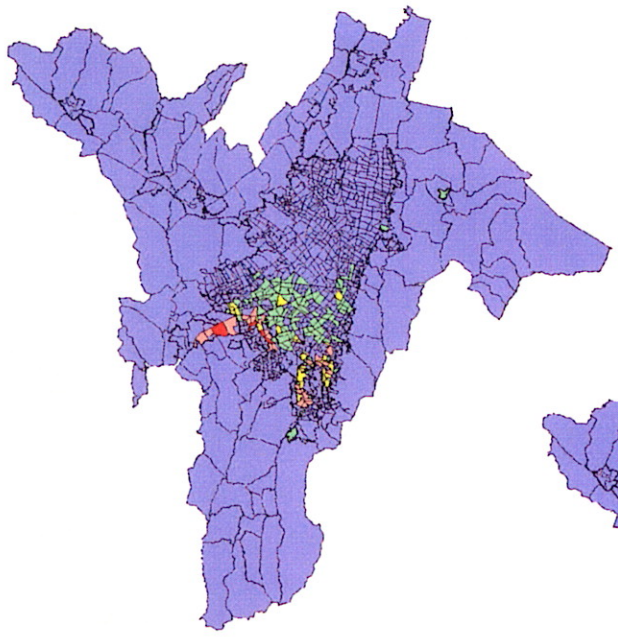
	Locality or Municipality	Status (m)	By Material: Asbest-cement pipe (ACP)	Cast Iron (CIP)	Galvanized iron (SP)	Polyvinyl-chloride pipe (VP)	Reinforced Concrete (ACP)	Steel (SP)	Steel Iron (SP)	Unknown	By Diameter: D is bigger than 500mm	D is 200 - 500mm	D is 100 - 200mm	D is samller than 100mm	Total: Sum (Points)	Damage ratio (Points/km)
Bogotá	Usaquen	488,253	47	0	0	6	1	0	0	1	1	4	17	32	55	0.1
	Chapinero	253,606	66	2	4	7	1	0	0	1	1	13	44	23	81	0.3
	Santa Fe	183,903	84	1	3	1	9	0	0	1	7	17	39	35	98	0.5
	San Cristobal	394,344	409	1	3	97	8	0	0	1	9	44	87	379	519	1.3
	Usme	164,430	419	1	0	90	7	0	1	1	11	18	98	391	517	3.1
	Tunjuelito	168,040	121	0	1	4	2	0	1	0	2	9	34	84	129	0.8
	Bosa	260,657	175	0	0	11	7	0	0	0	5	13	47	127	194	0.7
	Kennedy	668,722	271	0	0	31	8	0	0	1	5	23	78	206	312	0.5
	Fontibon	280,423	3	0	0	0	0	0	0	0	0	0	1	2	3	0.0
	Engativa	615,661	5	0	0	0	0	0	0	0	0	1	2	3	6	0.0
	Suba	716,915	8	0	0	6	0	0	0	0	0	2	4	8	14	0.0
	Barrios Unidos	272,517	3	0	0	0	0	0	0	0	0	0	1	2	4	0.0
	Teusaquillo.	269,816	52	0	7	0	2	0	0	1	2	5	23	32	62	0.2
	Martires	189,365	78	1	6	0	3	0	0	0	2	10	29	48	88	0.5
	Antonio Nariño	135,302	60	2	4	3	2	0	0	0	1	8	19	42	71	0.5
	Puente Aranda	418,009	164	1	2	7	4	0	0	0	3	20	51	105	178	0.4
	La Candelaria	55,631	34	0	1	0	4	0	0	1	3	8	18	11	41	0.7
	Rafael Uribe	333,689	278	3	8	47	4	0	2	0	4	21	93	225	342	1.0
	Ciudad Bolivar	384,162	687	0	9	68	20	0	1	3	19	79	229	462	789	2.1
	Sub-total (points)	6,253,444	2,964	13	49	379	83	0	5	11	76	296	914	2,217	3,504	0.6
Cundinamarca	Chia	142,361	0	0	0	1	0	0	0	0	0	0	0	1	1	0.0
	Cota	15,903	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	Facatativa	25,697	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	Funza	66,958	0	0	0	0	0	0	0	0	0	0	0	0	1	0.0
	La Calera	18,661	0	0	0	6	0	0	0	0	0	0	1	5	6	0.3
	Madrid	49,869	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	Mosquera	43,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	Soacha	173,080	199	0	1	33	6	0	0	1	4	13	65	158	240	1.4
	Sub-total (points)	536,048	200	0	1	41	6	0	0	2	4	14	67	165	249	0.5
	Total (points)	6,789,491	3,163	13	50	420	89	0	5	12	80	310	981	2,383	3,753	0.6

(Case 2)

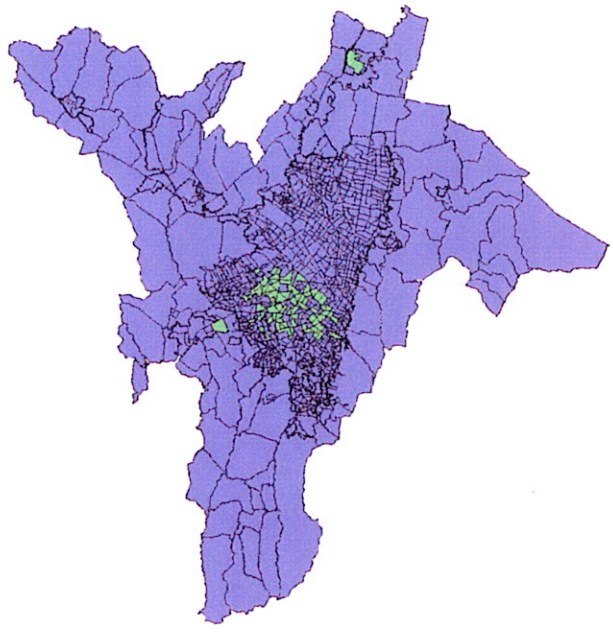
Locality or Municipality	By Material: Asbest-cement pipe (ACP)	Cast Iron (CIP)	Galvanized iron (SP)	Polyvinyl-chloride pipe (VP)	Reinforced Concrete (ACP)	Steel (SP)	Steel Iron (SP)	Unknown	By Diameter: D is bigger than 500mm	D is 200 - 500mm	D is 100 - 200mm	D is samller than 100mm	Total: Sum (Points)	Damage ratio (Points/km)
Usaquen	58	0	0	9	1	0	0	1	2	6	23	38	69	0.1
Chapinero	28	1	2	8	0	0	0	1	0	6	20	14	40	0.2
Santa Fe	36	0	1	1	3	0	0	0	2	5	14	19	41	0.2
San Cristobal	81	1	2	12	3	0	0	0	3	10	21	65	100	0.3
Usme	47	0	0	9	1	0	0	0	1	2	11	43	57	0.3
Tunjuelito	80	0	1	3	2	0	0	0	1	6	22	56	85	0.5
Bosa	35	0	0	2	1	0	0	0	1	2	11	24	39	0.1
Kennedy	255	0	0	26	7	0	0	1	5	22	72	191	290	0.4
Fontibon	28	0	0	1	1	0	0	0	1	4	10	15	31	0.1
Engativa	48	0	0	4	1	0	0	0	1	5	18	30	55	0.1
Suba	41	0	0	24	1	0	0	1	2	7	22	37	68	0.1
Barrios Unidos	38	1	2	5	0	0	0	0	1	4	18	24	47	0.2
Teusaquillo.	40	1	2	3	2	0	0	2	2	5	23	21	51	0.2
Martires	62	2	5	0	2	0	0	0	1	8	22	39	71	0.4
Antonio Nariño	55	2	4	3	1	0	0	0	1	8	18	39	65	0.5
Puente Aranda	172	3	2	9	5	0	0	0	4	22	61	104	191	0.5
La Candelaria	15	0	0	0	2	0	0	0	1	4	7	6	17	0.3
Rafael Uribe	85	2	6	11	2	0	2	0	1	11	31	64	107	0.3
Ciudad Bolivar	56	0	1	6	2	0	0	0	2	6	18	38	64	0.2
Sub-total (points)	1,260	14	28	138	37	0	3	8	32	146	444	867	1,488	0.2
Chia	0	0	0	14	0	0	0	0	0	1	2	12	14	0.1
Cota	0	0	0	0	0	0	0	2	0	0	0	2	2	0.1
Facatativa	0	0	0	0	0	0	0	1	0	0	0	0	1	0.0
Funza	2	0	0	2	0	0	0	0	0	0	1	3	4	0.1
La Calera	0	0	0	4	0	0	0	0	0	0	0	3	4	0.2
Madrid	2	0	0	1	0	0	0	0	0	0	1	2	3	0.1
Mosquera	1	0	0	1	0	0	0	0	0	0	0	1	2	0.0
Soacha	21	0	0	5	1	0	0	0	0	2	8	17	27	0.2
Sub-total (points)	25	0	0	28	1	0	0	3	0	4	12	40	57	0.1
Total (points)	1,284	14	29	165	38	0	3	11	32	150	456	907	1,545	0.2

(Case 3)

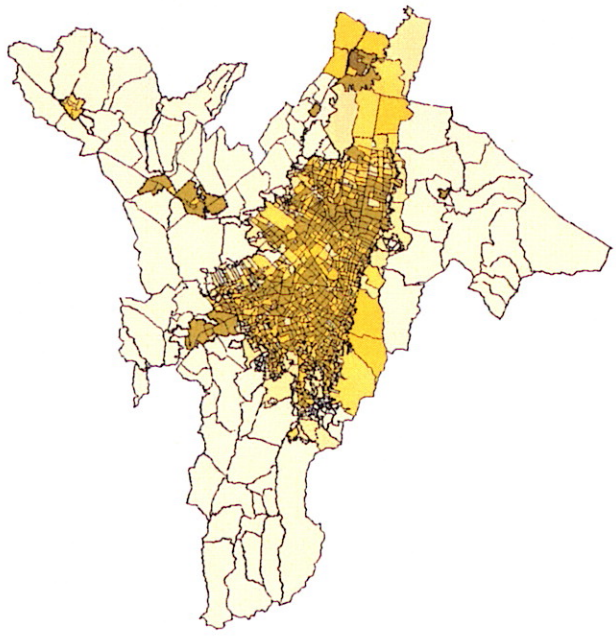
Locality or Municipality	By Material: Asbest-cement pipe (ACP)	Cast Iron (CIP)	Galvanized iron (SP)	Polyvinyl-chloride pipe (VP)	Reinforced Concrete (ACP)	Steel (SP)	Steel Iron (SP)	Unknown	By Diameter: D is bigger than 500mm	D is 200 - 500mm	D is 100 - 200mm	D is samller than 100mm	Total: Sum (Points)	Damage ratio (Points/km)
Usaquen	1	0	0	0	0	0	0	0	0	0	1	1	2	4.5
Chapinero	0	0	0	0	0	0	0	0	0	0	0	0	1	0.0
Santa Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
San Cristobal	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Usme	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Tunjuelito	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Bosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Kennedy	1	0	0	0	0	0	0	0	0	0	0	1	2	0.0
Fontibon	1	0	0	0	0	0	0	0	0	0	0	1	1	0.0
Engativa	2	0	0	0	0	0	0	0	0	0	1	1	2	0.0
Suba	1	0	0	1	0	0	0	0	0	0	1	1	2	0.0
Barrios Unidos	1	0	0	0	0	0	0	0	0	0	1	1	1	0.0
Teusaquillo.	1	0	0	0	0	0	0	0	0	0	1	0	1	0.0
Martires	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Antonio Nariño	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Puente Aranda	1	0	0	0	0	0	0	0	0	0	0	1	1	0.0
La Candelaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rafael Uribe	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Ciudad Bolivar	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Sub-total (points)	12	0	0	2	0	0	0	0	0	2	5	8	15	0.0
Chia	0	0	0	1	0	0	0	0	0	0	0	1	1	0.0
Cota	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Facatativa	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Funza	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
La Calera	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Madrid	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Mosquera	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Soacha	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Sub-total (points)	0	0	0	1	0	0	0	0	0	0	0	1	2	0.0
Total (points)	12	0	0	3	0	0	0	0	0	2	5	9	16	0.0



La Cajita Fault Model



Guayuriba Fault Model



Present Condition

LEGEND

Number of Damaged Water Pipeline (points)
- 0 - 5
- 5 - 15
- 15 - 30
- 30 - 70
- 70 - 150

Length of Water Pipeline (meter)
- 0
- 1 - 2000
- 2000 - 5000
- 5000 - 10000
- 10000 - 50000
- 50000 - 100000

Figure 4.2.24 | **Damage of Water Supply Lines**

B. Damage estimation of gas pipelines

a) Collected data

The gas pipeline for low-pressure (60 psi) distribution for Bogotá, Chia and Soacha excluding the pipeline to individual buildings is provided by Natural Gas Company. Other municipalities in Cundinamarca do not have gas pipelines. The distribution of gas pipelines in the Study Area is shown in Appendix 4.2.7.

b) Damage ratio definition

Basic damage ratio for gas pipelines is the same as that of the water supply pipelines. Correction factors for ground type and liquefaction effect are also the same. Regarding pipe material and pipe diameter, the following values currently used in Japan are adopted.

$C_p \times C_d$: Polyethylene pipes (60 psi) 0.1

c) Result of estimation

Table 4.2.25 shows status and damage points for each locality and municipality due to the three scenario earthquakes.

Case 1: La Cajita

Most damage is estimated at the southern part of the Study Area, especially in the localities of Ciudad Bolivar, Usme and San Cristobal in Bogotá and the municipality of Soacha in Cundinamarca as shown in Appendix 4.2.7. This is because of high seismic intensity and liquefaction in the area close to the fault. Mid west to northern part of the Study Area will suffer a little damage, but there will not be damage in Chia.

Case 2: Guayuriba

Damaged area spreads widely in Bogotá, especially in Kennedy, Puente Aranda, Rafael Uribe, Ciudad Bolívar. Damage of at least one point is expected in every locality in Bogotá. Damage is also expected in Chia and Cota in Cundinamarca.

Case 3: Subduction

Almost no damage is expected as liquefaction is not expected in this case.

Table 4.2.25 Estimated Length and Damage of Gas Pipelines

	Locaridad	Length (m)	Damage (points)			Damage ratio (points/km)		
			Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Bogotá	Usaquen	432,656	3	4	0	0.01	0.01	0.00
	Chapinero	171,736	5	2	0	0.03	0.01	0.00
	Santa Fe	168,985	7	3	0	0.04	0.02	0.00
	San Cristobal	577,386	53	9	0	0.09	0.02	0.00
	Usme	377,866	71	8	0	0.19	0.02	0.00
	Tuenjuelito	196,268	10	7	0	0.05	0.03	0.00
	Bosa	531,520	21	5	0	0.04	0.01	0.00
	Kennedy	981,395	28	25	0	0.03	0.03	0.00
	Fontibón	285,122	0	2	0	0.00	0.01	0.00
	Engativá	887,072	1	5	0	0.00	0.01	0.00
	Suba	912,479	1	5	0	0.00	0.01	0.00
	Barrios Unidos	310,006	0	4	0	0.00	0.01	0.00
	Teusaquillo	182,259	4	3	0	0.02	0.02	0.00
	Mártires	166,661	7	5	0	0.04	0.03	0.00
	Antonio Nariño	145,818	6	6	0	0.04	0.04	0.00
	Puente Aranda	406,013	15	15	0	0.04	0.04	0.00
	La Candelaria	30,535	2	1	0	0.07	0.03	0.00
	Rafael Uribe	550,978	48	13	0	0.09	0.02	0.00
	Ciudad Bolívar	709,046	107	9	0	0.15	0.01	0.00
	Sub Total	8,023,800	388	132	1	0.05	0.02	0.00
Cundinamarca	Chía	182,544	0	1	0	0.00	0.01	0.00
	Cota	0	0	0	0	0.00	0.01	0.00
	Facatativá	0	0	0	0	0.00	0.01	0.00
	Funza	0	0	0	0	0.00	0.01	0.00
	La Calera	0	0	0	0	0.00	0.01	0.00
	Madrid	0	0	0	0	0.00	0.01	0.00
	Mosquera	0	0	0	0	0.00	0.01	0.00
	Soacha	584,113	39	6	0	0.07	0.01	0.00
	Sub Total	766,657	39	7	0	0.05	0.01	0.00
	Total	8,790,457	428	139	1	0.05	0.02	0.00

C. Damage estimation of electric power supply cables

a) Collected data

Printed materials of the cable network and tables for 11kV intermediate voltage for Bogotá, Cota, Funza, Mosquera and Soacha is provided from CODENSA. Data include overhead and underground cables.

Three different methods according to the network density were used to estimate the cable length distribution for the Study Area. Thus data accuracy varies for each municipality. Details of the collected data and the process of distribution estimation are described in Appendix 4.2.6. Distribution of estimated cable length is shown in Table 4.2.26 and Appendix 4.2.8.

Table 4.2.26 Distribution of Estimated Electric Power Supply Cable Length

	Locarity or Municipality	Over Head (m)	Under Ground (m)	Total (m)
Bogotá	Usaquen	129,791	360,202	489,993
	Chapinero	28,028	125,621	153,649
	Santa Fe	73,894	48,649	122,543
	San Cristobal	108,035	658	108,693
	Usme	214,413	5,345	219,758
	Tuenjuelito	89,990	12,765	102,755
	Bosa	111,414	7,715	119,129
	Kennedy	414,611	66,868	481,478
	Fontibón	211,000	175,084	386,083
	Engativá	312,980	218,286	531,266
	Suba	510,471	373,249	883,720
	Barrios Unidos	48,743	206,178	254,921
	Teusaquillo	55,797	249,038	304,835
	Mártires	73,346	29,797	103,143
	Antonio Nariño	61,944	5,176	67,120
	Puente Aranda	195,646	46,907	242,553
	La Candelaria	9,410	4,541	13,951
	Rafael Uribe	173,190	5,556	178,746
	Ciudad Bolívar	143,950	12,930	156,880
	Sub Total	2,966,653	1,954,565	4,921,217
Cundinamarca	Chía	52,280	2,202	54,482
	Cota	90,491	0	90,491
	Facatativá	68,155	0	68,155
	Funza	141,510	0	141,510
	La Calera	94,364	0	94,364
	Madrid	45,499	0	45,499
	Mosquera	143,033	0	143,033
	Soacha	206,195	0	206,195
	Sub Total	841,528	2,202	843,730
	Total	3,808,180	1,956,767	5,764,947

Source: CODENSA

b) Methods and procedures

Overhead

Damage to the electric poles due to the 1995 Kobe Earthquake in Japan is as follows:

- No damage was observed in areas where PGA is less than 380 gal.
- 0.55% was broken or collapsed in areas where PGA is greater than 380 gal.

Damage to the electric facilities during the 1999 Quindío earthquake is as follows:

- In Armenia where PGA of 589 gal was observed, 50% of the damage was recovered in two days after the main shock.
- In Pereira where PGA of 291gal was observed, almost all damages were recovered in two days after the main shock.
- In Manizales where PGA of 102 gal was observed, no damage was recorded.

The strength of electric poles in the Study Area is assumed to be the same as those in Japan. In this study, damage function is proposed as shown in Figure 4.2.25 in the following manner:

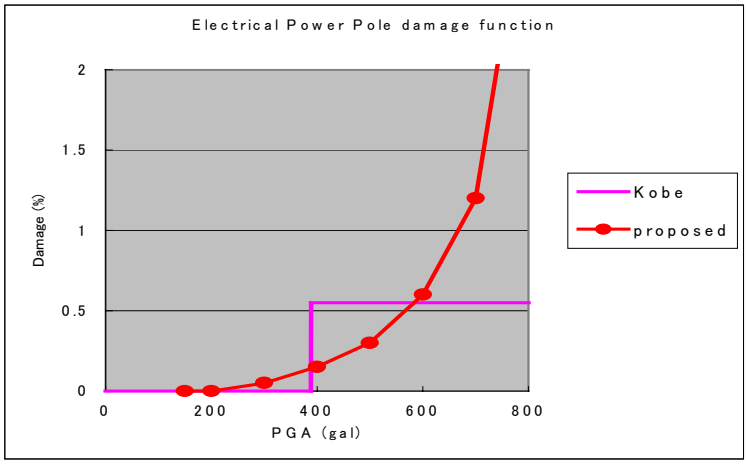


Figure 4.2.25 Damage Function for Electrical Power Pole

- Damage appears where PGA is greater than 300 gal.
- Same damage as that in Kobe occurs at PGA of 600 gal.

The damage to a pole causes damage to the cable between the poles of the broken pole, that is, half span of the cable is cut at each damaged pole.

Underground

Damages to underground cables during the 1995 Kobe earthquake in Japan were as follows:

- No damage occurred in areas where PGA is less than 380 gal.
- 0.3% was damaged in areas where PGA is over 380 gal.

No damage data for underground cable during the Quindío earthquake is available. The underground cables in the Bogotá City Area are assumed to have the same strength as that of Japan. The damage function is proposed based on the experiences in Japan earthquakes and this is shown in Figure 4.2.26.

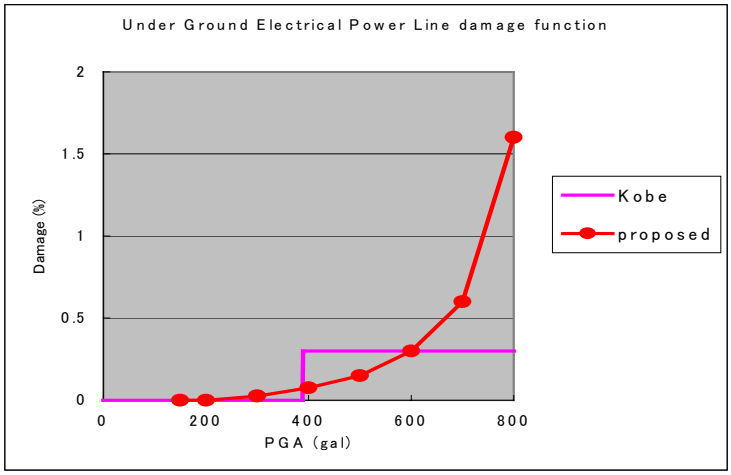


Figure 4.2.26 Damage Function for Underground Electrical Power Line

- Damage occurs at PGA higher than 300 gal.
- Damage ratio is 0.3% at PGA of around 600 gal.
- Damage ratio increases as PGA increases.

c) Results

The estimated damages for overhead cables, underground cables, and cables in total are shown in Table 4.2.27.

Case 1: La Cajita

The damage ratio for the whole area is 0.04%. The damages are estimated at the southern part of the Study Area, especially in Usme as shown in Appendix 4.2.8. This is because of high seismic intensity. The peak ground acceleration higher than 500 gal is estimated in some part of Usme, Ciudad Bolívar, San Cristobal, Rafael Uribe, Bosa and Soacha. During the 1999 Quindio earthquake, about 50% of electricity was cut-off during two days after the main shock in Armenia where 589 gal of peak ground acceleration was recorded. Therefore, service of electricity is very likely to be suspended in above-mentioned areas.

In the northern part of the Study Area except for Soacha, the damage ratio is less than 0.01%, due to the relatively low ground acceleration.

Case 2: Guayuriba

Damage ratio in the Study Area is 0.02%. Within Bogotá, areas with a damage ratio between 0.01% and 0.04% are widely distributed as shown in Appendix 4.2.8; the difference in damage ratios between areas is smaller compared to that in Case 1. Maximum damage ratio of 0.04% is estimated for Usme and Antonio Nariño.

Case 3: Subduction

Expected PGA is less than the threshold value of damage occurrence; therefore no damage is expected.

Table 4.2.27 Estimated Damage of Electric Overhead Cables

	Locarity or Municipality	Overhead Cable							Underground Cable							Cable in Total						
		Length (m)	Damage (m)			Damage ratio (%)			Length (m)	Damage (m)			Damage ratio (%)			Length (m)	Damage (m)			Damage ratio (%)		
			Case 1	Case 2	Case 3	Case 1	Case 2	Case 3		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Bogota	Usaquen	129,791	17	22	0	0.01	0.02	0.00	360,202	47	62	0	0.01	0.02	0.00	489,993	64	84	0	0.01	0.02	0.00
	Chapinero	28,028	14	6	0	0.05	0.02	0.00	125,621	61	28	0	0.05	0.02	0.00	153,649	75	34	0	0.05	0.02	0.00
	Santa Fe	73,894	40	16	0	0.05	0.02	0.00	48,649	28	11	0	0.06	0.02	0.00	122,543	68	28	0	0.06	0.02	0.00
	San Cristobal	108,035	138	25	0	0.13	0.02	0.00	658	1	0	0	0.13	0.02	0.00	108,693	139	25	0	0.13	0.02	0.00
	Usme	214,413	1,013	88	0	0.47	0.04	0.00	5,345	26	2	0	0.48	0.04	0.00	219,758	1,038	91	0	0.47	0.04	0.00
	Tunjuelito	89,990	50	31	0	0.06	0.03	0.00	12,765	7	4	0	0.06	0.03	0.00	102,755	57	36	0	0.06	0.03	0.00
	Bosa	111,414	46	10	0	0.04	0.01	0.00	7,715	3	1	0	0.04	0.01	0.00	119,129	49	11	0	0.04	0.01	0.00
	Kennedy	414,611	95	81	0	0.02	0.02	0.00	66,868	15	13	0	0.02	0.02	0.00	481,478	110	94	0	0.02	0.02	0.00
	Fontibon	211,000	0	25	0	0.00	0.01	0.00	175,084	0	21	0	0.00	0.01	0.00	386,083	0	47	0	0.00	0.01	0.00
	Engativa	312,980	0	32	0	0.00	0.01	0.00	218,286	0	23	0	0.00	0.01	0.00	531,266	0	55	0	0.00	0.01	0.00
	Suba	510,471	2	47	0	0.00	0.01	0.00	373,249	2	35	0	0.00	0.01	0.00	883,720	4	82	0	0.00	0.01	0.00
	Barrios Unidos	48,743	0	13	0	0.00	0.03	0.00	206,178	0	54	0	0.00	0.03	0.00	254,921	0	67	0	0.00	0.03	0.00
	Teusaquillo.	55,797	18	16	0	0.03	0.03	0.00	249,038	82	73	0	0.03	0.03	0.00	304,835	100	89	0	0.03	0.03	0.00
	Martires	73,346	34	25	0	0.05	0.03	0.00	29,797	14	10	0	0.05	0.03	0.00	103,143	47	35	0	0.05	0.03	0.00
	Antonio Nariño	61,944	25	23	0	0.04	0.04	0.00	5,176	2	2	0	0.04	0.04	0.00	67,120	27	25	0	0.04	0.04	0.00
	Puente Aranda	195,646	61	61	0	0.03	0.03	0.00	46,907	15	15	0	0.03	0.03	0.00	242,553	76	76	0	0.03	0.03	0.00
	La Candelaria	9,410	9	3	0	0.10	0.03	0.00	4,541	4	2	0	0.10	0.03	0.00	13,951	14	5	0	0.10	0.03	0.00
	Rafael Uribe	173,190	206	48	0	0.12	0.03	0.00	5,556	7	2	0	0.12	0.03	0.00	178,746	212	50	0	0.12	0.03	0.00
	Ciudad Bolivar	143,950	219	16	0	0.15	0.01	0.00	12,930	20	1	0	0.15	0.01	0.00	156,880	238	17	0	0.15	0.01	0.00
	Sub-total (points)	2,966,653	1,986	591	0	0.07	0.02	0.00	1,954,565	332	358	0	0.02	0.02	0.00	4,921,217	2,319	950	0	0.05	0.02	0.00
Cundinamarca	Chia	52,280	1	7	0	0.00	0.01	0.00	2,202	0	0	0	0.00	0.02	0.00	54,482	1	7	0	0.00	0.01	0.00
	Cota	90,491	0	5	0	0.00	0.01	0.00	0	0	0	0	0.00	0.00	0.00	90,491	0	5	0	0.00	0.01	0.00
	Facatativa	68,155	0	2	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	68,155	0	2	0	0.00	0.00	0.00
	Funza	141,510	0	6	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	141,510	0	6	0	0.00	0.00	0.00
	La Calera	94,364	2	2	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	94,364	2	2	0	0.00	0.00	0.00
	Madrid	45,499	0	4	0	0.00	0.01	0.00	0	0	0	0	0.00	0.00	0.00	45,499	0	4	0	0.00	0.01	0.00
	Mosquera	143,033	0	2	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	143,033	0	2	0	0.00	0.00	0.00
	Soacha	206,195	86	23	0	0.04	0.01	0.00	0	0	0	0	0.00	0.00	0.00	206,195	86	23	0	0.04	0.01	0.00
	Sub-total (points)	841,528	90	51	0	0.01	0.01	0.00	2,202	0	0	0	0.00	0.02	0.00	843,730	90	51	0	0.01	0.01	0.00
	Total (points)	3,808,180	2,077	642	0	0.05	0.02	0.00	1,956,767	332	359	0	0.02	0.02	0.00	5,764,947	2,409	1,001	0	0.04	0.02	0.00

Source: JICA Study Team

D. Damage estimation for telecommunication cable

a) Collected data

Summary of collected data is shown as follows:

Table 4.2.28 Summary of Collected Data

Institutions	Content of Data	Data Form
ETB	Location of local control stations and cabinets	GIS
	6 examples of primary network length of ETB central station	Printed table
	The total pole number in Bogotá plant of Soacha	Interview
	Radio link between overhead cable and underground cable	Interview
CAPITEL	Overhead cable network	GIS
	Underground cable network	GIS
	Location of poles	GIS
EPM BOGOTÁ	No information	

Data process

From the interview with ETB, the Study Team assumed that 99% and 51% of the primary network and the secondary network respectively is underground in the Study Area. An average distance between two adjacent electric poles is assumed to be 30m, according to CAPITEL.

Three estimation methods to estimate cable length for ETB are used according to the characteristics of data and that of area. The procedure of acquired data process is described in the Appendix 4.2.6. The estimated distribution of cable length is shown in Table 4.2.29 and in Appendix 4.2.9.

Table 4.2.29 Estimated Distribution of Telephone Cables

	Locarity or Municipality	Over Head (m)	Under Ground (m)	Total (m)
Bogotá	Usaquen	384,412	524,997	909,409
	Chapinero	251,764	372,311	624,075
	Santa Fe	126,244	147,694	273,938
	San Cristobal	236,409	219,587	455,996
	Usme	164,301	154,945	319,246
	Tuenjuelito	114,149	105,321	219,470
	Bosa	221,592	239,404	460,995
	Kennedy	429,220	483,137	912,358
	Fontibón	209,536	252,172	461,707
	Engativá	570,882	553,568	1,124,449
	Suba	558,514	641,483	1,199,997
	Barrios Unidos	298,584	326,643	625,227
	Teusaquillo	175,541	205,770	381,311
	Mártires	188,367	198,766	387,133
	Antonio Nariño	116,377	106,859	223,236
	Puente Aranda	374,512	382,335	756,847
	La Candelaria	36,793	59,389	96,182
	Rafael Uribe	277,146	256,321	533,466
	Ciudad Bolívar	263,122	275,081	538,203
	Sub Total	4,997,464	5,505,781	10,503,245
Cundinamarca	Chía	48,536	16,373	64,909
	Cota	90,491	0	90,491
	Facatativá	68,155	0	68,155
	Funza	141,510	0	141,510
	La Calera	94,364	0	94,364
	Madrid	45,499	0	45,499
	Mosquera	143,033	3,853	146,886
	Soacha	326,444	218,265	544,710
	Sub Total	958,033	238,491	1,196,524
	Total	5,955,497	5,744,273	11,699,770

Source: ETB and CAPITEL

b) Damage function definition

Same procedure is applied as that of the electric power supply cables for the estimation of overhead and underground telecommunications cables.

c) Result of estimation

The damage to telephone overhead cables, underground cables, and cables in total is shown in Table 4.2.30. The damage distribution of telephone cables in total for case 1 and case 2 is shown in Appendix 4.2.9.

Table 4.2.30 Estimated Damage of Telephone Overhead Cable

	Locarity or Municipality	Overhead Cable							Underground Cable							Cable in Total						
		Length (m)	Damage (m)			Damage ratio (%)			Length (m)	Damage (m)			Damage ratio (%)			Length (m)	Damage (m)			Damage ratio (%)		
			Case 1	Case 2	Case 3	Case 1	Case 2	Case 3		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Bogota	Usaquen	384,412	40	64	0	0.01	0.02	0.00	524,997	51	92	0	0.01	0.02	0.00	909,409	91	156	0	0.01	0.02	0.00
	Chapinero	251,764	104	57	0	0.04	0.02	0.00	372,311	145	89	0	0.06	0.04	0.00	624,075	249	146	0	0.04	0.02	0.00
	Santa Fe	126,244	93	31	0	0.07	0.02	0.00	147,694	126	37	0	0.10	0.03	0.00	273,938	219	68	0	0.08	0.02	0.00
	San Cristobal	236,409	254	55	0	0.11	0.02	0.00	219,587	244	52	0	0.10	0.02	0.00	455,996	498	107	0	0.11	0.02	0.00
	Usme	164,301	746	60	0	0.45	0.04	0.00	154,945	726	58	0	0.44	0.04	0.00	319,246	1,471	118	0	0.46	0.04	0.00
	Tunjuelito	114,149	58	35	0	0.05	0.03	0.00	105,321	54	33	0	0.05	0.03	0.00	219,470	112	68	0	0.05	0.03	0.00
	Bosa	221,592	105	20	0	0.05	0.01	0.00	239,404	136	23	0	0.06	0.01	0.00	460,995	241	43	0	0.05	0.01	0.00
	Kennedy	429,220	96	84	0	0.02	0.02	0.00	483,137	110	97	0	0.03	0.02	0.00	912,358	206	181	0	0.02	0.02	0.00
	Fontibon	209,536	0	24	0	0.00	0.01	0.00	252,172	0	32	0	0.00	0.02	0.00	461,707	1	56	0	0.00	0.01	0.00
	Engativa	570,882	0	54	0	0.00	0.01	0.00	553,568	0	53	0	0.00	0.01	0.00	1,124,449	0	108	0	0.00	0.01	0.00
	Suba	558,514	3	57	0	0.00	0.01	0.00	641,483	4	74	0	0.00	0.01	0.00	1,199,997	7	131	0	0.00	0.01	0.00
	Barrios Unidos	298,584	0	70	0	0.00	0.02	0.00	326,643	0	77	0	0.00	0.03	0.00	625,227	0	148	0	0.00	0.02	0.00
	Teusaquillo.	175,541	57	48	0	0.03	0.03	0.00	205,770	70	56	0	0.04	0.03	0.00	381,311	127	104	0	0.03	0.03	0.00
	Martires	188,367	77	60	0	0.04	0.03	0.00	198,766	79	62	0	0.04	0.03	0.00	387,133	156	122	0	0.04	0.03	0.00
	Antonio Nariño	116,377	45	40	0	0.04	0.03	0.00	106,859	41	37	0	0.04	0.03	0.00	223,236	86	77	0	0.04	0.03	0.00
	Puente Aranda	374,512	100	109	0	0.03	0.03	0.00	382,335	98	111	0	0.03	0.03	0.00	756,847	198	220	0	0.03	0.03	0.00
	La Candelaria	36,793	36	12	0	0.10	0.03	0.00	59,389	57	19	0	0.16	0.05	0.00	96,182	93	30	0	0.10	0.03	0.00
	Rafael Uribe	277,146	303	74	0	0.11	0.03	0.00	256,321	281	69	0	0.10	0.02	0.00	533,466	584	143	0	0.11	0.03	0.00
	Ciudad Bolivar	263,122	371	28	0	0.14	0.01	0.00	275,081	377	31	0	0.14	0.01	0.00	538,203	747	58	0	0.14	0.01	0.00
	Sub-total (m)	4,997,464	2,489	982	0	0.05	0.02	0.00	5,505,781	2,599	1,101	0	0.05	0.02	0.00	10,503,245	5,088	2,083	0	0.05	0.02	0.00
Cundinamarca	Chia	48,536	1	6	0	0.00	0.01	0.00	16,373	0	2	0	0.00	0.00	0.00	64,909	1	8	0	0.00	0.01	0.00
	Cota	90,491	0	4	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	90,491	0	4	0	0.00	0.00	0.00
	Facatativa	68,155	0	2	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	68,155	0	2	0	0.00	0.00	0.00
	Funza	141,510	0	5	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	141,510	0	5	0	0.00	0.00	0.00
	La Calera	94,364	2	1	0	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	94,364	2	1	0	0.00	0.00	0.00
	Madrid	45,499	0	4	0	0.00	0.01	0.00	0	0	0	0	0.00	0.00	0.00	45,499	0	4	0	0.00	0.01	0.00
	Mosquera	143,033	0	2	0	0.00	0.00	0.00	3,853	0	0	0	0.00	0.00	0.00	146,886	0	2	0	0.00	0.00	0.00
	Soacha	326,444	278	43	0	0.09	0.01	0.00	218,265	213	37	0	0.07	0.01	0.00	544,710	492	80	0	0.09	0.01	0.00
	Sub-total (m)	958,033	282	67	0	0.03	0.01	0.00	238,491	213	39	0	0.02	0.00	0.00	1,196,524	495	106	0	0.04	0.01	0.00
	Total (points)	5,955,497	2,771	1,049	0	0.05	0.02	0.00	5,744,273	2,813	1,140	0	0.05	0.02	0.00	11,699,770	5,583	2,189	0	0.05	0.02	0.00

Case 1

The damage ratio for the Study Area is 0.05%. The damage is expected to concentrate in the southern part of the Study Area, especially in Usme. This is because of a high seismic intensity. The peak ground acceleration higher than 500 gal exists in some part of the localities of Usme, Ciudad Bolívar, San Cristóbal, Rafael Uribe, Bosa and Soacha.

In the northern part of Bogotá and municipalities in Cundinamarca except for Soacha, the damage ratios are less than 0.01%, due to the relatively low ground acceleration.

Case 2

The damage ratio in the whole Study Area is 0.02%. Within Bogotá, areas with a damage ratio between 0.01% and 0.04% are widely distributed; the difference in damage ratios between areas is smaller compared to that in case 1. The maximum damage ratio of 0.04 % is estimated at the locality of Usme.

Case 3

The estimated PGA is less than the threshold value of damage to be incurred; therefore no damage is estimated.