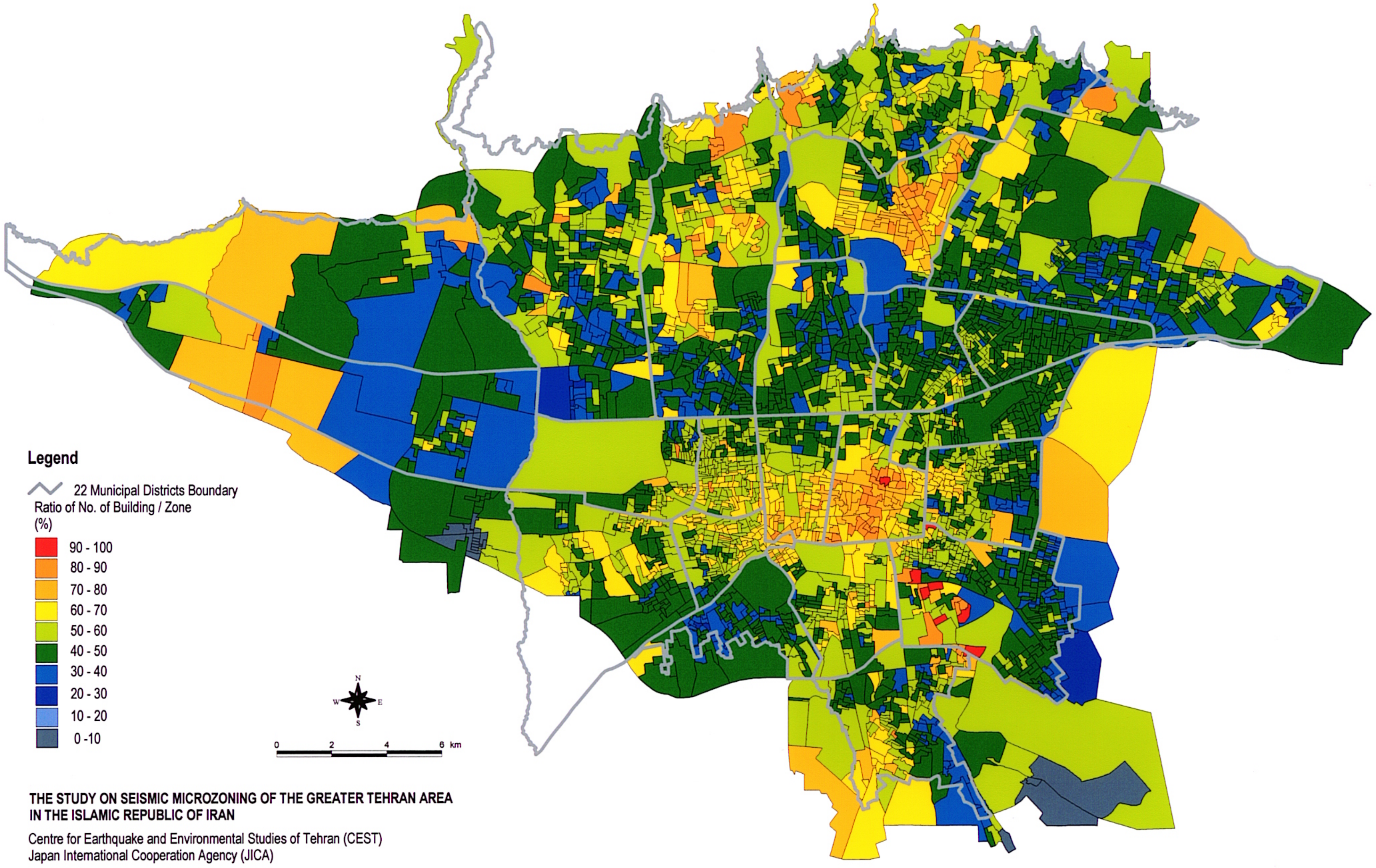
Figure 4.1.22

Heavily Damaged or Collapsed Building Ratio Distribution (Floating model)



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4.2. Human Casualties

Direct causes of earthquake casualties include collapse of buildings, fires, tsunamis, rock falls and landslides. The governing causes depend on the characteristics of the sites concerned. For example, fires are the main cause in locations such as Japan and California, where many wooden houses exist. Tsunamis should be emphasised in areas such as Sumatra of Indonesia. Human casualties due to building collapse are a general phenomenon observed in all areas subject to earthquake disasters. Building collapse will be the most notable cause of human casualty, particularly in Tehran, because of the following reasons. Tsunamis do not affect the site. Slopes of potential landslides are distributed only in the northern edge of the city. There is very little possibility of fire spreading. In addition, the Study estimated critical damage of buildings, as described in the previous section. Therefore, the human casualties caused by building collapse were taken into account in the Study.

The flowchart of the human casualties estimation is shown in Figure 4.2.1. The estimation of human casualties requires a database of the residents. The 1996 Population Census data, which included the number of inhabitants in each dwelling unit, was available. An inhabitants database for individual census zones along with building structural type was prepared. The procedure was similar to the case of the preparation of the Residential Building Inventory Database described in section 4.1.2.

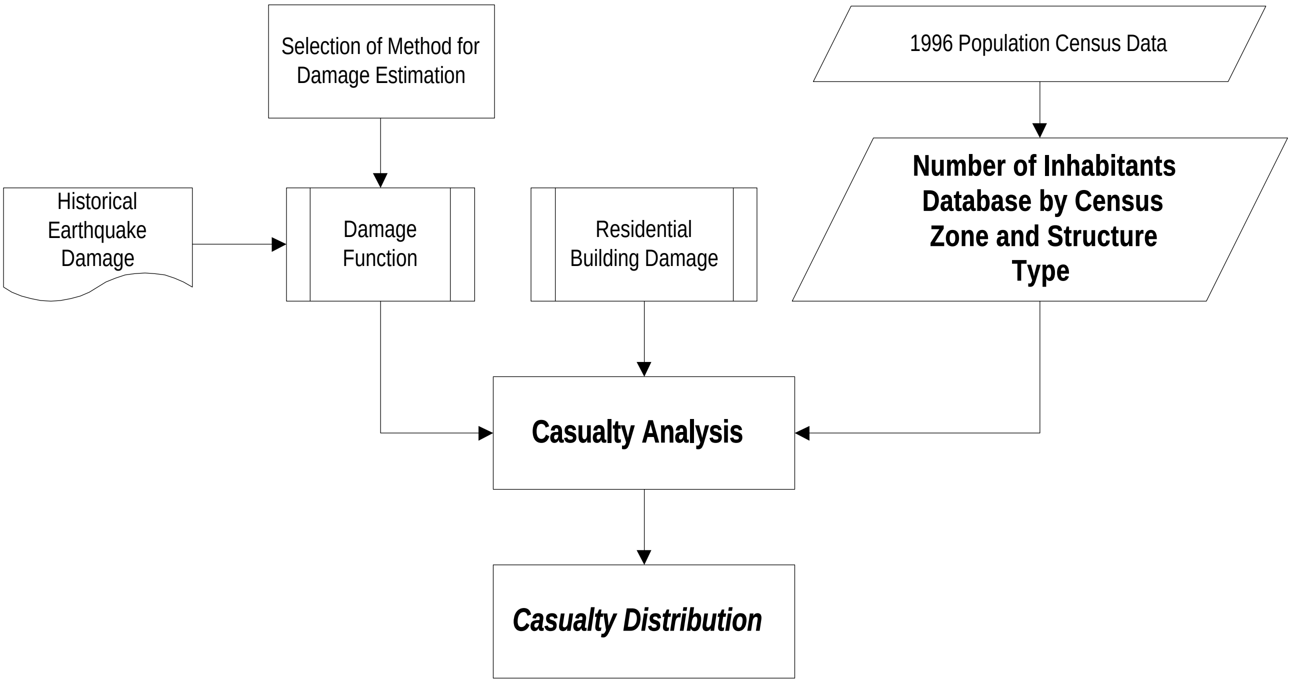


Figure 4.2.1 Flowchart of Human Casualties Estimation

4.2.1. Method of Casualty Estimation

For the estimation of human casualties caused by building collapse, the following information is required: 1) the number of residents in collapsed buildings and 2) the ratio of fatalities to the number of total residents in the collapsed buildings. The information on the number of residents was available from the 1996 Population Census Data. The death ratio is affected by various factors. The site characteristics significantly affect this variable. For instance, in case of the collapse of masonry structures, different numbers of casualties are estimated for different beam material types. Therefore, it is desirable that 1) records of past earthquake damage in the areas concerned are considered as much as possible and, 2) the damage functions are established fully, taking into account the local characteristics and building structures.

The Study adopted the basic concept introduced by Coburn et al.(1992) for the estimation of casualties. Since the concept was derived from considering worldwide earthquake damage, which includes the case of Iran as well, the concept is applicable. However, parameters used in the estimation are not necessarily suitable for the building characteristics of Tehran. Consequently, cases of earthquake damage that occurred in Iran in recent years were examined in detail to obtain the basic parameters.

(1) Methodology

Figure 4.2.2 shows the flowchart of the human casualties estimation concept derived from Coburn et al. (1992). He explained the relationship between the death ratio and the types of rescue operations as follows:

- With regard to people in buildings at the time of the occurrence of an earthquake, the ratio of the people who will not be able to escape from the collapsed buildings is estimated.
- Some percentage of the people who will be trapped in collapsed buildings are assumed to die instantly because of the shock of falling floors and roofs, or due to suffocation by smashed bits of adobe.
- As for the people who will not die instantly, it will be almost impossible to escape by their own efforts. They will be buried under fallen furniture and/or beams, or they will be trapped in underground rooms once ground floors collapse. Some of these people will eventually die.
- The success of the emergency rescue operations will depend mainly on the time after the occurrence of the earthquake. The rescue ratio becomes almost zero at 72 hours after the damage. That is, if people are not rescued within 72 hours of the occurrence of the earthquake, most of them will die. Therefore, rescue operations are the basic factor in determining the death ratio for people who do not die immediately after the collapse of buildings.

The idea mentioned above is formulated as follows:

Evaluation formula $Ks = D5 \times M1 \times M2 \times M3 \times (M4d+(1-M4d) \times M5)$

where

Ks : Human casualties

D5 : Number of collapsed buildings

M1 : Number of people in each building

M2 : Occupancy at the time of the earthquake

M3 : Number of occupants trapped by collapsed buildings

M4d : Death ratio at 0-hrs after the collapse of buildings

M5 : Post-collapse mortality (ratio of the injured that subsequently die before they are rescued)

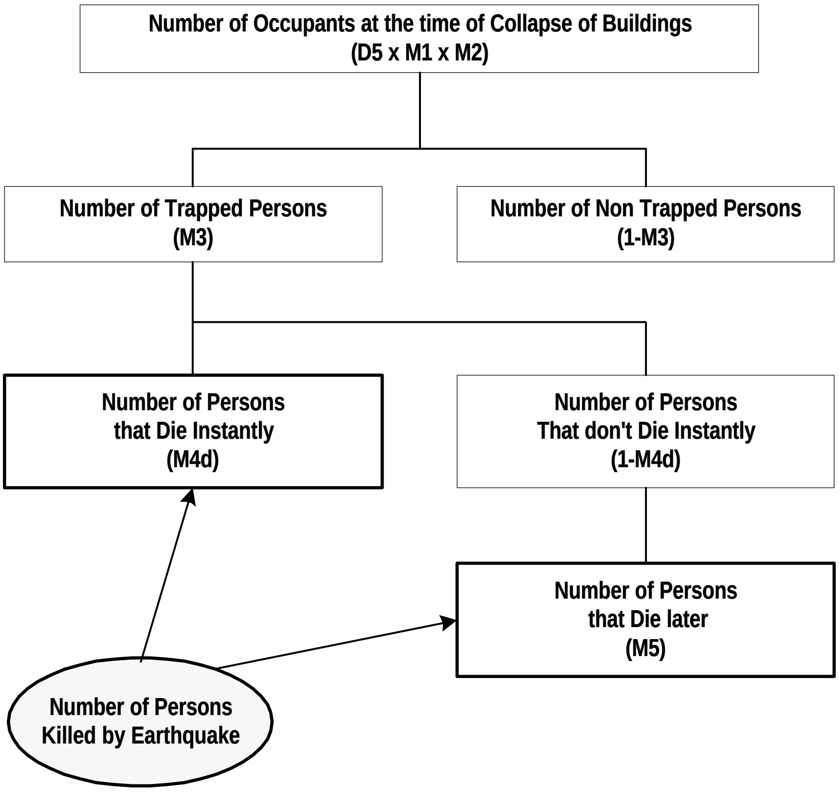


Figure 4.2.2 Flowchart of Casualty Estimation

(2) Parameters

The parameters for the evaluation formula were determined as follows:

1) D5: The number of collapsed buildings

The number of damaged residential buildings for each census zone was applied.

2) M1: Number of persons per building

The number of residents in each building was calculated from the census data.

3) M2: Occupancy at the time of the earthquake occurrence

M2 was assumed as 1.0 to estimate the number of casualties during night-time, when the residents are in their homes. This is because the population census data is based on the survey of the residents of the buildings, which corresponds to the night-time occupancy of the buildings.

The number of casualties during daytime was also estimated. In this case, the death ratio for daytime to night-time was correlated with the seismic intensity (MMI). In this correlation, past actual damages in Iran were taken into account. The details will be described in later sections.

4) M3: Number of occupants trapped by collapsed buildings

M4d: Death ratio at 0-hrs after the collapse of buildings

M5: Post-collapse mortality (ratio of the injured that subsequently die before they can be rescued)

The coefficient of Coburn et al.(1992) was adjusted to satisfy the relationship between the seismic intensity (MMI) and the death ratio in past earthquake damages in Iran.

The building structures were categorised into the following eight types, considering building properties:

1) Adobe
2) Block and brick
3) All wood
4) RC-2
5) RC-1
6) Brick and steel
7) Steel-2
8) Steel-1, RC-0

Emergency rescue activities were defined as the following four cases:

1) No rescue
2) Community rescue

   People who were not trapped rescue nearby trapped inhabitants.

   Hands or simple tools are used.

3) Community + emergency squads

   In addition to the community rescue, the Red Crescent Society and the fire fighting teams join the rescue activities. Systematic operations with devices such as jackhammers and chainsaws are undertaken.

4) Community + emergency squads + experts

   In addition to the above-mentioned operations, experts and emergency rescue squads coming from other areas, including foreign countries, join the rescue operations. Fiberscopes, rescue dogs and other special measures are used.

(3) Death Ratios of Past Disastrous Iranian Earthquakes

The relationship between seismic intensity (MMI) and the death ratio for earthquake damage in Iran was reviewed in order to establish a damage function. The review was carried out by CEST. The data of six earthquakes is shown in Table 4.2.1. Two earthquakes occurred during the day, when workers and students were absent from their homes. The other four earthquakes occurred in the early morning or during the night, when almost all residents were in their homes. Figure 4.2.3 shows the relationship between seismic intensity (MMI) and the death ratio at different times. Very few people died in case of MMI 6 or less. The death ratio in case of MMI 8 was 10% and less. The death ratio suddenly increases in the case of MMI 9 or over. It differs widely depending on the individual earthquakes. There is a distinct difference in death ratio in case of daytime or night-time earthquakes. It is considered that many people were outside their residential buildings and/or many people were in office buildings with stronger anti-seismic structures during the daytime. In addition, the number of people who are trapped under collapsed buildings increases according to intensity of earthquake, unless they could escape from the buildings within a short time after the occurrence of the earthquake. Furthermore, quick escape is difficult during the night-time because many people are asleep, and this leads to an increased death ratio.

Figure 4.2.4 shows the relationship between the death ratio at night-time and in the daytime. The data is given in Figure 4.2.3. The death ratio in the daytime is about one fourth (0.25) of that of night-time for MMI 10. These results were derived from past damage experiences and the effects of movements of the population and other variables were not considered. In this Study, the human casualties in the daytime were estimated from casualties at night-time, by applying the relationship shown in Figure 4.2.4 as an index.

Table 4.2.1 Death Ratio by Earthquake in Iran

Earthquake	Ghir		Tabas			Golbaft		Sirch		Manjil		Ardekul	
Year	1972		1978			1981		1981		1990		1997	
Time	6:36		20:06			11:54		21:52		1:30		12:27	
Daytime / Night-time	Night-time		Night-time			Daytime		Night-time		Night-time		Daytime	
Major Structure	Adobe, Masonry					Adobe		Adobe				Adobe, Masonry	
Data For Each Village	MMI	Death	MMI	Death	Injured	MMI	Death	MMI	Death	MMI	Death	MMI	Death
	9	67.1	10	84.3	3.8	7	9.2	9	57.1	6	0.795	10	2.7
	9	20.4	9	42.8	4.2			9	32.1	6	0.103	10	13.4
			9	19.2	4.0			8	9.8	6	0.0	9	23.1
			8	8.7	3.9			8	2.1	9	90.0	10	45.5
								7	0.08	10	90.0	8	6.5
								7	0.8	7	9.0	8	11.0
										10	66.7	8	1.7
										8	13.3	7	5.8
												8	3.0

MMI: Seismic Intensity, Death: Death Ratio (%), Injured: Injured Ratio (%)

Source:
Ghir: Ghir Earthquake of 10 April 1992, Ambraysys, N.N., A.A. Moinfar and J.S.Tchalenko, UNESCO, Serial No. 2789/RMO. RD/SCE
Tabas: Berberian, M., 1979a, 1979b, 1979c, B.S.S.A., No.69
Golbaft: Hojjat Adeli: The Sirch(Kerman, Iran) Earthquake of 28 July 1981 - A Field Investigation, B.S.S.A., Vol. 72, No. 3, 1982
Sirch: Hojjat Adeli: The Sirch(Kerman, Iran) Earthquake of 28 July 1981 - A Field Investigation, B.S.S.A., Vol. 72, No. 3, 1982
Manjjl: Tsukuda, T. et al.: A Field Study on Variou Phenomena Associated with the 1990 Rudbar, Northwest Iran, Earthquake of M7.3, B.E.R.I., Vol.66, 1991.
Ardekul: Zirkouh (Ghaenat) Earthquake of May 10th, 1997, BHRC Report #255.

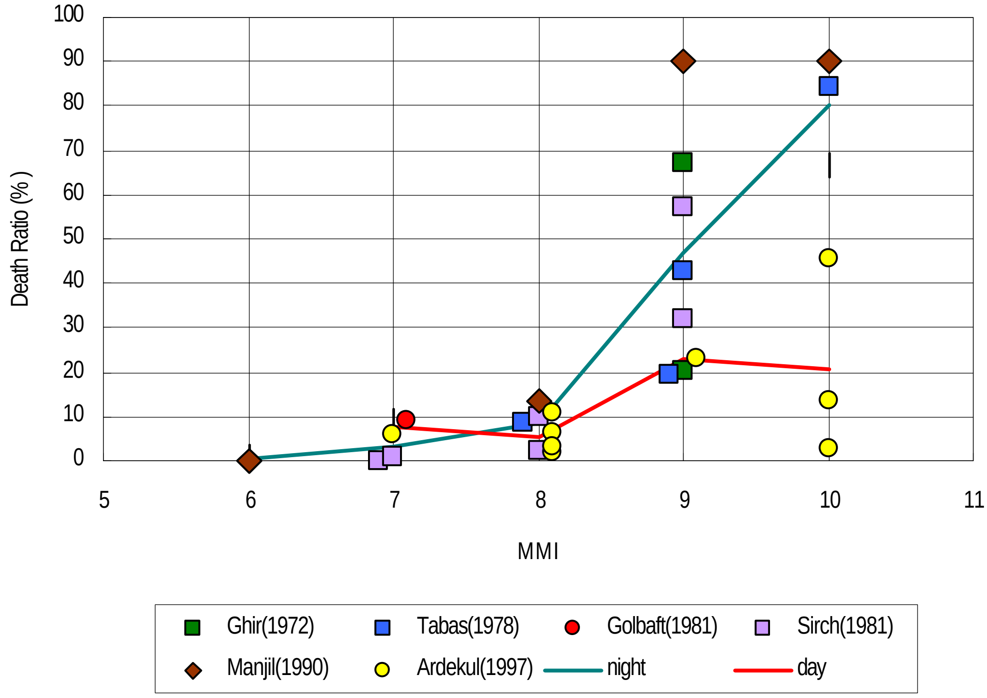


Figure 4.2.3 Death Ratio by Earthquake in Iran

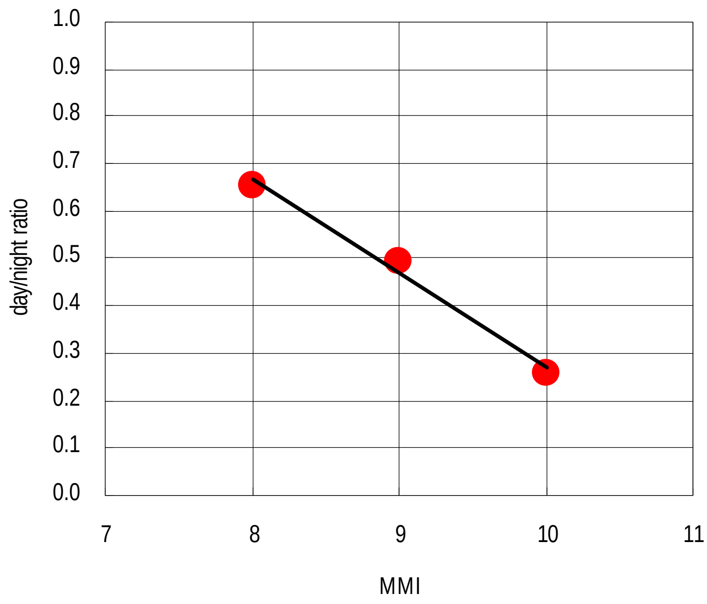


Figure 4.2.4 Daytime/Night-time Ratio for Number of Dead

(4) Parameter Setting of M3, M4d, M5

The coefficients of Coburn were modified to satisfy the relationship between the death ratio and seismic intensity (MMI) for cases of earthquake damage during the night-time in Iran (refer to Table 4.2.1). Since the damaged structures and their distribution ratio are not identified, by taking into account the local characteristics, it was assumed that three types of structures (adobe, block and brick, and brick and steel) were evenly distributed. Figure 4.2.5 shows the relationship between seismic intensity and the death ratio of earthquake damages in Iran, together with those of the established death ratio functions and those of Coburn et al. (1992). The established death ratio functions are average values for the cases of adobe, block and brick, and brick and steel structures. They consist of four types of emergency rescue activities.

In case of relatively strong structures, i.e., RC-0 and Steel-1, the death ratio function was determined in the following way:

- Preparation of relationship between damage ratio and death ratio on relatively older RC structures in Japan (Figure 4.2.6);
- Correction of the death ratio function based upon the actual damage ratio of RC-0 structures (Japan ratio x 1); and
- Correction of the death ratio function considering the effect of the difference in wall materials, as double the above function (Japan ratio x 2).

The items considered for the adjustments of the coefficients are the following:

M3: Number of occupants trapped by collapsed buildings

- Adobe structures break into pieces and generate dust of adobe upon collapsing, which prevent the formation of space, thus increasing the rate of entrapment.
- Block and brick structures are better than adobe structures. However, block and brick structures have less number of beams, which prevents space formation, thus also increasing the rate of entrapment.
- Wood, RC, and brick and steel structures offer possibilities of escape, owing to the formation of space by beams.
- Steel structures should provide much more space, due to the use of lots of steel skeletons.
- RC-0 and Steel-1 structures form space by the bracing and wall materials, thus providing a higher rate of escape.

M4d: Death ratio at 0-hrs after the collapse of buildings

- Adobe structures induce death by suffocation under collapsed roofs and walls.
- Block and brick and brick and steel structures also yield high death ratios from suffocation under collapsed bricks.
- Wood, RC, and steel structures form space, which results in less suffocation and a smaller ratio of instantaneous death.
- RC-0 and Steel-1 structures give a very low ratio of instantaneous death.

M5a: Post-collapse mortality with no rescue operations

- In case of absence of rescue, 95% of the entrapped people will die later.

M5b: Post-collapse mortality with community operations

- The rescue by the inhabitants is mainly done by hand. The work gives a high rescue ratio in wood structures, which rescue work can more easily be applied to, followed by block and brick, brick and steel, and RC-2 structures, in which bricks and blocks can be removed by hand.
- Adobe structures give a high ratio of instantaneous death and a low rescue ratio.
- RC-0 and Steel-1 structures are difficult for rescue, unless adequate tools are available.

M5c: Post-collapse mortality with community operations and emergency squads

- Since the rescue work by fire fighting teams and the Red Crescent Society make use of relatively large-scale equipment, the rescue ratio is high in RC-1, RC-0, and Steel-1 structures.

M5d: Post-collapse mortality with community operations, emergency squads and experts

- The activities by emergency rescue teams, including those of foreign countries, concentrate on the rescue of people who are entrapped in large buildings, owing to the use of special tools and rescue dogs. Thus, they are effective in Steel-1 and RC-0 structures. In other structures, however, the rescue ratio is low.

The parameters and the death ratio functions established in the Study are shown in Figure 4.2.7 to Figure 4.2.9 and Table 4.2.2 to Table 4.2.3.

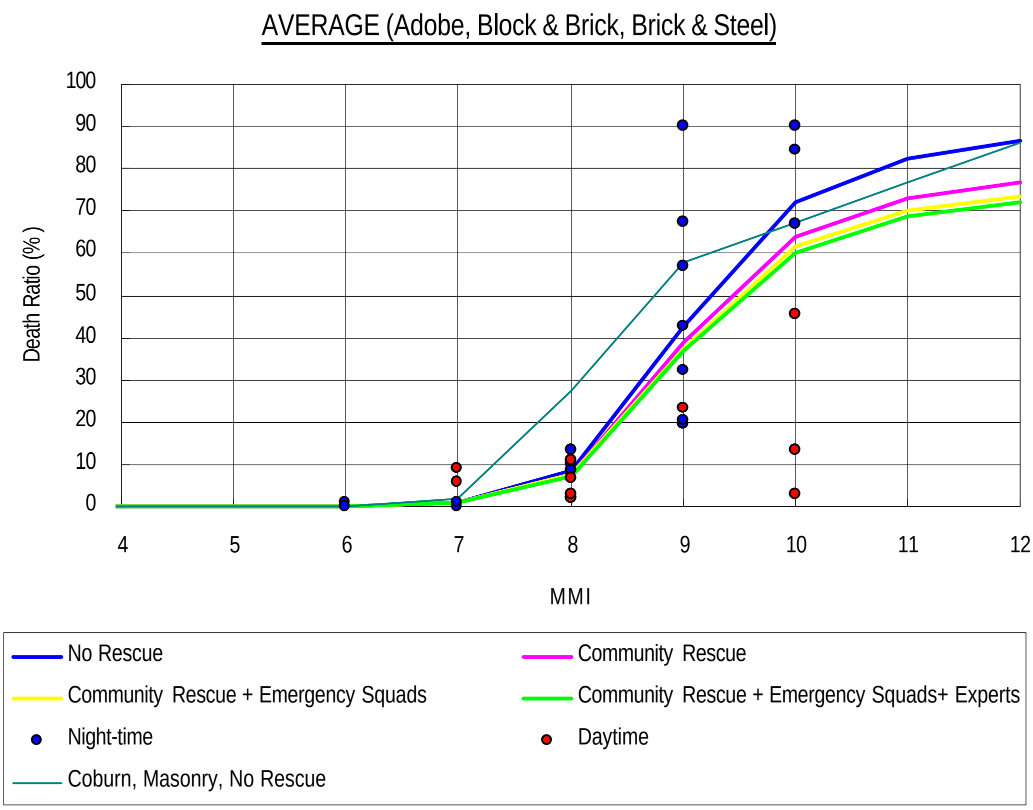


Figure 4.2.5 Comparison of Death Ratios by Iranian Earthquakes and Casualty Functions

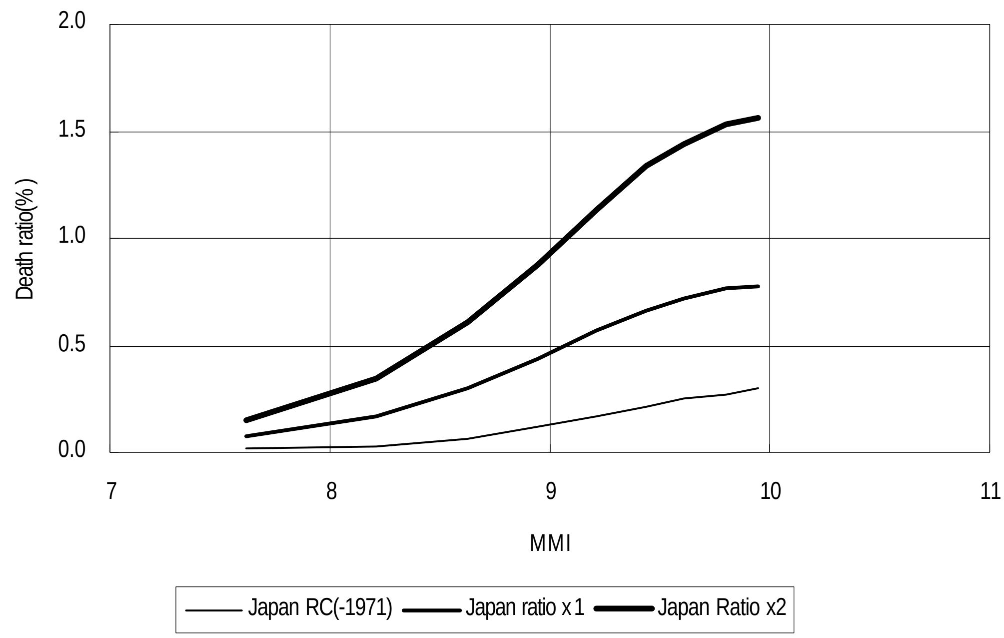


Figure 4.2.6 Death Ratio in Engineered Structures

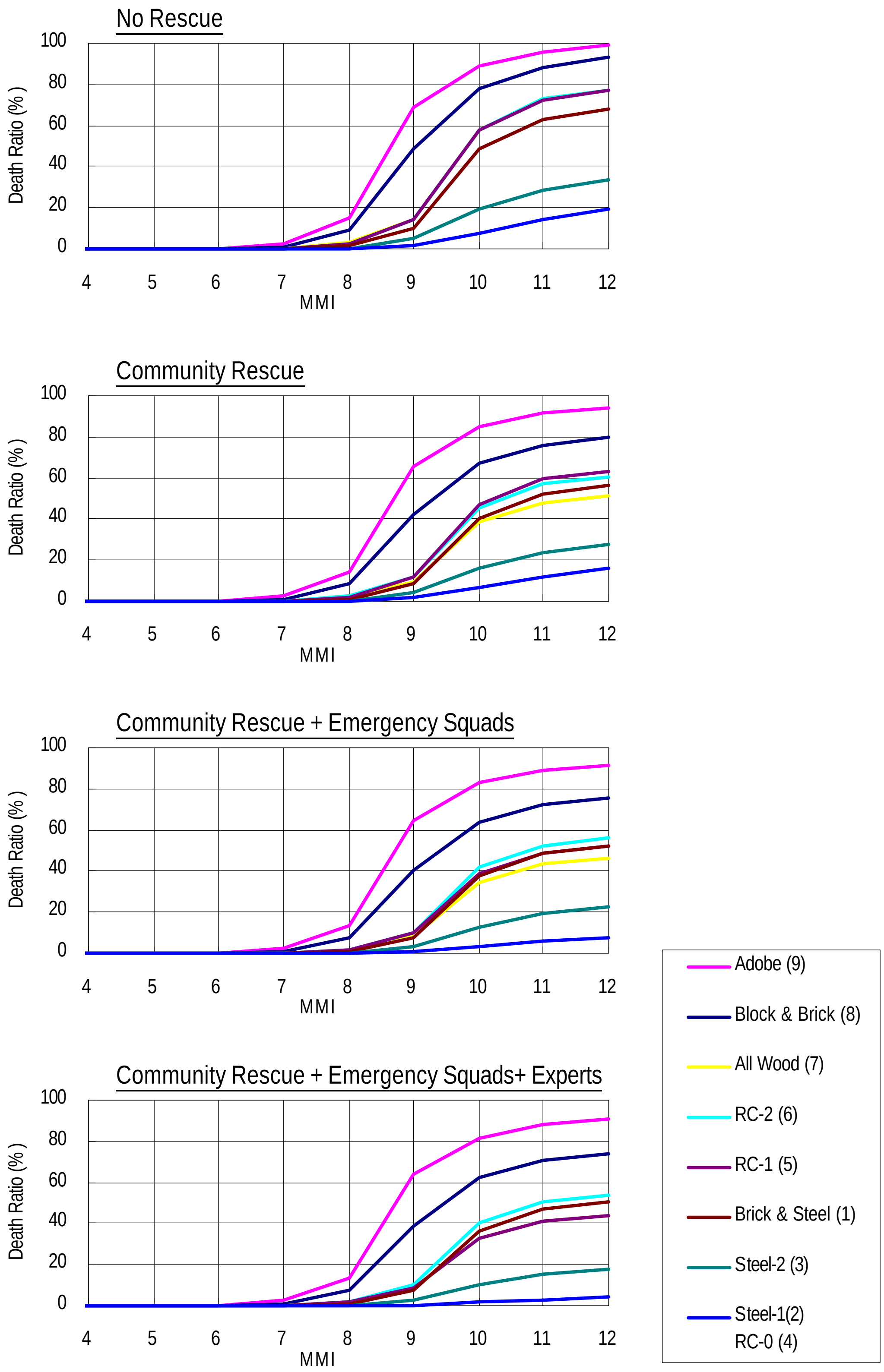


Figure 4.2.7 Casualty Function by Rescue Type

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

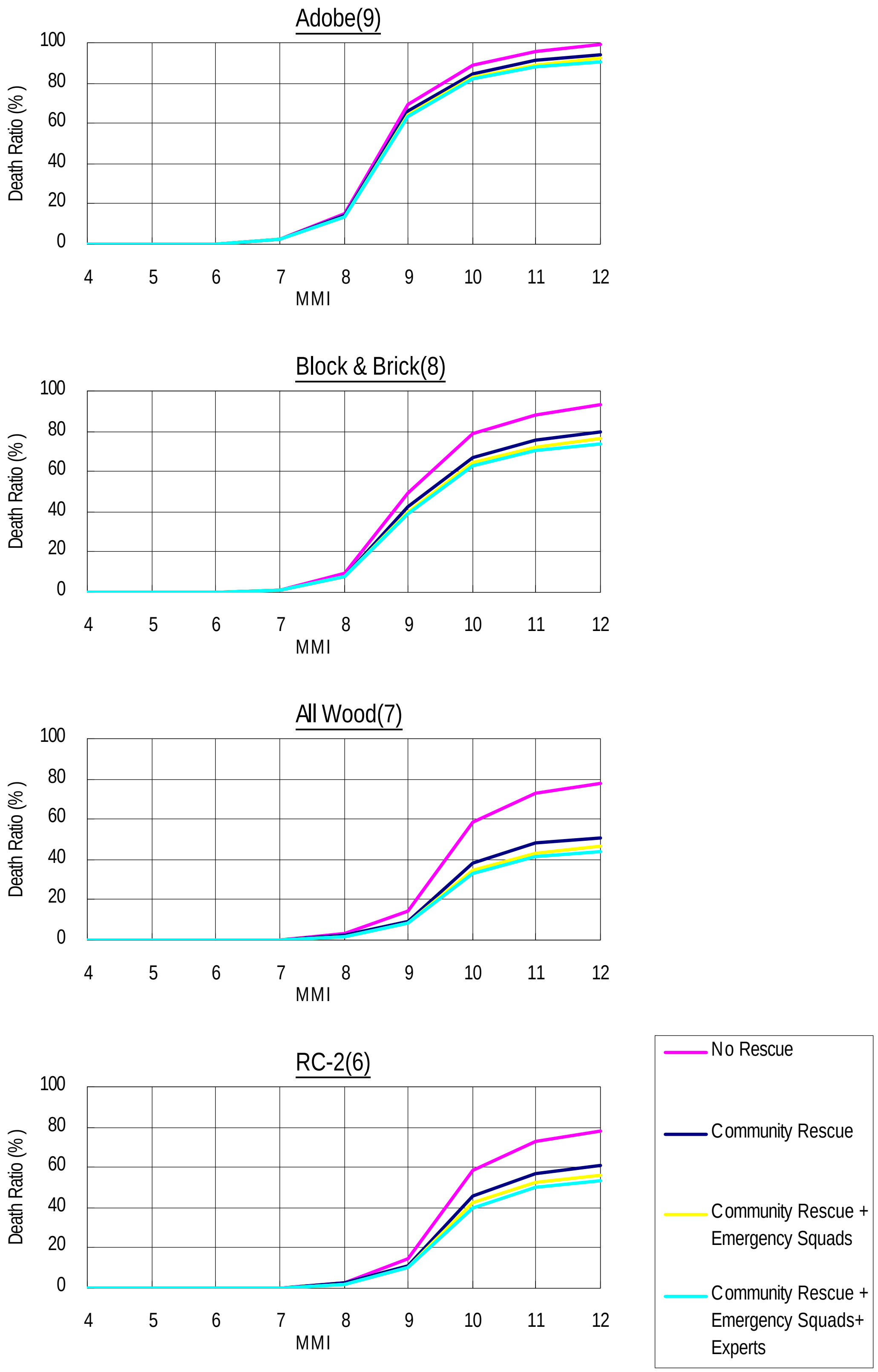


Figure 4.2.8 Casualty Function by Structure of Buildings (1)

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

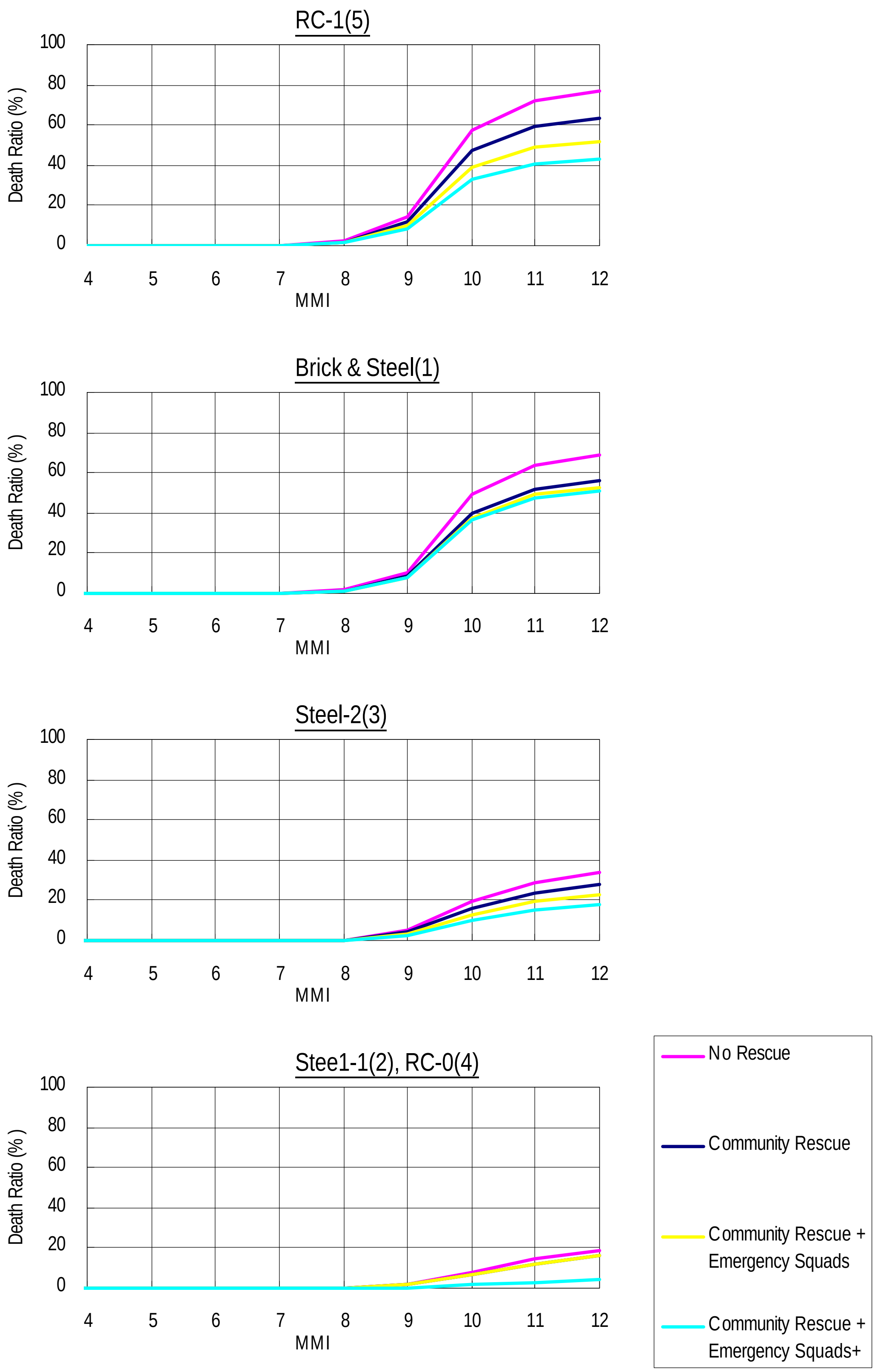


Figure 4.2.9 Casualty Function by Structure of Buildings (2)

The Number of structures is the same as those in Figure 4.1.5, Vulnerability Function of Residential Buildings Applied in the Study.

Table 4.2.2 Parameters of M3, M4d, M5 (1)

Coefficient M3 (Number of trapped by collapsed buildings) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	3	2	1	1	1	1	1	0.5	5
8	15	10	4	4	4	4	2	1	30
9	70	50	15	15	15	12	8	3	60
10	90	80	60	60	60	50	20	8	70
11	97	90	75	75	75	65	30	15	80
12	100	95	80	80	80	70	35	20	90

Coefficient M4d (Death ratio at 0-hrs after the collapse of buildings) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	80	60	40	40	30	50	30	5	20
4	80	60	40	40	30	50	30	5	20
5	80	60	40	40	30	50	30	5	20
6	80	60	40	40	30	50	30	5	20
7	80	60	40	40	30	50	30	5	20
8	80	60	40	40	30	50	30	5	20
9	80	60	40	40	30	50	30	5	20
10	80	60	40	40	30	50	30	5	20
11	80	60	40	40	30	50	30	5	20
12	80	60	40	40	30	50	30	5	20

Coefficient M5 a (Post-collapse mortality, No Rescue) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	95	95	95	95	95	95	95	95	95
4	95	95	95	95	95	95	95	95	95
5	95	95	95	95	95	95	95	95	95
6	95	95	95	95	95	95	95	95	95
7	95	95	95	95	95	95	95	95	95
8	95	95	95	95	95	95	95	95	95
9	95	95	95	95	95	95	95	95	95
10	95	95	95	95	95	95	95	95	95
11	95	95	95	95	95	95	95	95	95
12	95	95	95	95	95	95	95	95	95

Coefficient M5b (Post-collapse mortality, Community Rescue) (unit: %)									
MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	70	60	40	60	70	60	70	80	60
4	70	60	40	60	70	60	70	80	60
5	70	60	40	60	70	60	70	80	60
6	70	60	40	60	70	60	70	80	60
7	70	60	40	60	70	60	70	80	60
8	70	60	40	60	70	60	70	80	60
9	70	60	40	60	70	60	70	80	60
10	70	60	40	60	70	60	70	80	60
11	70	60	40	60	70	60	70	80	60
12	70	60	40	60	70	60	70	80	60

Table 4.2.3 Parameters of M3, M4d, M5 (2)

Coefficient M5c (Post-collapse mortality ,Community + Emergency Squads) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	60	50	30	50	50	50	50	35	50
4	60	50	30	50	50	50	50	35	50
5	60	50	30	50	50	50	50	35	50
6	60	50	30	50	50	50	50	35	50
7	60	50	30	50	50	50	50	35	50
8	60	50	30	50	50	50	50	35	50
9	60	50	30	50	50	50	50	35	50
10	60	50	30	50	50	50	50	35	50
11	60	50	30	50	50	50	50	35	50
12	60	50	30	50	50	50	50	35	50

Coefficient M5d(Post-collapse mortality ,Community + Emergency Squads + Experts) (unit: %)

MMI	Adobe	Block & Brick	All Wood	RC-2	RC-1	Brick & Steel	Steel-2	Steel-1 RC-0	Coburn Masonry
3	55	45	25	45	35	45	30	15	45
4	55	45	25	45	35	45	30	15	45
5	55	45	25	45	35	45	30	15	45
6	55	45	25	45	35	45	30	15	45
7	55	45	25	45	35	45	30	15	45
8	55	45	25	45	35	45	30	15	45
9	55	45	25	45	35	45	30	15	45
10	55	45	25	45	35	45	30	15	45
11	55	45	25	45	35	45	30	15	45
12	55	45	25	45	35	45	30	15	45

4.2.2. Damage Estimation

The number of fatalities due to the scenario earthquakes was estimated. The definition of fatalities is those people killed only as a result of building collapse and not because of any other cause. Particularly, in large-scale earthquakes, people may die from diseases in refugee camps and, therefore, those people are not accounted for by the Study.

Definition of Damage	
Human Casualties	Fatalities
Unit	Persons
Cause of Damage	Collapse of Buildings

The human casualty damage was estimated for every building structure in each census zone, and the results were aggregated into district data. The census zones include cases extending outside the 22 districts, and these were excluded from the total district figures. The number of fatalities, with distinction of night-time and daytime and types of emergency rescue activities, is summarised in Table 4.2.4 to Table 4.2.7 and Figure 4.2.10 to Figure 4.2.22. The four types of emergency rescue activities during night-time and daytime earthquakes lead to eight kinds of estimations against each scenario earthquake. The case of a night-time earthquake with no rescue activity results in the most serious damage.

From all the fault models, the Ray Fault Model yields the largest damages. In this case, about 380 thousand inhabitants, or about 6% of the total population will die. The casualties in District 15 will be vast because of the large number of its inhabitants. The death ratio in Districts 11 and 12 will be as high as 15 to 20% because there are many vulnerable buildings in the area and high seismic intensity 9 in MMI scale. The death ratio in the northern part of the city, i.e., in Districts 1 to 5 shall only be about 2%.

In case of the NTF Model, the worst case indicates about 130 thousand fatalities, or about 2% of the total population. The death ratio in the northern part of the city, in Districts 1 to 5, shall be high, approximately 3%. The death ratio in the southern part shall be low, approximately 1%.

In case of the Mosha Fault Model, the death ratio does not exceed 0.3 % of the total population of the city. The casualties in District 12 shall be vast, approximately 1.7%. This is due to the existence of many vulnerable buildings of adobe and wood and brick structure, the high damage ratio of these buildings and the low rescue ratio. Such a tendency is also observed in the case of the Floating Model.

The distribution of numbers of human casualties by district at night-time for the Ray Fault Model and the NTF Model are shown in Figure 4.2.14 to Figure 4.2.17. The ‘ no rescue’ and ‘ full rescue’ cases are presented in these figures. A ‘ full rescue’ case is a case where a combination of the community rescue, emergency squads and expert operations is available.

In the Ray Fault Model, human casualties are estimated to culminate in the southern part of the city. In some census zones, the number of dead will exceed 1,000.

On the contrary, in the NTF Model, many human casualties are estimated to occur in the northern part of the city. In some census zones, the number of dead will amount to 100 or more. This area corresponds to Districts 11 and 12, where vulnerable buildings such as adobe are prevailing and emergency rescue activities are not effective for these kinds of structures.

The distributions of death ratios for the above cases are shown in Figure 4.2.18 to Figure 4.2.21.

In case of the Ray Fault Model, the death ratio in several census zones in Districts 11 and 12 shall be enormous, 40% or more. In these districts, the emergency rescue activities are not effective. In the NTF Model, the high-death ratio area is limited. If sufficient rescue activities are undertaken, the death ratio would drop to 20% or below for the entire census zone.

Table 4.2.4 Casualties by District – Ray Fault model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		---		---		---		No Rescue		---		---		---		
	---		CR		CR		CR		---		CR		CR		CR		
	---		---		ES		ES		---		---		ES		ES		
	---		---		---		EX		---		---		---		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	2,719	1.2	2,242	1.0	2,065	0.9	1,953	0.9	1,925	0.9	1,588	0.7	1,464	0.7	1,385	0.6	221,552
2	8,812	2.0	7,125	1.6	6,395	1.4	5,879	1.3	5,692	1.3	4,601	1.0	4,131	0.9	3,800	0.8	448,997
3	5,187	2.4	4,241	2.0	3,812	1.8	3,491	1.6	3,181	1.5	2,602	1.2	2,338	1.1	2,143	1.0	217,416
4	6,777	1.1	5,549	0.9	5,043	0.8	4,703	0.7	4,617	0.7	3,780	0.6	3,436	0.5	3,205	0.5	641,614
5	5,768	1.4	4,668	1.1	4,083	1.0	3,710	0.9	3,788	0.9	3,066	0.7	2,684	0.6	2,442	0.6	423,537
6	6,517	3.1	5,335	2.5	4,814	2.3	4,431	2.1	3,879	1.8	3,175	1.5	2,864	1.4	2,635	1.3	209,704
7	12,817	4.6	10,592	3.8	9,688	3.5	9,053	3.3	7,432	2.7	6,142	2.2	5,618	2.0	5,249	1.9	276,809
8	14,610	4.4	12,018	3.7	11,005	3.3	10,318	3.1	8,391	2.6	6,903	2.1	6,318	1.9	5,920	1.8	328,538
9	9,755	5.7	7,999	4.7	7,393	4.3	7,019	4.1	5,447	3.2	4,468	2.6	4,129	2.4	3,919	2.3	171,721
10	21,983	7.9	18,328	6.6	17,075	6.1	16,329	5.9	11,558	4.1	9,631	3.5	8,973	3.2	8,581	3.1	278,902
11	31,635	14.7	27,175	12.6	25,560	11.9	24,549	11.4	15,265	7.1	13,108	6.1	12,324	5.7	11,832	5.5	215,160
12	37,058	20.1	32,747	17.8	31,234	16.9	30,344	16.5	18,632	10.1	16,461	8.9	15,697	8.5	15,247	8.3	184,325
13	10,312	4.6	8,553	3.8	7,876	3.5	7,430	3.3	6,049	2.7	5,018	2.2	4,622	2.1	4,361	1.9	225,166
14	22,968	6.3	19,303	5.3	17,840	4.9	16,864	4.6	12,510	3.4	10,505	2.9	9,704	2.7	9,170	2.5	365,924
15	50,973	8.6	42,520	7.2	39,382	6.6	37,378	6.3	25,436	4.3	21,212	3.6	19,628	3.3	18,610	3.1	593,217
16	29,732	10.5	25,107	8.8	23,467	8.3	22,449	7.9	14,869	5.2	12,557	4.4	11,738	4.1	11,230	4.0	283,869
17	28,547	9.8	23,681	8.2	21,957	7.6	20,874	7.2	13,651	4.7	11,326	3.9	10,502	3.6	9,986	3.4	290,539
18	24,564	8.4	20,202	6.9	18,505	6.3	17,383	5.9	11,862	4.1	9,755	3.3	8,936	3.1	8,395	2.9	292,207
19	16,472	7.9	13,523	6.5	12,362	5.9	11,590	5.6	8,038	3.9	6,599	3.2	6,033	2.9	5,655	2.7	208,230
20	30,188	10.1	25,061	8.4	22,954	7.7	21,513	7.2	14,398	4.8	11,953	4.0	10,946	3.6	10,257	3.4	299,931
21	4,776	3.8	3,934	3.1	3,548	2.8	3,275	2.6	2,810	2.2	2,315	1.8	2,088	1.7	1,929	1.5	125,939
22	651	1.2	521	0.9	462	0.8	423	0.8	446	0.8	357	0.6	317	0.6	290	0.5	55,758
Sum	382,822	6.0	320,424	5.0	296,518	4.7	280,958	4.4	199,876	3.1	167,121	2.6	154,490	2.4	146,239	2.3	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.5 Casualties by District – NTF Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		---		---		---		No Rescue		---		---		---		
	---		CR		CR		CR		---		CR		CR		CR		
	---		---		ES		ES		---		---		ES		ES		
	---		---		---		EX		---		---		---		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	14,032	6.3	11,564	5.2	10,543	4.8	9,830	4.4	7,829	3.5	6,451	2.9	5,881	2.7	5,483	2.5	221,552
2	11,914	2.7	9,618	2.1	8,642	1.9	7,997	1.8	7,308	1.6	5,899	1.3	5,301	1.2	4,904	1.1	448,997
3	10,290	4.7	8,419	3.9	7,531	3.5	6,852	3.2	5,642	2.6	4,617	2.1	4,129	1.9	3,757	1.7	217,416
4	15,277	2.4	12,504	1.9	11,272	1.8	10,430	1.6	9,476	1.5	7,757	1.2	6,995	1.1	6,473	1.0	641,614
5	12,217	2.9	9,915	2.3	8,779	2.1	7,992	1.9	7,383	1.7	5,991	1.4	5,302	1.3	4,825	1.1	423,537
6	3,144	1.5	2,569	1.2	2,321	1.1	2,142	1.0	2,050	1.0	1,675	0.8	1,514	0.7	1,397	0.7	209,704
7	4,337	1.6	3,589	1.3	3,296	1.2	3,097	1.1	2,845	1.0	2,355	0.9	2,163	0.8	2,033	0.7	276,809
8	4,750	1.4	3,910	1.2	3,595	1.1	3,388	1.0	3,115	0.9	2,565	0.8	2,358	0.7	2,222	0.7	328,538
9	1,880	1.1	1,544	0.9	1,434	0.8	1,370	0.8	1,316	0.8	1,081	0.6	1,004	0.6	959	0.6	171,721
10	3,701	1.3	3,103	1.1	2,911	1.0	2,805	1.0	2,557	0.9	2,144	0.8	2,011	0.7	1,938	0.7	278,902
11	5,128	2.4	4,457	2.1	4,233	2.0	4,105	1.9	3,496	1.6	3,038	1.4	2,885	1.3	2,798	1.3	215,160
12	7,722	4.2	6,883	3.7	6,605	3.6	6,454	3.5	5,232	2.8	4,664	2.5	4,476	2.4	4,373	2.4	184,325
13	2,614	1.2	2,180	1.0	2,028	0.9	1,936	0.9	1,794	0.8	1,496	0.7	1,392	0.6	1,329	0.6	225,166
14	4,191	1.1	3,551	1.0	3,321	0.9	3,181	0.9	2,946	0.8	2,495	0.7	2,333	0.6	2,234	0.6	365,924
15	7,177	1.2	6,037	1.0	5,646	1.0	5,414	0.9	5,022	0.8	4,221	0.7	3,946	0.7	3,782	0.6	593,217
16	4,213	1.5	3,604	1.3	3,404	1.2	3,291	1.2	2,960	1.0	2,532	0.9	2,392	0.8	2,312	0.8	283,869
17	3,433	1.2	2,868	1.0	2,683	0.9	2,576	0.9	2,368	0.8	1,978	0.7	1,850	0.6	1,777	0.6	290,539
18	2,622	0.9	2,160	0.7	1,994	0.7	1,892	0.6	1,826	0.6	1,504	0.5	1,389	0.5	1,318	0.5	292,207
19	1,466	0.7	1,205	0.6	1,111	0.5	1,054	0.5	1,075	0.5	883	0.4	815	0.4	773	0.4	208,230
20	2,797	0.9	2,341	0.8	2,173	0.7	2,068	0.7	2,063	0.7	1,727	0.6	1,603	0.5	1,525	0.5	299,931
21	1,761	1.4	1,450	1.2	1,325	1.1	1,244	1.0	1,176	0.9	968	0.8	885	0.7	831	0.7	125,939
22	1,540	2.8	1,237	2.2	1,081	1.9	970	1.7	956	1.7	768	1.4	672	1.2	603	1.1	55,758
Sum	126,204	2.0	104,705	1.6	95,927	1.5	90,086	1.4	80,435	1.3	66,809	1.1	61,294	1.0	57,645	0.9	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.6 Casualties by District – Mosha Fault Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		---		---		---		No Rescue		---		---		---		
	---		CR		CR		CR		---		CR		CR		CR		
	---		---		ES		ES		---		---		ES		ES		
	---		---		---		EX		---		---		---		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	1,174	0.5	968	0.4	892	0.4	844	0.4	932	0.4	769	0.3	709	0.3	671	0.3	221,552
2	627	0.1	509	0.1	459	0.1	425	0.1	540	0.1	438	0.1	395	0.1	366	0.1	448,997
3	944	0.4	772	0.4	701	0.3	652	0.3	732	0.3	599	0.3	544	0.3	506	0.2	217,416
4	2,444	0.4	2,002	0.3	1,821	0.3	1,705	0.3	1,922	0.3	1,574	0.2	1,432	0.2	1,340	0.2	641,614
5	313	0.1	255	0.1	224	0.1	204	0.0	280	0.1	228	0.1	200	0.0	182	0.0	423,537
6	570	0.3	466	0.2	423	0.2	391	0.2	466	0.2	381	0.2	345	0.2	320	0.2	209,704
7	831	0.3	688	0.2	634	0.2	598	0.2	683	0.2	566	0.2	521	0.2	491	0.2	276,809
8	786	0.2	648	0.2	596	0.2	563	0.2	653	0.2	538	0.2	495	0.2	468	0.1	328,538
9	158	0.1	130	0.1	120	0.1	114	0.1	139	0.1	115	0.1	106	0.1	101	0.1	171,721
10	373	0.1	319	0.1	300	0.1	290	0.1	323	0.1	276	0.1	260	0.1	251	0.1	278,902
11	1,520	0.7	1,337	0.6	1,276	0.6	1,242	0.6	1,241	0.6	1,091	0.5	1,041	0.5	1,013	0.5	215,160
12	3,095	1.7	2,777	1.5	2,672	1.4	2,614	1.4	2,483	1.3	2,229	1.2	2,144	1.2	2,098	1.1	184,325
13	599	0.3	499	0.2	463	0.2	441	0.2	499	0.2	416	0.2	386	0.2	367	0.2	225,166
14	1,265	0.3	1,084	0.3	1,016	0.3	975	0.3	1,039	0.3	890	0.2	834	0.2	800	0.2	365,924
15	1,841	0.3	1,566	0.3	1,468	0.2	1,410	0.2	1,515	0.3	1,287	0.2	1,207	0.2	1,159	0.2	593,217
16	1,140	0.4	991	0.3	941	0.3	912	0.3	945	0.3	821	0.3	779	0.3	755	0.3	283,869
17	935	0.3	785	0.3	735	0.3	707	0.2	769	0.3	645	0.2	605	0.2	581	0.2	290,539
18	631	0.2	520	0.2	479	0.2	453	0.2	511	0.2	422	0.1	388	0.1	367	0.1	292,207
19	131	0.1	108	0.1	99	0.0	93	0.0	118	0.1	97	0.0	89	0.0	83	0.0	208,230
20	584	0.2	493	0.2	458	0.2	436	0.1	494	0.2	418	0.1	388	0.1	369	0.1	299,931
21	104	0.1	87	0.1	79	0.1	73	0.1	94	0.1	78	0.1	71	0.1	66	0.1	125,939
22	41	0.1	33	0.1	29	0.1	26	0.0	37	0.1	30	0.1	26	0.0	24	0.0	55,758
Sum	20,107	0.3	17,036	0.3	15,886	0.2	15,166	0.2	16,415	0.3	13,906	0.2	12,965	0.2	12,377	0.2	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

Table 4.2.7 Casualties by District – Floating Model

District	Night-time								Daytime								Population
	Type of Rescue								Type of Rescue								
	No Rescue		---		---		---		No Rescue		---		---		---		
	---		CR		CR		CR		---		CR		CR		CR		
	---		---		ES		ES		---		---		ES		ES		
	---		---		---		EX		---		---		---		EX		
	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	Death	%	
1	9,581	4.3	7,894	3.6	7,203	3.3	6,724	3.0	5,749	2.6	4,736	2.1	4,322	2.0	4,035	1.8	221,552
2	16,183	3.6	13,086	2.9	11,695	2.6	10,711	2.4	9,793	2.2	7,919	1.8	7,078	1.6	6,483	1.4	448,997
3	11,902	5.5	9,734	4.5	8,691	4.0	7,887	3.6	6,232	2.9	5,098	2.3	4,552	2.1	4,133	1.9	217,416
4	21,804	3.4	17,858	2.8	16,075	2.5	14,818	2.3	13,114	2.0	10,740	1.7	9,668	1.5	8,911	1.4	641,614
5	12,973	3.1	10,524	2.5	9,203	2.2	8,309	2.0	7,844	1.9	6,363	1.5	5,565	1.3	5,025	1.2	423,537
6	6,828	3.3	5,585	2.7	5,017	2.4	4,592	2.2	4,125	2.0	3,374	1.6	3,030	1.4	2,773	1.3	209,704
7	10,902	3.9	9,015	3.3	8,249	3.0	7,712	2.8	6,537	2.4	5,405	2.0	4,946	1.8	4,623	1.7	276,809
8	12,173	3.7	10,013	3.0	9,144	2.8	8,544	2.6	7,293	2.2	5,999	1.8	5,479	1.7	5,119	1.6	328,538
9	8,000	4.7	6,560	3.8	6,062	3.5	5,754	3.4	4,696	2.7	3,852	2.2	3,560	2.1	3,378	2.0	171,721
10	15,778	5.7	13,149	4.7	12,259	4.4	11,733	4.2	9,121	3.3	7,600	2.7	7,086	2.5	6,782	2.4	278,902
11	18,654	8.7	16,068	7.5	15,142	7.0	14,568	6.8	10,661	5.0	9,181	4.3	8,650	4.0	8,321	3.9	215,160
12	27,264	14.8	24,121	13.1	23,024	12.5	22,384	12.1	15,186	8.2	13,432	7.3	12,820	7.0	12,462	6.8	184,325
13	9,551	4.2	7,926	3.5	7,307	3.2	6,902	3.1	5,709	2.5	4,738	2.1	4,368	1.9	4,126	1.8	225,166
14	18,495	5.1	15,529	4.2	14,356	3.9	13,578	3.7	10,731	2.9	9,006	2.5	8,324	2.3	7,871	2.2	365,924
15	27,765	4.7	23,174	3.9	21,430	3.6	20,298	3.4	16,517	2.8	13,784	2.3	12,745	2.1	12,071	2.0	593,217
16	17,507	6.2	14,820	5.2	13,881	4.9	13,307	4.7	10,176	3.6	8,613	3.0	8,067	2.8	7,733	2.7	283,869
17	15,955	5.5	13,251	4.6	12,309	4.2	11,726	4.0	9,137	3.1	7,588	2.6	7,048	2.4	6,714	2.3	290,539
18	13,052	4.5	10,735	3.7	9,839	3.4	9,248	3.2	7,512	2.6	6,179	2.1	5,664	1.9	5,325	1.8	292,207
19	6,512	3.1	5,347	2.6	4,900	2.4	4,610	2.2	3,976	1.9	3,264	1.6	2,992	1.4	2,814	1.4	208,230
20	14,207	4.7	11,820	3.9	10,850	3.6	10,193	3.4	8,348	2.8	6,945	2.3	6,375	2.1	5,988	2.0	299,931
21	4,524	3.6	3,724	3.0	3,369	2.7	3,120	2.5	2,752	2.2	2,265	1.8	2,050	1.6	1,898	1.5	125,939
22	1,906	3.4	1,533	2.7	1,342	2.4	1,206	2.2	1,158	2.1	931	1.7	815	1.5	733	1.3	55,758
Sum	301,515	4.7	251,462	4.0	231,345	3.6	217,924	3.4	176,366	2.8	147,014	2.3	135,202	2.1	127,320	2.0	6,359,055

Type of rescue
CR: Community Rescue ES: Emergency Squads EX: Experts

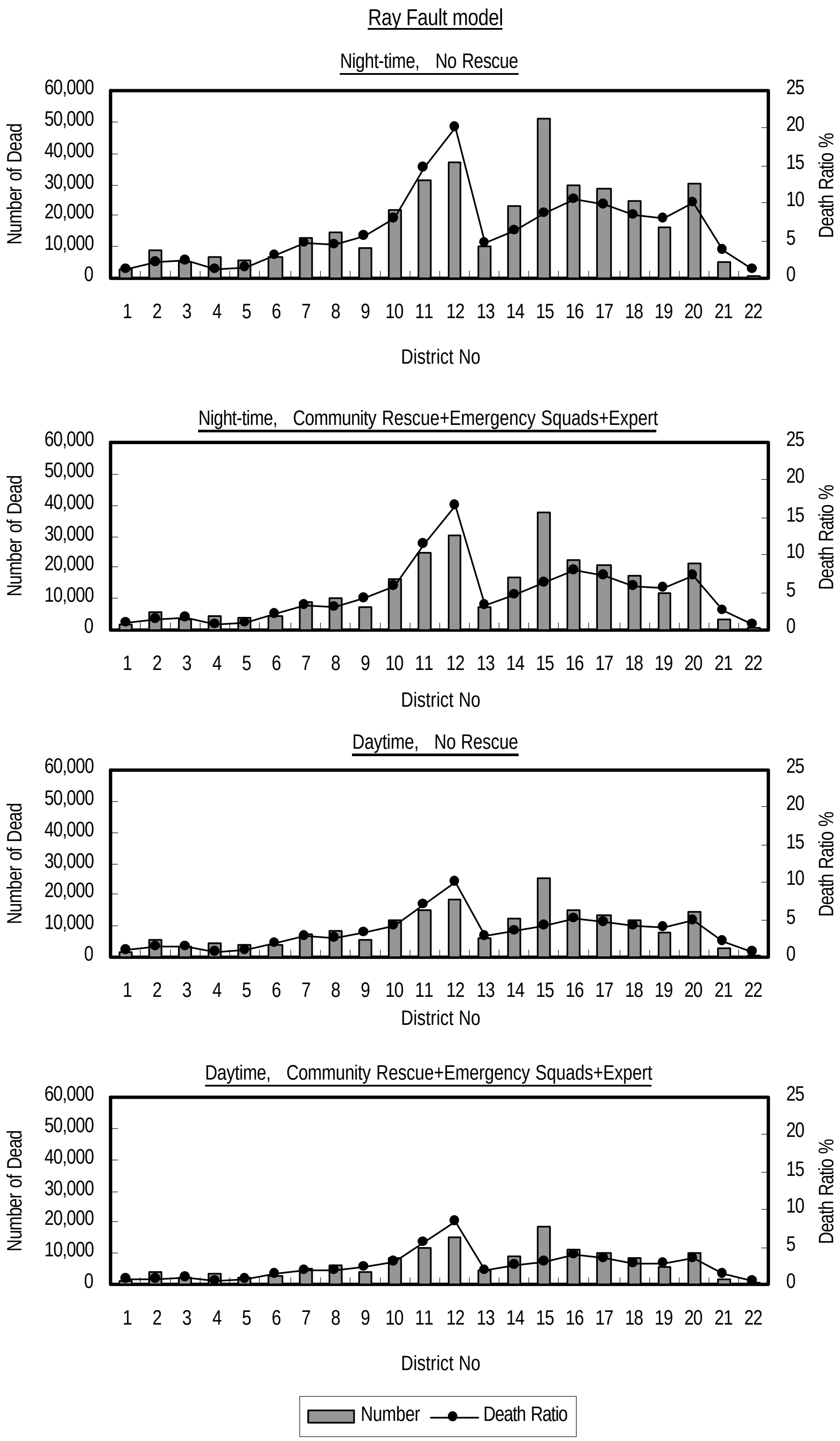


Figure 4.2.10 Distribution of Casualties by District – Ray Fault Model

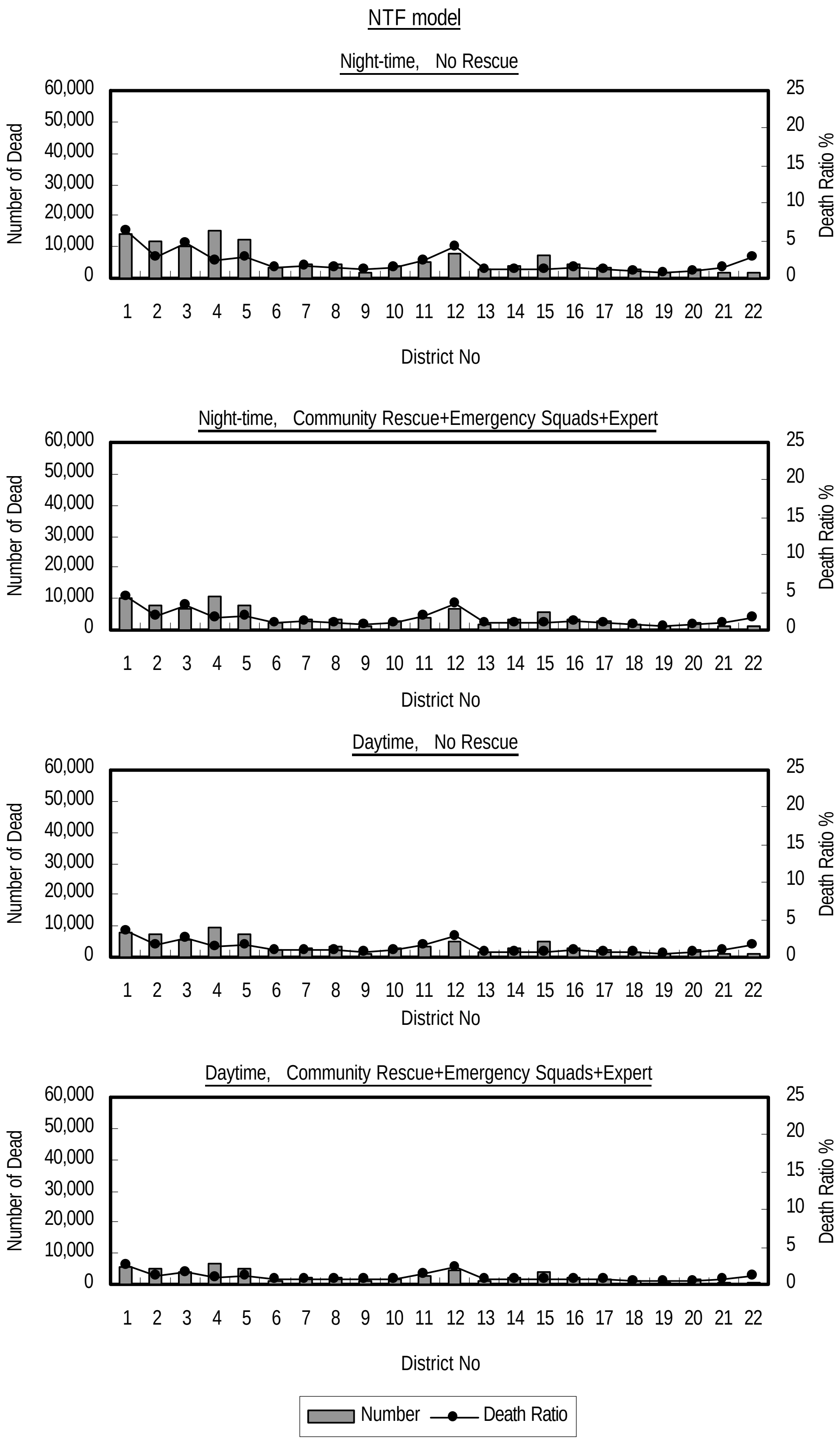


Figure 4.2.11 Distribution of Casualties by District – NTF Model

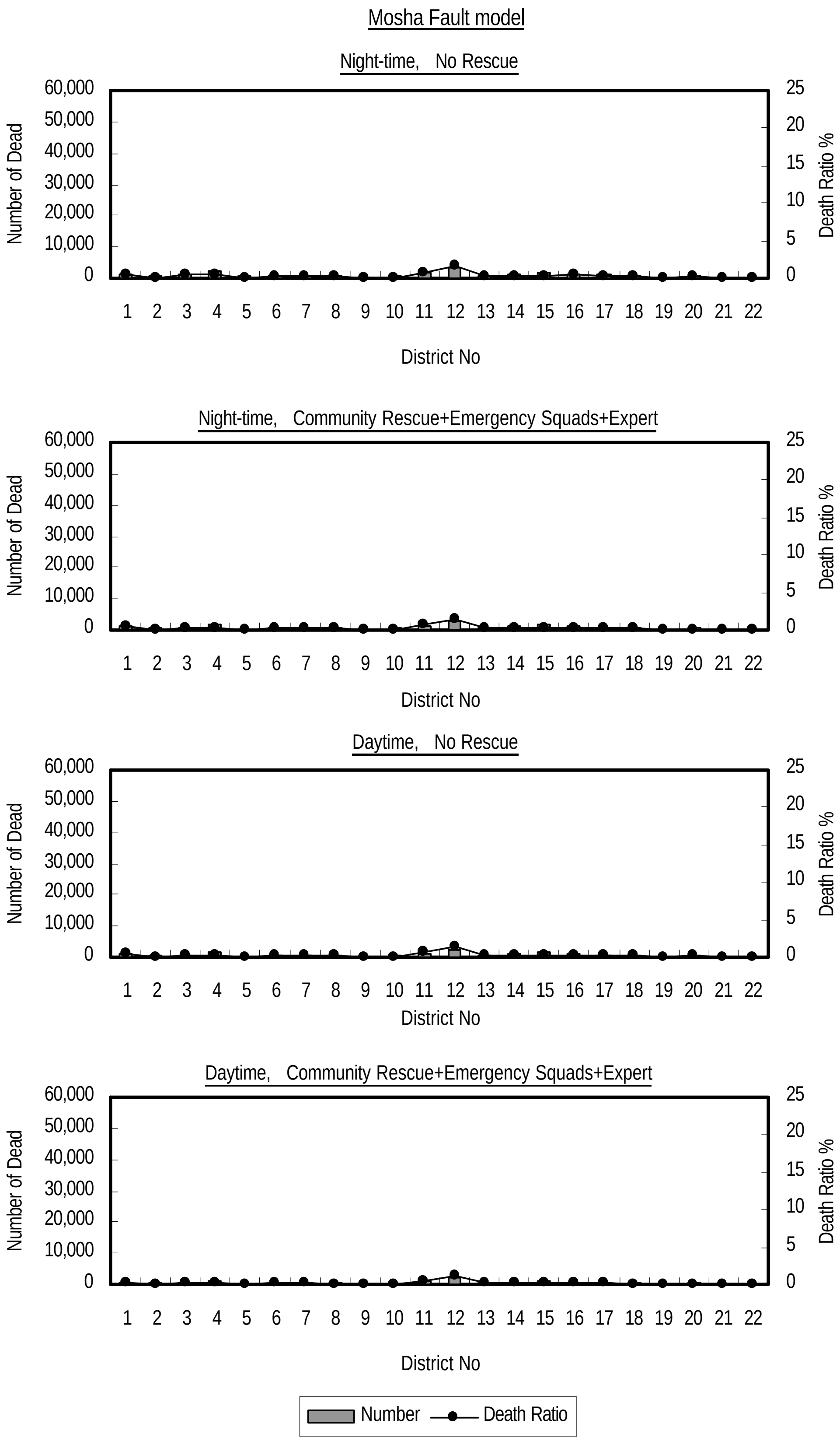


Figure 4.2.12 Distribution of Casualties by District – Mosha Fault Model

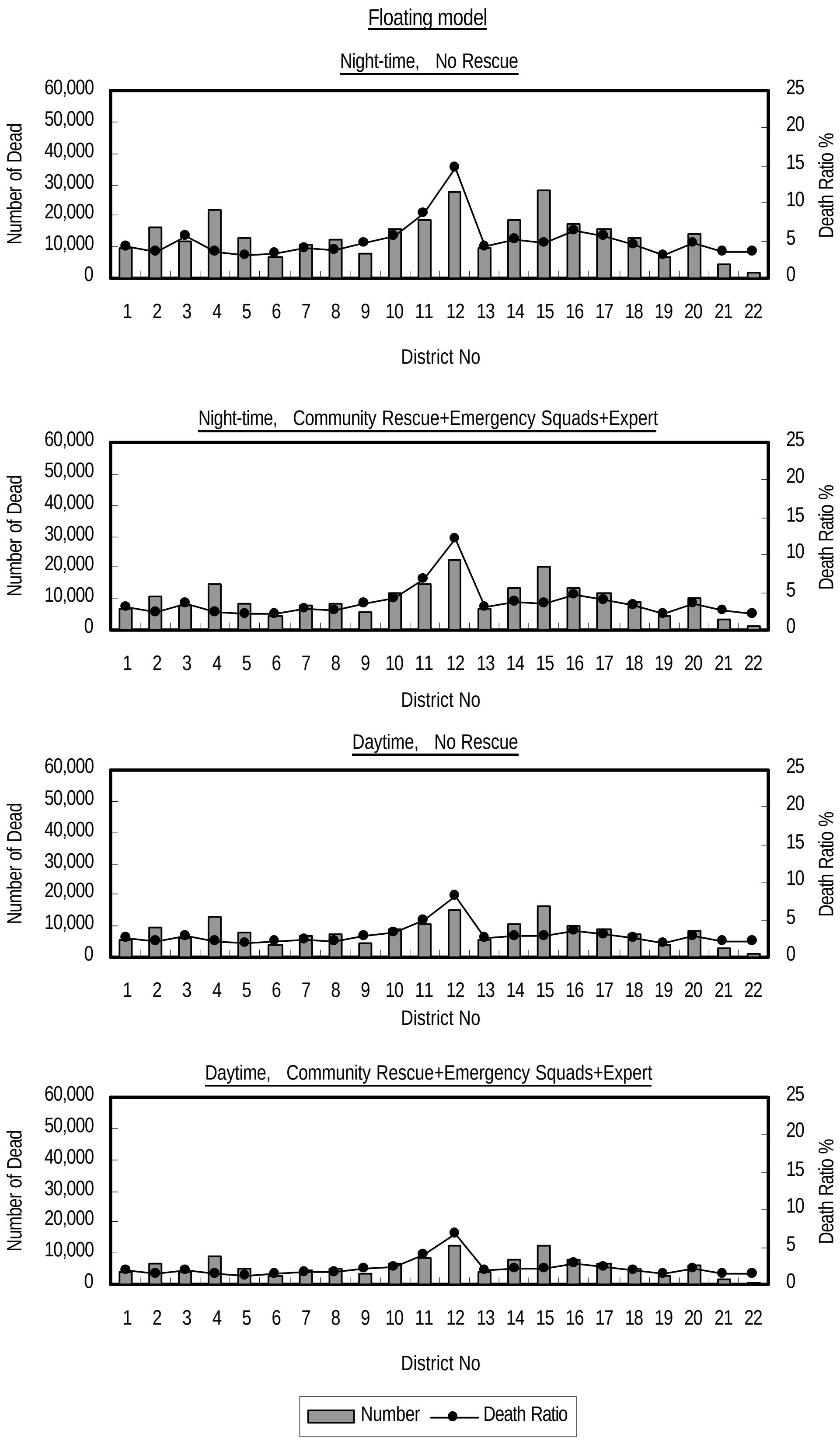
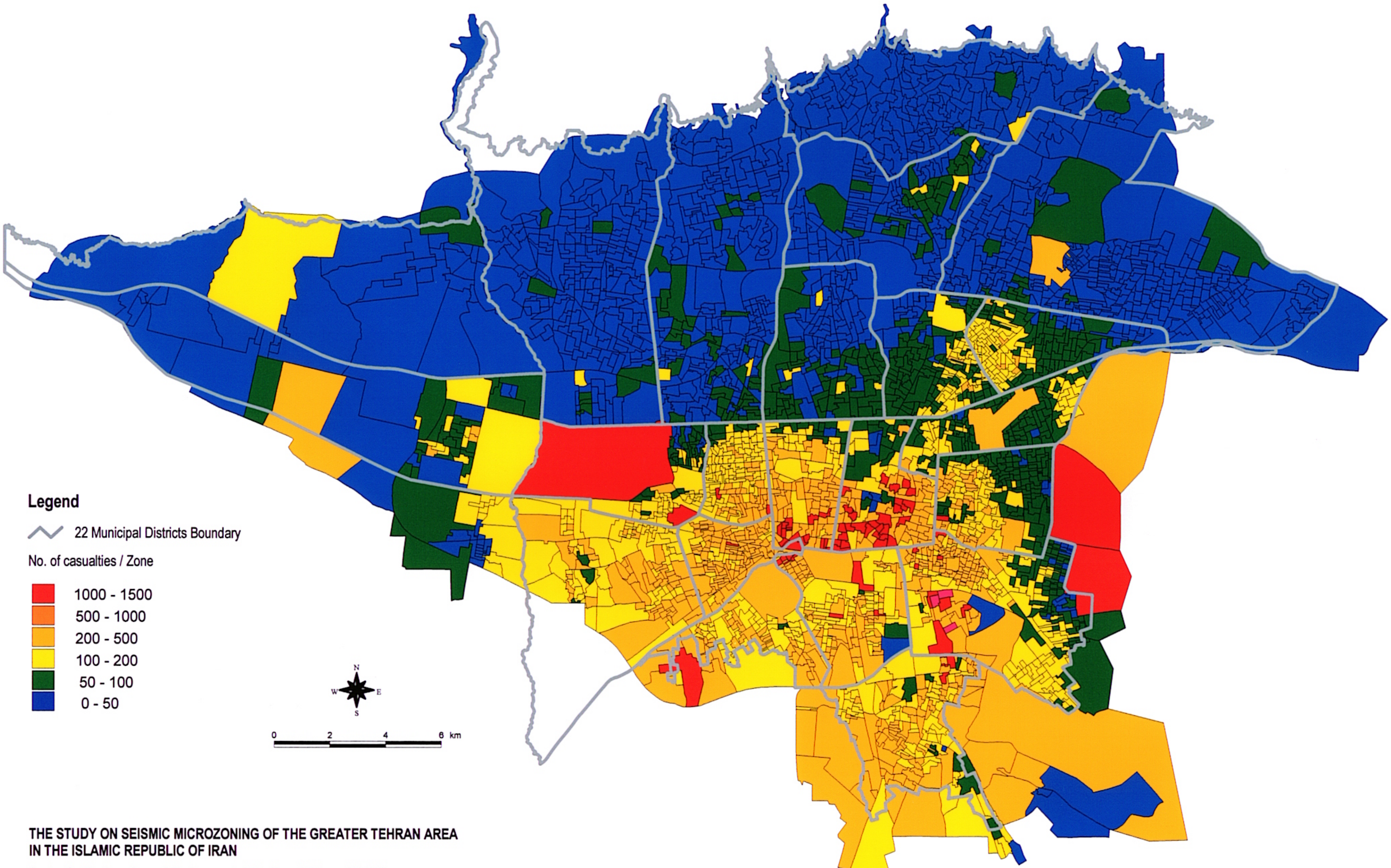


Figure 4.2.13 Distribution of Casualties by District – Floating Model

Figure 4.2.14

Casualty Distribution - Night No Rescue Work (Ray Fault model)



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)