Chapter 14. Urban Spatial Analysis on Vulnerability for Earthquake in Metropolitan Manila

CHAPTER 14. URBAN SPATIAL ANALYSIS ON VULNERABILITY FOR EARTHQUAKE IN METROPOLITAN MANILA

14.1 Introduction

In this chapter, the regional vulnerability of Metropolitan Manila and the relationship between vulnerability and resource are evaluated. These evaluations will give an idea on the relative vulnerability within Metropolitan Manila spatially.

14.2 Regional Vulnerability Evaluation

14.2.1 General

1) Purpose

Understanding the urban earthquake vulnerability correctly together with urban structure is important in order to come up with appropriate measures to lower the level of vulnerability. In relation to this, regional vulnerability evaluation aims to achieve the following:

1) An index for planning an earthquake prepared city
2) A reference for selecting the regions for establishing projects on earthquake measures, and
3) A tool of understanding the urban earthquake vulnerability for the community members, to raise awareness

2) Assumptions

Among the earthquake scenario prepared for this study, model 08, the west valley fault model, damages Metropolitan Manila the most. If the urban structure is being prepared for the impact of the Model 08 earthquake, it will also be prepared for less destructive earthquake scenarios. Therefore, model 08 was applied for all analyses.

3) Methodologies

Three indices, building collapse, flammability, and evacuation difficulty, were used for determining the existing vulnerabilities of earthquake in the region. Lastly, an evaluation on the comprehensive regional vulnerability is also added to understand the foremost vulnerable areas within the Metropolitan Manila[14-1].

Simplified flow of this analysis is shown in Figure 14.2.1.

[14-1] The result of this analysis, shown by maps, highlights the area with high vulnerability. It is important to understand that this is only a relative comparison within the Metropolitan Manila, indicating where areas with the higher vulnerability. It does not mean that the area with low rank is always safe.

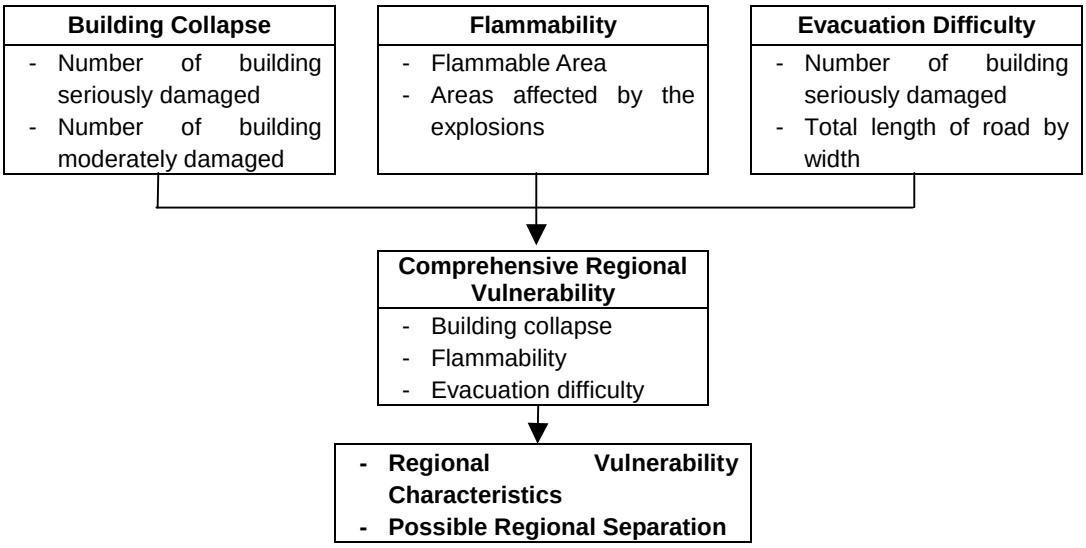


Figure 14.2.1 Flow of the Regional Vulnerability Evaluation

Target area for this analysis is the whole Metropolitan Manila. The analysis uses 2,621 grids with dimensions of 500m by 500m covering the whole target area. The uniformly sized grids were used as units for the analysis because they are more appropriate to indicate regional characteristics rather than administrative boundaries which are irregularly shaped. Among the 2,621 grids, 288 grids were not counted for evaluation, because these grids are not and will not be developed for the urban activities such grids coving La Mesa Dam and the international airport.

4) Used Data

Data used for this analysis is basically year 2000, when the national population census together with building survey was conducted by NSO. All other data used aside from the national census, is established recently. Table 14.2.1 is the summary of data used in this analysis.

Table 14.2.1 Summary of Data used in Regional Vulnerability Analysis

Vulnerability	Classification	Type of Data	Description
Building Collapse	Building Damage	- Number of building seriously damaged - Number of building moderately damaged	Number of buildings by the classification (Census 2000) - type of wall - year of construction <NSO, 2000> Ground condition - Ground condition <Phivolcs, 2000/ MMEIRS, 2003> - Liquefaction potential < MMEIRS, 2003>
Flammability	Flammable Area	- Land use map - Building type and numbers	Land use, 2003 - Open spaces and parks <MMEIRS, 2003> Road networks <MMDA, 2002 / MMUTIS 1999> Building type (Census 2000) - Wooden buildings - Concrete and wood buildings <NSO, 2000>
	Secondary Explosion	- Hazardous facilities	Hazardous Facilities - Location - Facility type <BFP, 2003>
Evacuation Difficulty	Building Damage	- Number of building seriously damaged	Number of Buildings by the classification (Census 2000) <NSO, 2000>
	Road Type	- Total length of road by width	Total length of road with width more than 6m and 8m <MMDA, 2002 / MMUTIS 1999>

Note: Data Source and Data Year are described in < >.

5) Interpreting the Ranks

Evaluation done here is the relative comparison of the vulnerability between grids. Therefore in interpreting results, areas with higher vulnerability such as grids with rank 5, simply means that vulnerability in these areas are relatively higher than that of grids with lower ranking. An area with lower vulnerability, for example rank1, only means that relatively, the vulnerability is low, but is not necessarily absolutely safe.

14.2.2 Building Collapse

1) Purpose

Building collapse evaluates the vulnerability of building damages caused by earthquake motion, by comparing the building collapse probability among the regions relatively. The results of this building collapse can be utilized for selecting the regions for urban renewal projects, such as re-development and urban renewal in dense areas. It will also highlight the areas where to implement or consider upgrades on the individual buildings, such as building diagnosis or individual reinforcement.

2) Method of Calculation

Indices used for this evaluation are the followings.

1) Rate of building seriously damaged
2) Rate of building moderately damaged

For each indices, rate of building damage was calculated by the grid. These two indices were then accumulated without any weights and re-classified by equal intervals between the scores of smallest and largest to indicate the degree of vulnerability. Calculation method on score and rank is shown in appendices.

3) Result

(1) Condition

Rate of building moderately damaged, and rate of building seriously damaged represented by the 5 ranks are shown in Figure 14.2.2 and Figure 14.2.3 respectively. Figure 14.2.3 shows that eastern part of Marikina city, western part of Pasig city, and some parts of western Muntinlupa city has the highest rate of building seriously damaged. On the other hand, figure shows that a wide area of buildings will be moderately damaged along the west valley fault area and the manila bay area.

(2) Result on building collapse

Based on the two indices described above, building collapse was calculated as shown in Figure 14.2.4. It indicates that there are four main areas high collapse possibility, as listed below.

1) Western Marikina city area
2) Eastern Pasig area
3) Muntinlupa city along the Laguna Bay
4) South Eastern Manila City Area

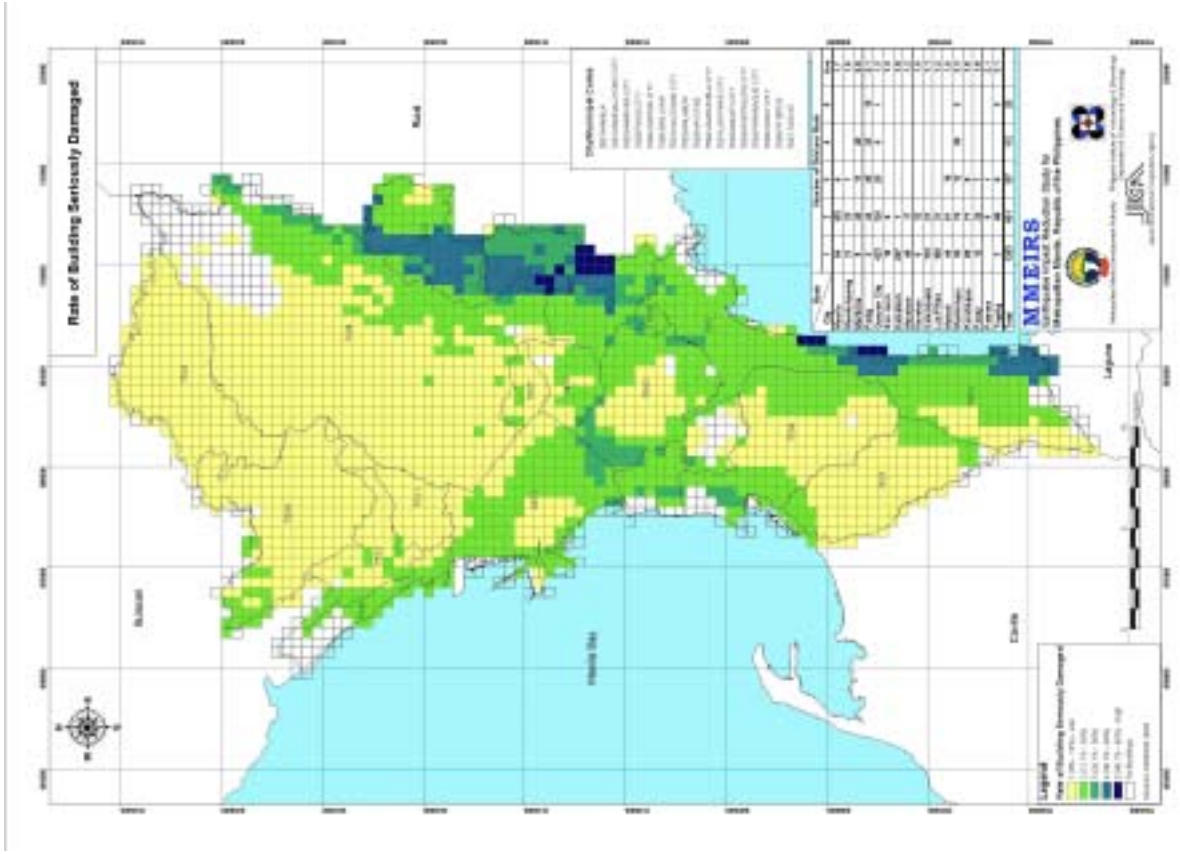


Figure 14.2.3 Rate of Building Seriously Damaged

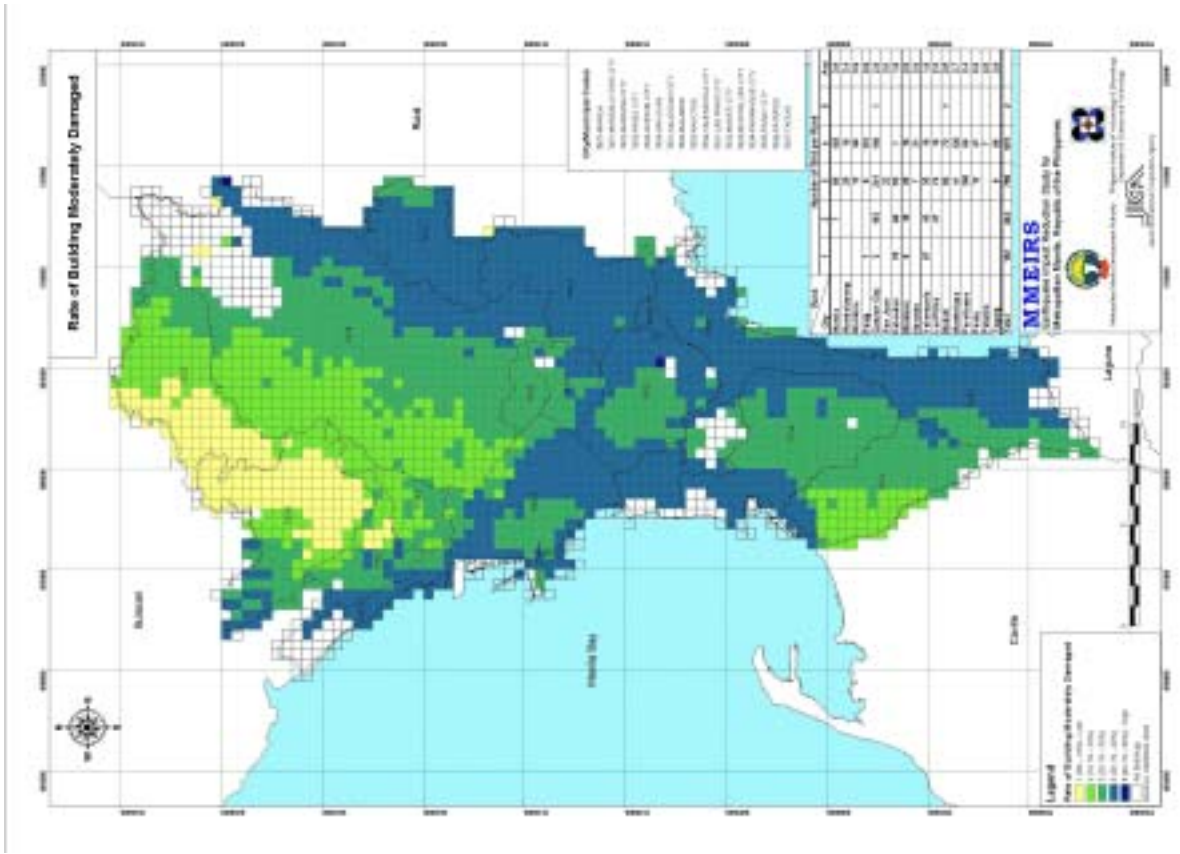
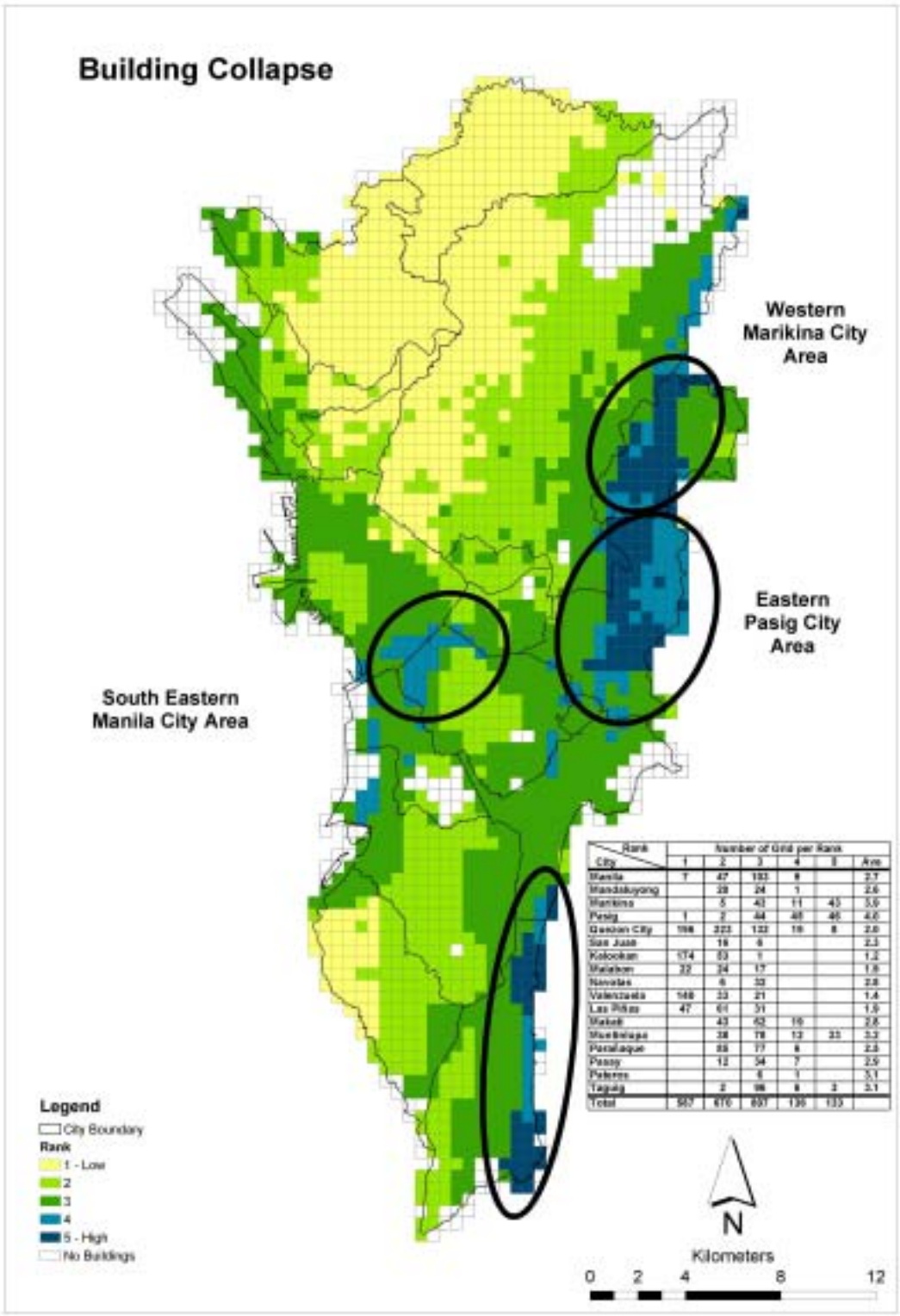


Figure 14.2.2 Rate of Building Moderately Damaged



Rank / City	Number of Grid per Rank					
	1	2	3	4	5	Ave.
Manila	7	47	183	8		2.7
Mandaluyong		28	24	1		2.6
Marikina		5	43	11	43	3.9
Pasig	1	2	44	46	46	4.0
Quezon City	198	223	122	19	8	2.0
San Juan		19	6			2.3
Kalookan	174	63	1			1.3
Malabon	22	24	17			1.8
Navotas		6	32			2.8
Valenzuela	148	33	21			1.4
Las Piñas	47	61	31			1.9
Makati		43	62	10		2.8
Muntinlupa		38	78	12	33	3.3
Parañaque		83	77	8		2.5
Pasay		12	54	7		2.9
Pateros			6	1		3.1
Taguig		2	96	8	3	3.1
Total	597	670	857	130	133	

Figure 14.2.4 Building Collapse

14.2.3 Flammability

1) Purpose

Flammability aim to evaluate the comprehensive vulnerability of flammable areas and secondary affected areas. Flammable area is meant for the areas with open spaces and high occupancy for wooden building structure. Open spaces are comprised of major roads, vacant lands, and parks in this analysis. Secondary affected areas are zones affected by the explosion of hazardous materials facilities.

Result of this flammability can be utilized for knowing the regions prone to fire. Such area can be the target for fireproof promoting, and urban renewal projects can be set in.

2) Method of Calculation

Indices used for this evaluation are the followings.

1) Flammable area
2) Areas affected by the secondary explosions

(1) Flammable area

Flammable area is calculated using the open space ratio and the area rate of wooden building. Here, open space ratio is defined by the area ratio of the road, vacant land, and parks in a grid. Rank of vulnerability in this index is classified as shown in Table 14.2.2.

Table 14.2.2 Vulnerability Classification of Flammable Area

Rank of the Vulnerability	Open Space Ratio, Rate of Wooden Building
1	Open space ratio more than 70%
2	Open space ratio less than 70%, and wooden building ratio less than 10%
3	Open space ratio less than 70%, and wooden building ratio less than 20%, more than 10%
4	Open space ratio less than 70%, and wooden building ratio less than 30%, more than 20%
5	Open space ratio less than 70%, and wooden building ratio more than 30%

(2) Areas affected by the explosions (Secondary impacts)

This is calculated using the location of hazardous facilities with a weighted value of affected area depending on the type of hazardous material stood. Area to be affected by hazardous facility type is described as follows.

Table 14.2.3 Distance Areas Affected by the Explosions by Hazardous Facility Type

Type of hazardous facility	Areas to be affected (radius)
Gas stations	0.3 km
Acetylene & Oxygen	0.3 km
Chemicals	1 km
LPG and Gas Tanks	2 km
Oil	0.5 km
Petroleum	0.5 km
Power generation	0.5 km

Each index was calculated by the grid. These two indices were then added and re-classified by equal intervals on the value to indicate the degree of flammability. Calculation method on score and rank of vulnerability is shown in Appendices.

3) Result

(1) Condition

Flammable area, and areas affected by the explosions (secondary impact) represented by ranks are shown in Figure 14.2.5 and Figure 14.2.6 respectively. Figure 14.2.5 shows that four major regions, namely Manila Bay Area, South-west Metropolitan Manila, Metropolitan Manila Northern Fringe, and Long-established Village Areas, as high flammability area. Detailed areas are described below.

1) Manila Bay Area: Navotas bay area, Kalookan South, Manila North Harbor
2) South west MM: Pasay, seashore of Paranaque and Las Pinas
3) MM Northern Fringe: Kalookan North, North- eastern Quezon
4) Long-established village areas: Pasig, Taguig, Pateros intersection

Figure 14.2.6 shows that there are two major regions with high possibility of affection by explosions. Those are the large area of north-western Metropolitan Manila, and Pasay airport area. Other than these areas, there are small high flammability area distributions among Metropolitan Manila.

(2) Result on flammability (Including the secondary effect)

Based on the two indices described above, flammability was calculated as shown in Figure 14.2.7. This figure indicates that there are mainly three areas to pay most attention to, as listed below.

1) Northern Manila Bay Area
2) South Eastern Manila City Area
3) Central Manila Bay Area

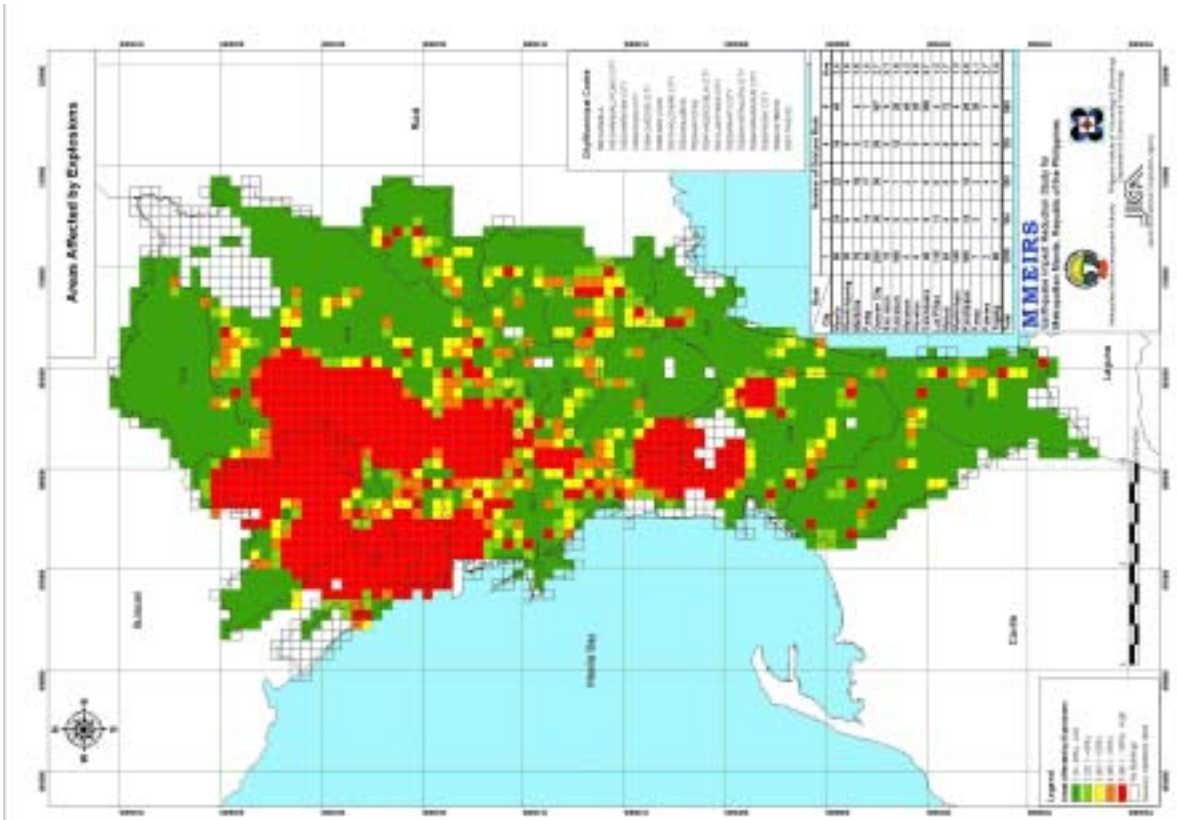


Figure 14.2.6 Areas Affected by the Explosion

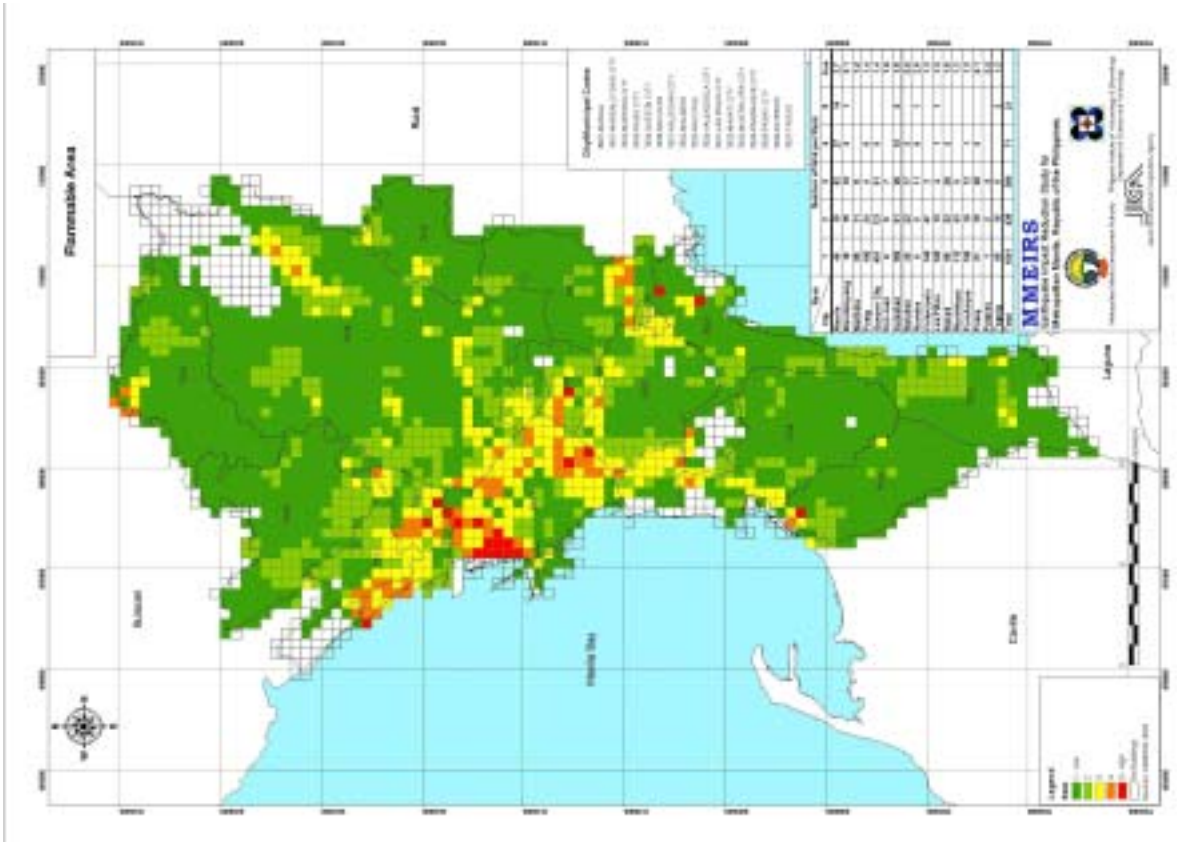
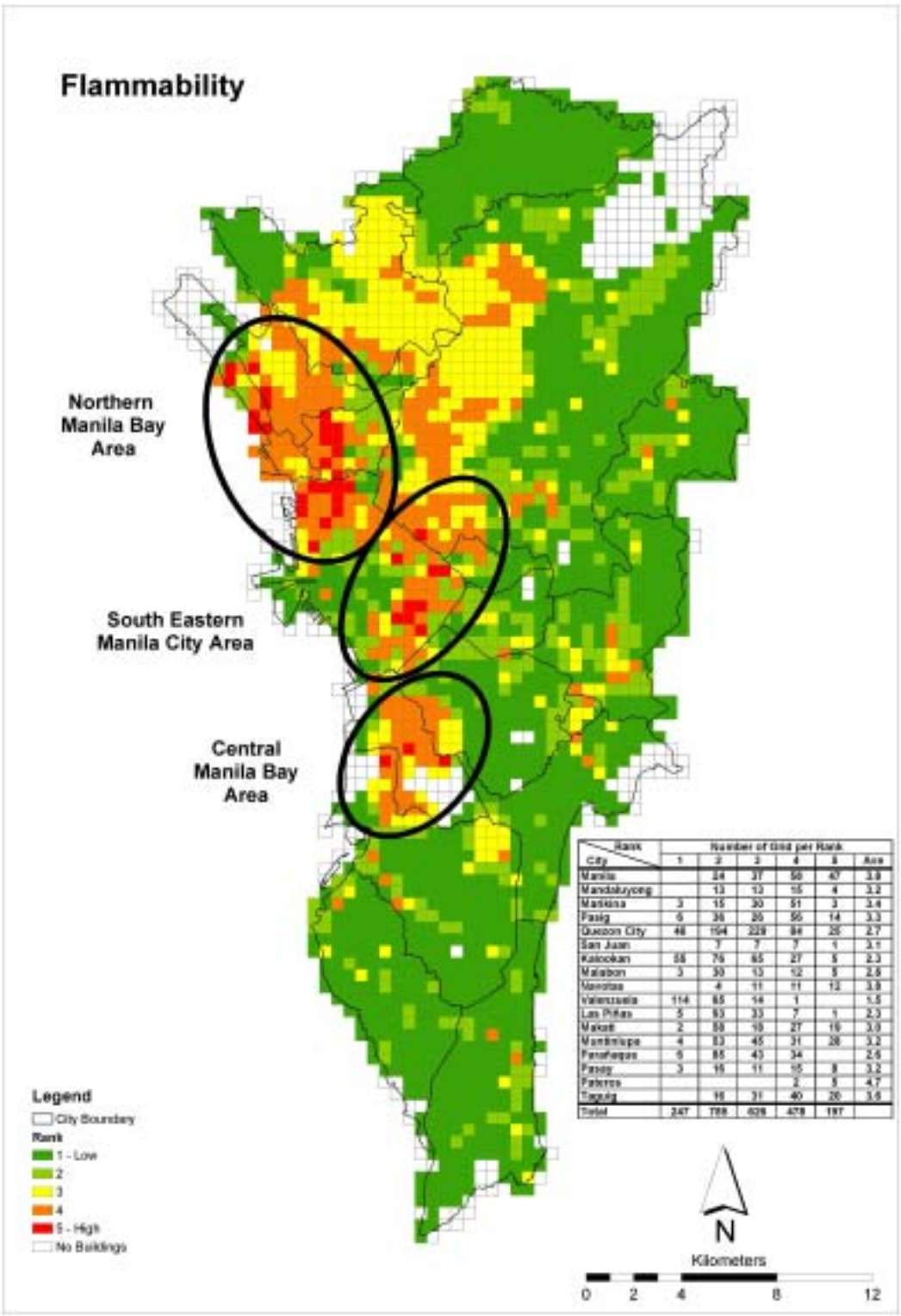


Figure 14.2.5 Flammable Area



City \ Rank	Number of Grid per Rank					
	1	2	3	4	5	Ave
Manila		24	37	50	47	3.9
Mandaluyong		13	13	15	4	3.2
Marikina	3	15	30	51	3	3.4
Pasig	6	36	20	55	14	3.3
Quezon City	46	104	229	84	25	2.7
San Juan		7	7	7	1	3.1
Kalookan	55	75	65	27	5	2.3
Malabon	3	33	13	12	5	2.9
Navotas		4	11	11	12	3.9
Valenzuela	114	65	14	1		1.5
Las Piñas	5	53	33	7	1	2.3
Makati	2	58	18	27	16	3.3
Muntinlupa	4	53	45	31	28	3.2
Parañaque	5	85	43	34		2.6
Pasay	3	15	11	15	8	3.2
Pateros				2	3	4.7
Taguig		16	31	40	20	3.6
Total	247	788	629	479	197	

Figure 14.2.7 Flammability

14.2.4 Evacuation Difficulty

1) Purpose

Evacuation difficulty is to evaluate the difficulty of an area for securing road, for evacuation and accessibility. If the total length of road is longer, it is interpret that there are higher number of road network, meaning that there are higher chance of evacuation. In overall, it is meant to show the difficultness to leave or access the affected area.

Result of this evacuation difficulty can be utilized for knowing the regions where need to be considered for securing roads. Such area can be the target for road widening and building strengthening projects.

2) Method of Calculation

Indices used for this evaluation are the followings.

1) Number of buildings seriously damaged
2) Total length of usable road

Number of seriously damaged buildings establishes the amount of debris to be expected in case of earthquake. Usable road was based upon the number of building collapsed in the grid. Supposing if the total number of seriously damaged building is less than 150 in a grid, road width with 6m and more can be used. If the total number of seriously damaged building is more than 150 in a grid, road width with 8m and more can be used. The usage possibility by the width of road is based on the Kobe earthquake experience. Calculation method on score and rank of vulnerability is shown in Appendices.

3) Condition

Number of seriously damaged buildings in 5 ranks is shown in Figure 14.2.8. This figure indicates that there are mainly three regions, namely, manila bay side, west valley fault side, and central Metropolitan Manila, with high number of buildings seriously damaged.

1) Manila Bay Side: Navotas Bay Area, Manila North Port Area, South Eastern Manila City Area , and Central South Manila Bay Area
2) West Valley Fault Side: North Eastern Quezon City Area, Western Marikina City Area, Eastern Pasig Area, Pateros Municipality Area, and Muntinlupa City along the Laguna Bay
3) Central Metropolitan Manila: Makati-Mandaluyong intersection

4) Result on evacuation difficulty

Based on the classification described above, evacuation difficulty was calculated. For the grid area with rank 4 and 5 which is shown in total length of road wider than 8m was calculated. For other grid areas, total length of road wider than 6 m was accumulated. This result, with the

classification by total length of usable roads, is shown in Figure 14.2.9. This figure indicates that there are mainly four portions of areas to pay most attention to, as listed below.

1) Metropolitan Manila North-eastern Fringes Number of Building Seriously Damaged
2) South-eastern Manila City Area
3) Central-south Manila Bay Area
4) West Valley Fault Area

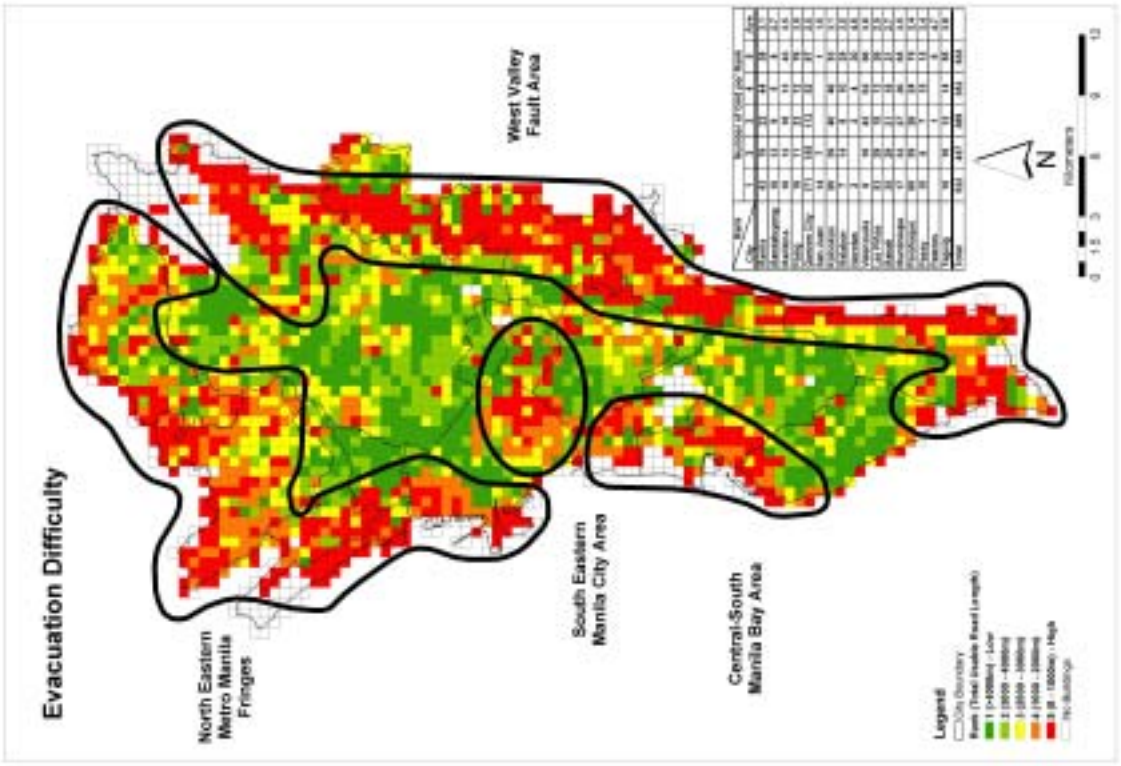


Figure 14.2.9 Evacuation Difficulty

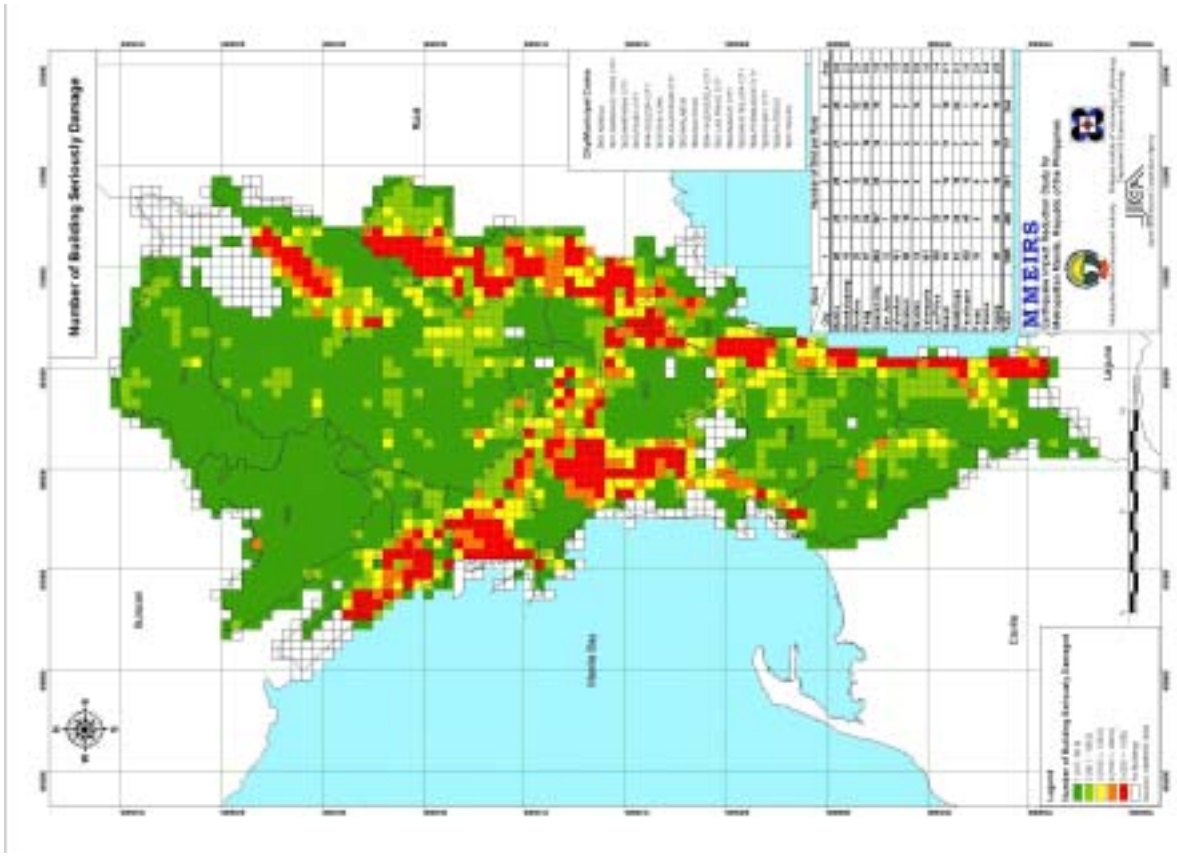


Figure 14.2.8 Number of Buildings Seriously Damaged

14.2.5 Comprehensive Regional Vulnerability and its Characteristics

1) Purpose

Comprehensive regional vulnerability is to show the areas with high vulnerability of all three kinds of vulnerabilities, building collapse, flammability, and, evacuation difficulty, as discussed above.

This comprehensive evaluation gives an idea on which area of the Metropolitan Manila has the highest vulnerability on the earthquake situations. It is also possible to utilize for administrative and planning purposes, or for the community members to know their living environment. Areas with high vulnerability are priority areas for being cautious to the earthquake impact.

Characteristics of the comprehensive regional vulnerability are also expressed by integrating the result of three vulnerabilities. Figure of regional vulnerability characteristics is the simplified expression of the region, for people to understand easily, on the characteristics of the vulnerabilities facing the area.

2) Method of Calculation

Indices used for comprehensive regional vulnerability are the following.

1) Building Collapse
2) Flammability, and,
3) Evacuation Difficulty

These three indices were accumulated and re-classified by equal intervals to indicate the degree of vulnerability.

For the creation of regional vulnerability characteristics, areas with high vulnerability, for rank 4 and 5, for all indices on building collapse, flammability, evacuation difficulty, and comprehensive regional vulnerability were taken into account. Calculation method on score and rank of vulnerability is shown in Appendices.

3) Result

(1) Comprehensive regional vulnerability

Figure 14.2.11 shows the comprehensive regional vulnerability based on the method described above. This figure indicates that there are 9 areas to pay most attention to among the Metropolitan Manila as for the comprehensive regional vulnerability. Those areas are as the following.

1) Navotas Bay Area
2) Manila North Port Area
3) South Eastern Manila City Area

4) Central Manila Bay Area
5) North Eastern Quezon City Area
6) Western Marikina City Area
7) Eastern Pasig City Area
8) Muntinlupa Laguna Bay Area
9) Mandaluyong Makati City Border Area

Among these selected areas, the first four areas, from 1) to 4), are with the high vulnerability of flammability and evacuation difficulty. Areas 5) to 9) are the areas with building collapse and evacuation difficulty.

(2) Regional Vulnerability Characteristics

Based on the results of four vulnerability analyses, regional vulnerability characteristics are indicated as shown in Figure 14.2.10. This figure indicates the high vulnerability areas by type. In summary, Metropolitan Manila has the following vulnerability characteristics.

1) 4 areas with high flammability and evacuation difficulty
2) 4 areas with building collapse and evacuation difficulty
3) 1 area with high flammability
4) Metropolitan Manila's fringe areas have evacuation difficulties

Table 14.2.4 describes in detail on areas by type of vulnerability.

Table 14.2.4 High Vulnerable Area by Type

Type of Vulnerability	Area
Flammability and Evacuation Difficulty	1) Navotas Bay Area 2) Manila North Port Area 3) South Eastern Manila City Area 4) Central Manila Bay Area
Building Collapse and Evacuation Difficulty	1) North Eastern Quezon City Area 2) Western Marikina City Area 3) Eastern Pasig City Area 4) Muntinlupa Laguna Bay Area 5) Mandaluyong Makati City Border Area
Flammability	1) Valenzuela-Kalookan South-Quezon west intersection
Evacuation Difficulty	1) Metropolitan Manila Fringes - Northern Fringe - Taguig Fringe - Las Pinas Fringe

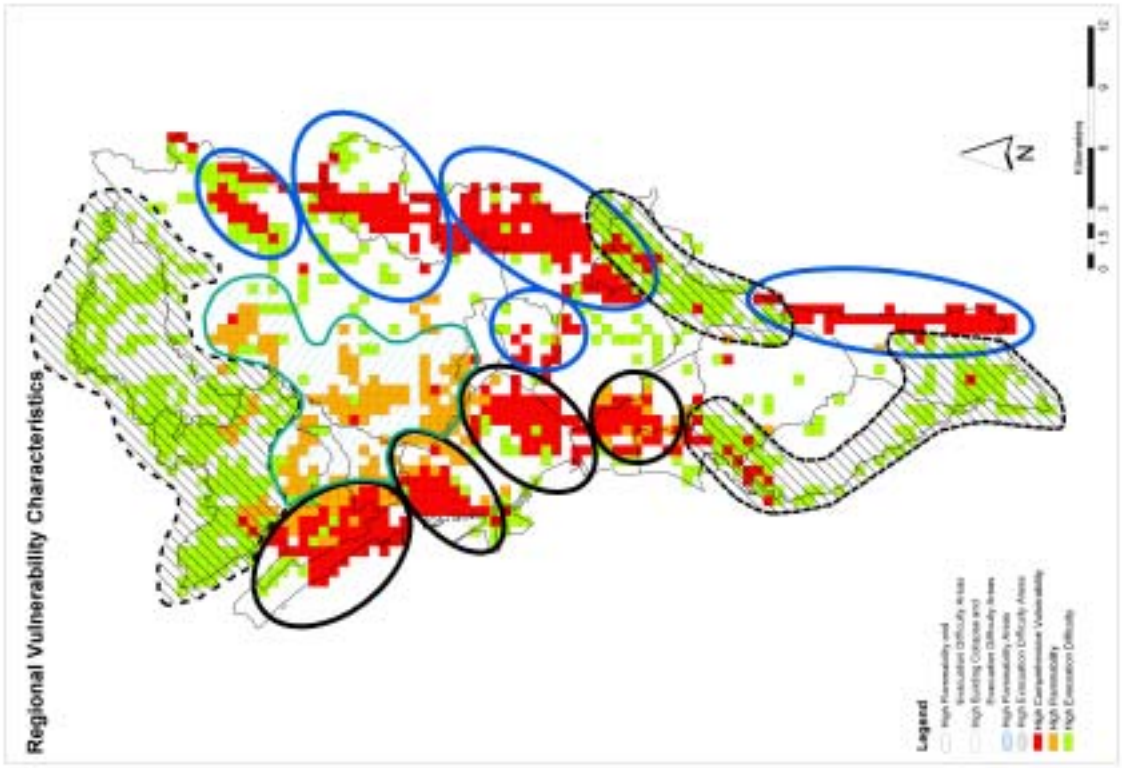


Figure 14.2.10 Regional Vulnerability Characteristics

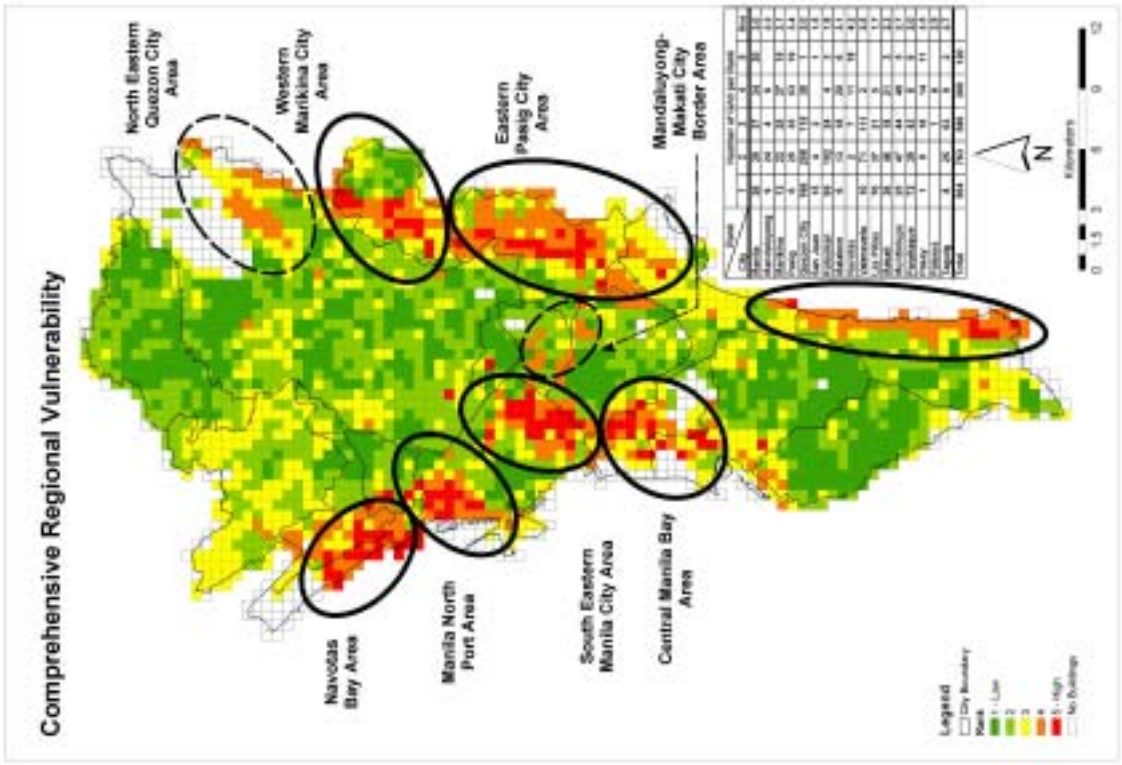


Figure 14.2.11 Comprehensive Regional Vulnerability

14.2.6 Possible Regional Separation

1) Possible Regional Separation

By overlaying proposed emergency road network onto comprehensive regional vulnerability, Figure 14.2.12 shows the possible regional separation of an earthquake impact in Metropolitan Manila. Obviously, roads crossing or passing through the high vulnerable areas, are with a high probability of becoming impassable. Overall, by analyzing passable and impassible roads, it can be deduced that Metropolitan Manila will possibly be separated into four regions by the earthquake impact. Four regions are 1) MM west, Metropolitan Manila west for the Manila Bay Area, 2) MM north, Metropolitan Manila north, 3) MM east, Metropolitan Manila east for the Pasig - Marikina Area, and 4) MM south, Metropolitan Manila south. Reasons for regional separation are summarized below.

MM West

Western part of Metropolitan Manila will be isolated from other part of Metropolitan Manila by fire and building collapse

MM North, and MM South

Northern and Southern part of Metropolitan Manila will be separated by the building collapse and the geographical condition. The intersecting area between Mandaluyong and Makati has a high possibility of building collapse; moreover, Pasig River is running through east-west which is naturally disadvantageous in terms of separation.

MM East

All road networks running east-west, which are on the fault will be broken due to the movement. Other roads running North-South in fault areas will be difficult to use, due to the high number of building collapse.

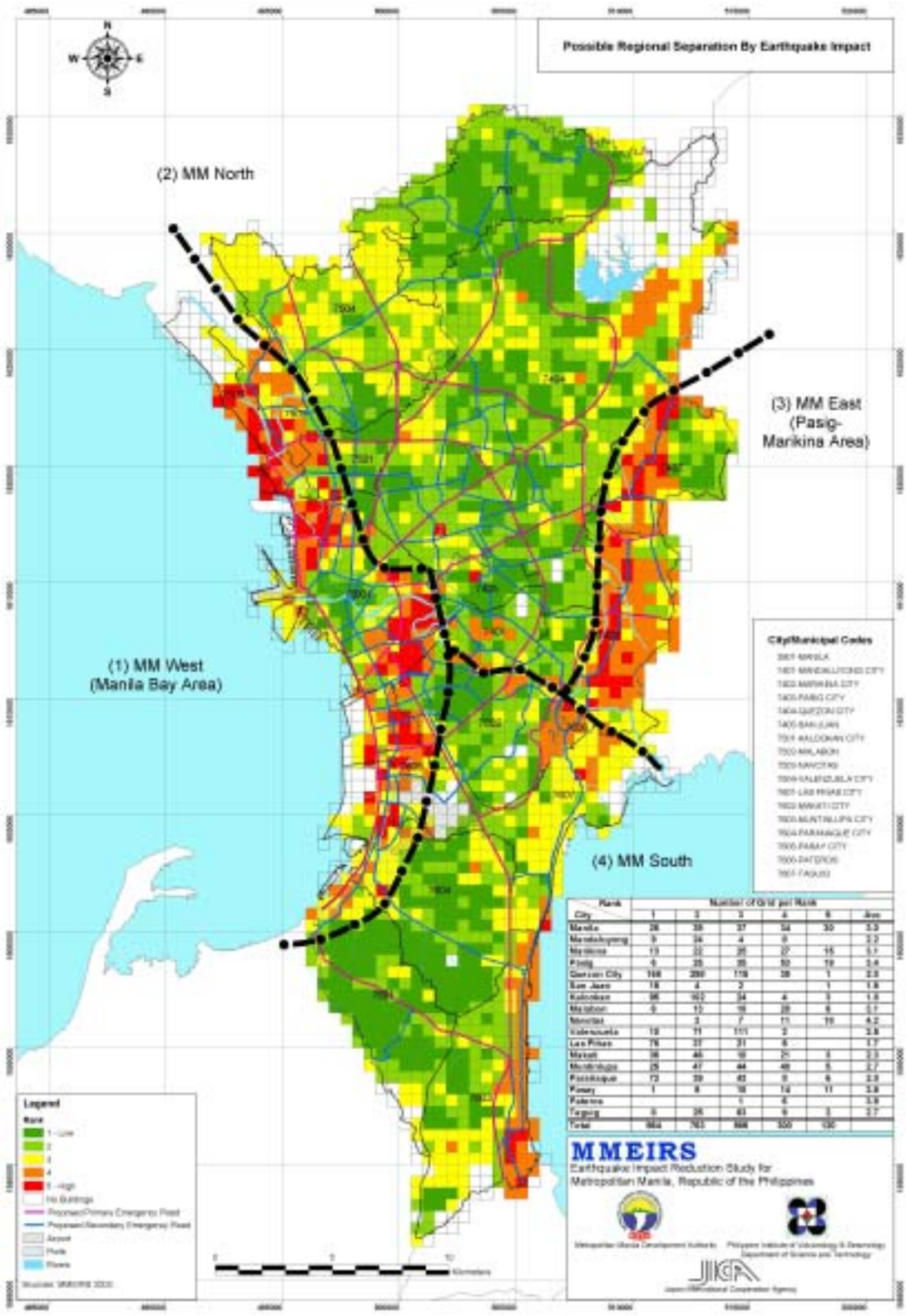


Figure 14.2.12 Possible Regional Separation by Earthquake Impact

14.3 Resource and Vulnerability Evaluation

14.3.1 General

1) Purpose

Understanding the correlation between the present distribution of resources to the possible vulnerability is also important. In this analysis, resource is defined as the facilities with capacity to reduce the secondary impact. The result will indicate the area with high vulnerability by the type of secondary damage possibilities. In this aspect, evaluation on resource and vulnerability aims to achieve the following:

1) An index for new investment on facilities or strengthening capacities for reducing the secondary damage effect,
2) A reference for knowing the regions where most attention are needed, by type of secondary effect, and;
3) a tool of understanding the incapability of the resources to reduce the secondary damage effect. This result can be utilized by decision makers, and community members to understand the limitation of resources.

2) Assumptions

Regional vulnerabilities used in this analysis are the results achieved in the former evaluation explained in 14.2 Regional Vulnerability Evaluation. Resources, as defined above, in this analysis are fire stations, public schools, hospitals, and specified parks and open spaces.

One more important factor to mention is that the evaluation done here is based on relative comparisons. Therefore, in interpreting the analysis results, an area with rank 5 is relatively high in vulnerability within Metropolitan Manila, and the area with rank 1 is relatively low in vulnerability, but it does not necessarily mean the area is absolutely safe.

3) Methodology

Four indices on vulnerabilities, fire extinguishing service shortage, evacuation facility shortage, hospital service shortage, and evacuation area shortage, are the indices used to evaluate the resources and vulnerability. Figure 14.3.1 shows the simplified flow of this analysis.

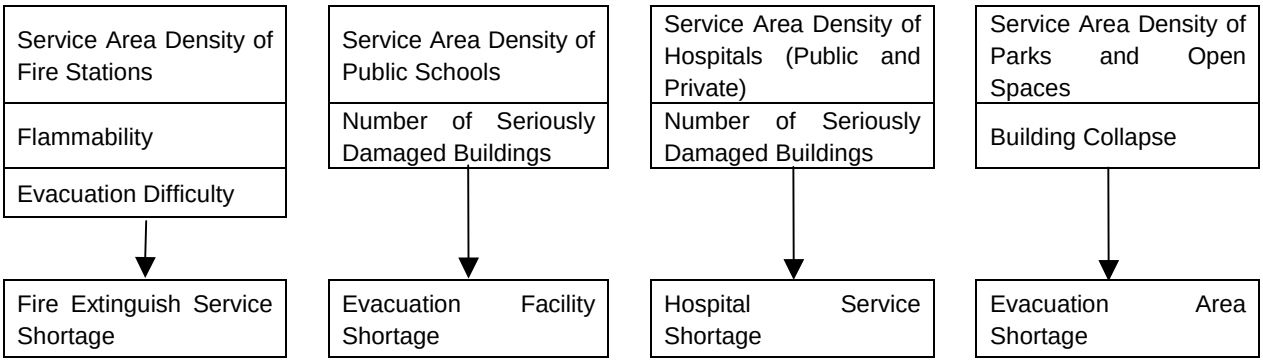


Figure 14.3.1 Flow of the Resource and Vulnerability Evaluation

Target area for this analysis is the whole Metropolitan Manila, with 500m×500m grid as the basic unit of analysis.

4) Data Used

Data used for the evaluation of resource and vulnerability is summarized in Table 14.3.1. Source of data and published data year varies depending on data type.

Table 14.3.1 Summary of Data used in Resource and Vulnerability Evaluation

Vulnerability	Classification	Type of Data	Description
Fire Extinguish Service Shortage	Service area density of fire stations	- Fire stations	Location of fire stations by service type <BFP, 2003>
	Flammability	- Flammability	Flammable Area <MMEIRS, 2003> - Existing land use maps - Building Type Road networks <MMDA, 2002 / MMUTIS, 1999> Secondary Explosion < MMEIRS, 2003> - Hazardous Facilities
	Evacuation difficulty	- Evacuation difficulty	Number of buildings seriously damaged <NSO, 2000> Road type < MMDA 2002 / MMUTIS, 1999>
Evacuation Facility Shortage	Service area density of public schools	- Public schools	Location of public schools by service type <Dep Ed, 2003, CHED, 2003)
	Building damage	- Number of buildings seriously damaged	Number of buildings seriously damaged <NSO, 2000>
Hospital Service Shortage	Service area density of hospitals (Public and Private)	- Location of hospitals by service type	Location of hospitals by service type (DOH, 2003)
	Building damage	- Number of buildings seriously damaged	Number of buildings seriously damaged <NSO, 2000>
Evacuation Area Shortage	Service area density of parks and open spaces	- Location of parks and open spaces	Land use 2003 <MMEIRS, 2003> - Location of parks and open spaces
	Building damage	- Number of buildings seriously damaged	Number of buildings seriously damaged <NSO, 2000>

Note: Data Source and Data Year are described in < >.

14.3.2 Fire Extinguishing Service Shortage

1) Purpose

Fire extinguishing service shortage aims to find the most prominent areas which are incapable of extinguishing fire after the earthquake. Result of this fire extinguishing service shortage can be utilized for knowing the area with shortage for fire extinguishing service, and for investing and

strengthening fire extinguishing service, or for raising awareness and measures for fire extinguish tips to the community residents, where fire extinguishing service are not available.

2) Method of Calculation

Fire extinguishing service shortage is measured by 3 indices as follows.

1) Service area density of fire stations,
2) Flammability, and
3) Evacuation difficulty

The first index, service area density of fire stations, is the result of calculating the density of service coverage area per grid. Coverage area of each facility varies, depending on the capacity of service. It was assumed that central fire stations, of which one exists in each LGU, have twice as much capacity as sub-stations, of which several are located in each LGU. Therefore, in the calculation, it was given that the stations cover an area of 4km in radius, while sub-stations cover an area of 2km in radius.

The second and third indices are used by applying the result achieved in section 14.2. Flammability, shown in Figure 14.2.7, indicates the area with flammable possibilities. Evacuation difficulty, shown in Figure 14.2.1, indicates the area with difficulty in approaching. Calculation method on score and rank is shown in Appendices.

3) Results

(1) Service Area Density of Fire Stations

shows service area density of fire stations. This figure explains that the service density it self is originally low in the area in Kalookan North, Quezon City, and fringe areas.

(2) Fire Extinguish Service Shortage

Based on the three indices described above, Figure 14.3.2 shows the area with fire extinguishing service shortage. This figure indicates that there are mainly five areas especially short in fire extinguishing service, they are:

1) Northern Manila Bay Area
2) South Eastern Manila City Area
3) Pasay City Area
4) Eastern Valenzuela Area
5) North Western Quezon City Area

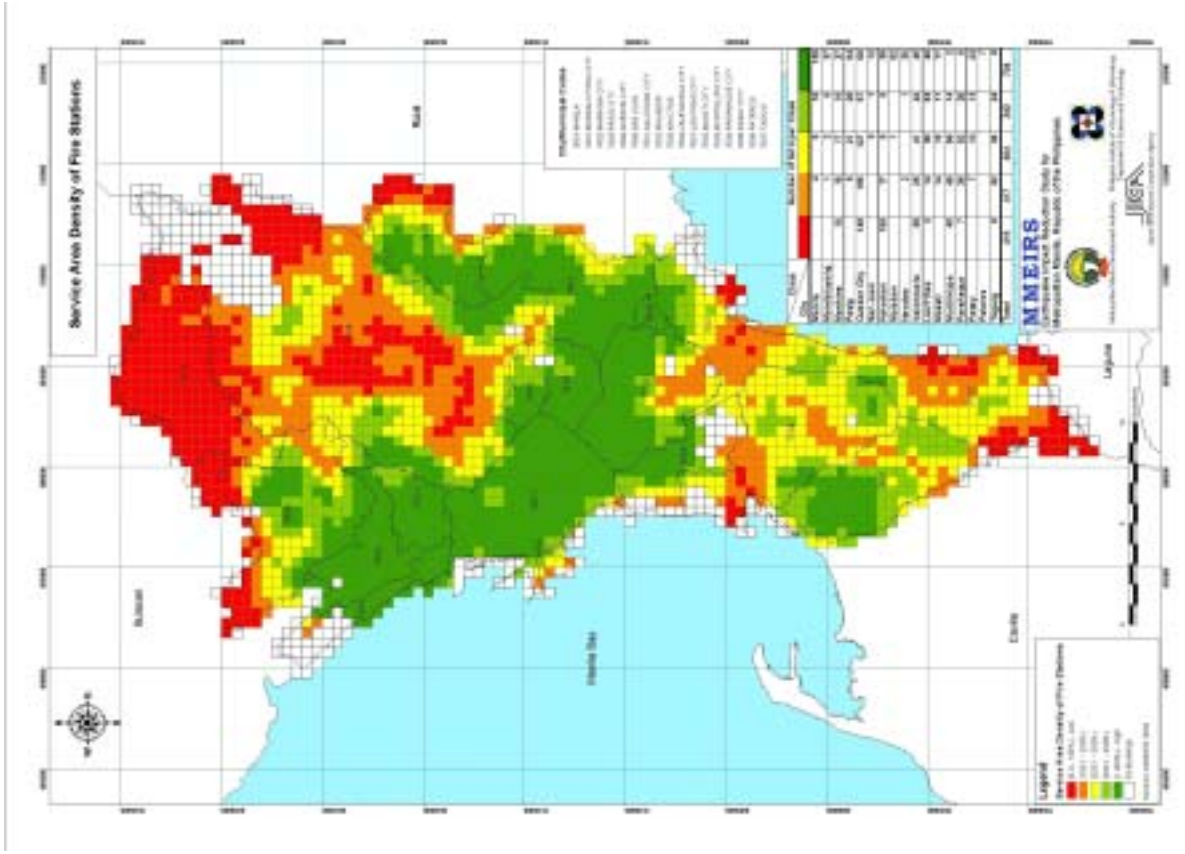


Figure 14.3.3 Service Area Density of Fire Stations

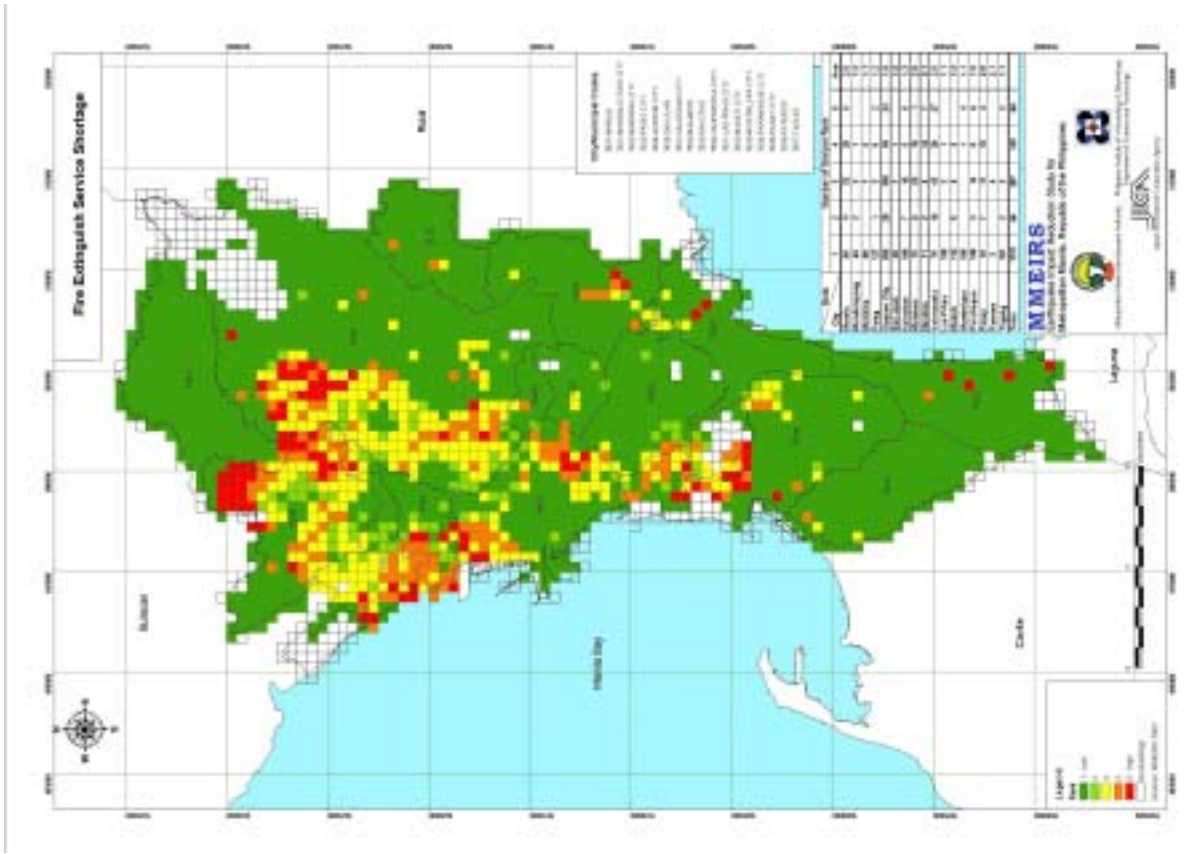


Figure 14.3.2 Fire Extinguish Service Shortage

14.3.3 Evacuation Facility Shortage

1) Purpose

Evacuation facility shortage is to find the most prominent area with evacuation facility shortage. Shortage is correlated with the number of seriously damaged buildings, assuming more people will be losing their homes in those areas with high number of building collapse. Result of this evacuation facility shortage can be utilized for identifying the area with shortage for evacuation facility, and in investing and strengthening evacuation facilities, in searching for agreement on cooperation with private schools acting for evacuation facility, or in raising awareness and creating measures among the community residents for mutual assistance.

2) Method of Calculation

Indices used for this evaluation are the following:

1) Service area density of public school, and;
2) Number of buildings seriously damaged

Public schools usually act as evacuation facility in case of disaster. Thus, location data of public schools are used in this analysis, and private schools are not included. Service area density of public school is calculated using weighted coverage area by the type of school. It is assumed that the accommodation capacity is larger in college than in secondary school, which in turn is larger than in elementary school. Therefore, in the calculation, it is given that the collages cover the area of 2km in radius, while secondary schools cover the area of 1km, and elementary schools cover the area of 0.5km.

The second index, which is the number of buildings seriously damaged is used by applying the result achieved in Figure 14.2.9. Calculation method on score and rank is shown in the Appendices.

3) Results

(1) Service Area Density of Public School

shows service area density of public school. This figure explains the following three characteristics on the density distribution.

1) Service area density is high in the older urbanized areas, this means that there is a higher density in Manila City and its vicinity.
2) Service area density is higher in the central cities than in the sub-urban areas.
3) Overall, establishment of public school is not catching up with the population growth in the urban fringes.

(2) Evacuation Facility Shortage

Based on the result of service area density of public schools and number of buildings seriously damaged, Figure 14.3.4 shows the evacuation facility shortage. The figure shows that there are mainly 5 portions within the Metropolitan Manila with high shortage in evacuation facilities, as listed below.

1) Manila North Port Area
2) South Eastern Manila City Area
3) Almanza Area, Las Pinas
4) North Eastern Quezon City Area
5) West Valley Fault Area

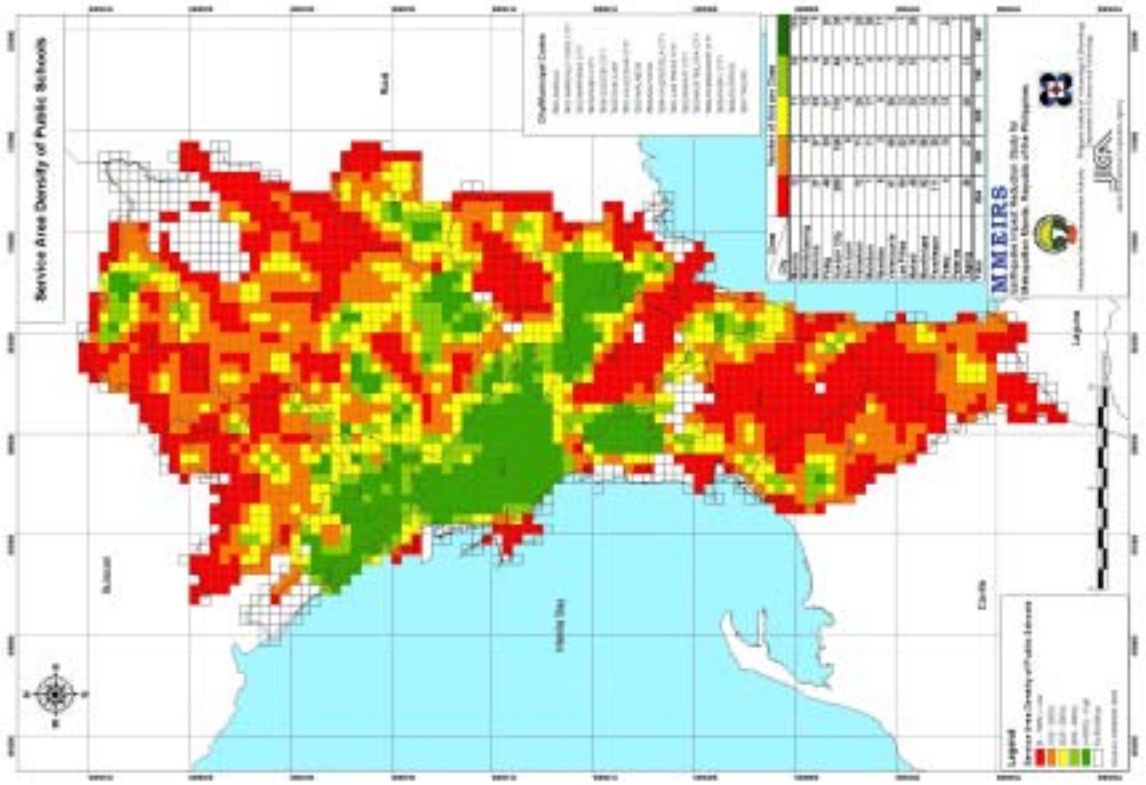


Figure 14.3.5 Service Area Density of Public Schools

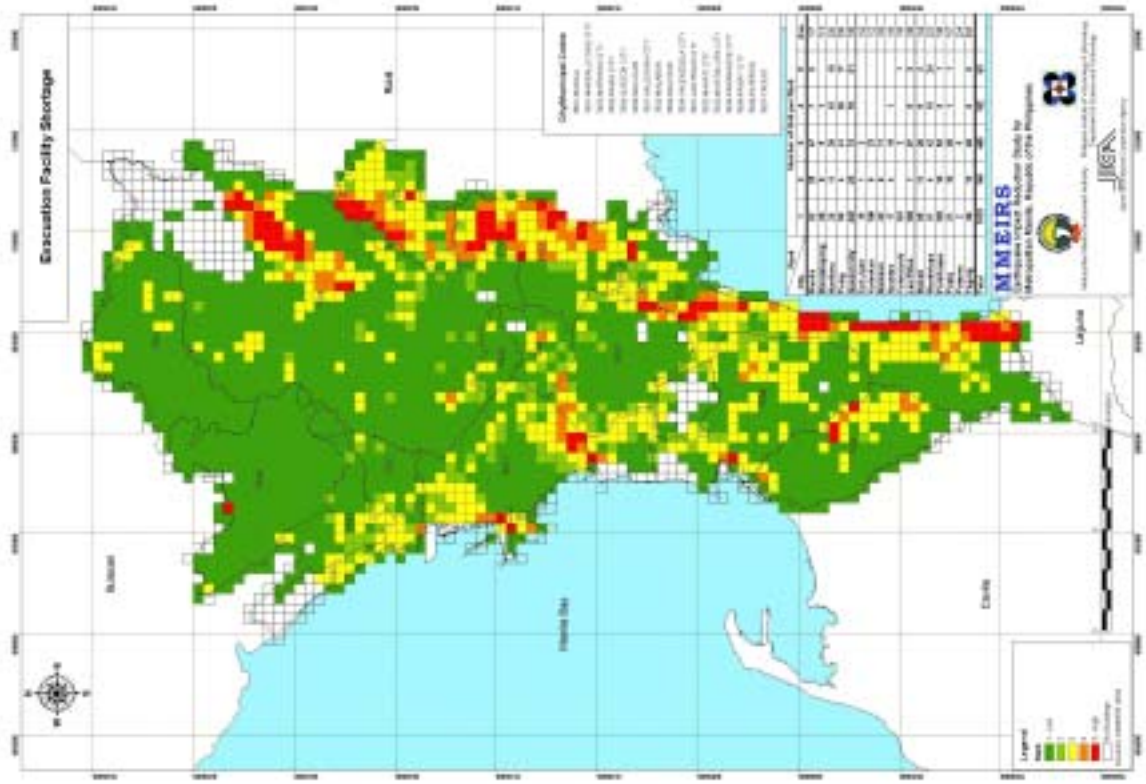


Figure 14.3.4 Evacuation Facility Shortage

14.3.4 Hospital Service Shortage

1) Purpose

Hospital service shortage aims to find the most prominent area with hospital shortage. Hospital service shortage is correlated with the number of seriously damaged buildings. It is assumed that more injured people will be in need for hospital treatment from the areas with higher number of building collapse. Result of this hospital service shortage can be utilized to determine the area with shortage for medical treatment, and to search for the measures to strengthen the hospital service.

2) Method of Calculation

Indices used for this evaluation are the followings.

1) Service area density of hospitals
2) Number of buildings seriously damaged

Location data for hospitals include both the public and private. Service area density of hospital is calculated using weighted coverage area by the level of hospital referral system. Since the accommodation capacity is larger in tertiary level than in secondary level, which in turn is higher than in elementary level, it was assumed that the tertiary level hospitals cover the area of 2km in radius, while secondary level hospitals cover the area of 1km, and primary level hospitals cover the area of 0.5km in the calculations.

The second index, number of buildings seriously damaged is applied from the result achieved in section 14.2, Figure 14.2.9. Calculation method on score and rank is shown in Appendices.

3) Results

(1) Service Area Density of Hospitals

shows service area density of hospitals. This figure explains following two characteristics of the density distribution.

1) Service area density is higher in the older urbanized areas, especially within the inner Metropolitan Manila.
2) Service area density is originally low along the West Valley Fault System, where it is expected that many injured people will be in need for medical treatment.

(2) Hospital Service Shortage

Based on the result of service area density of hospitals and the number of buildings seriously damaged, Figure 14.3.6 shows the hospital service shortage. The figure shows that there are mainly 5 portions within the Metropolitan Manila where it will be especially likely to have shortage in hospital service, as listed below.

1) Navotas Bay Area

2) South Eastern Manila City Area
3) Central South Manila Bay Area
4) North Eastern Quezon City Area
5) West Valley Fault Area

Manila City and adjacent areas seem to have certain levels of service; however, there is high risk of hospitals burning due to the high possibility of fire.

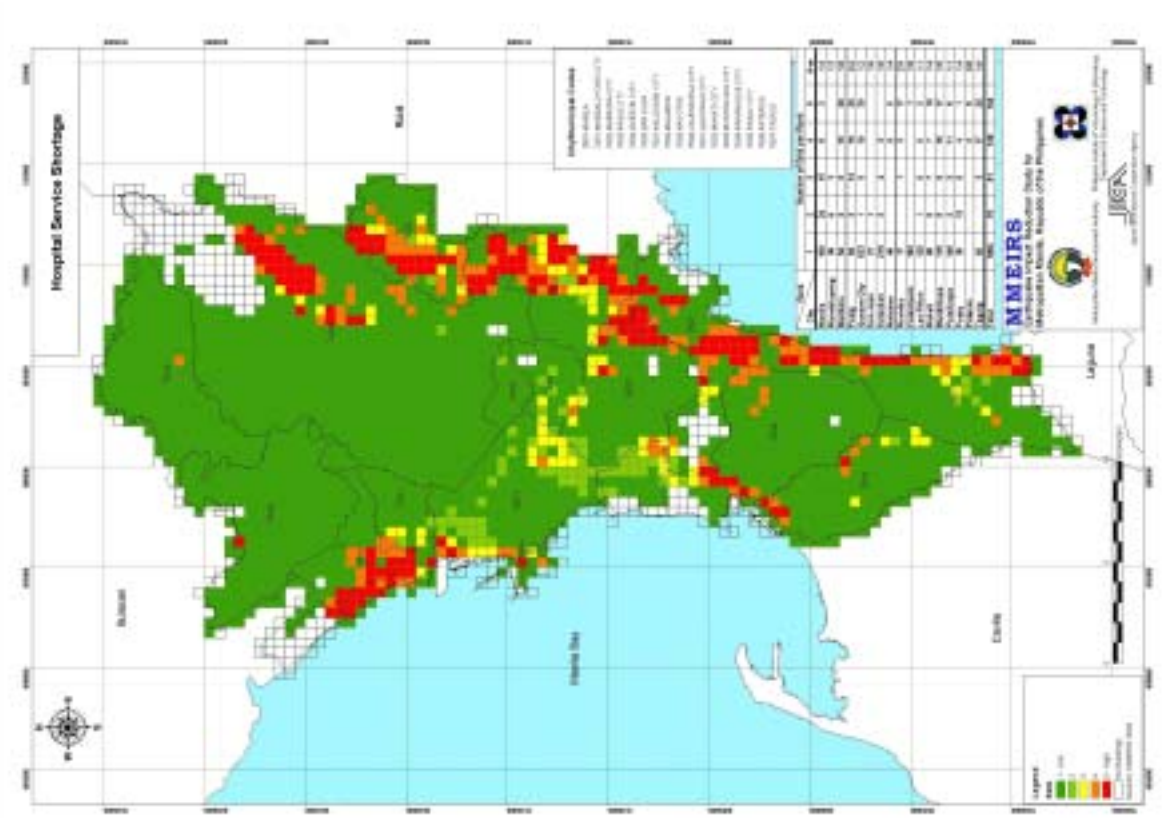


Figure 14.3.6 Hospital Service Shortage Service Area

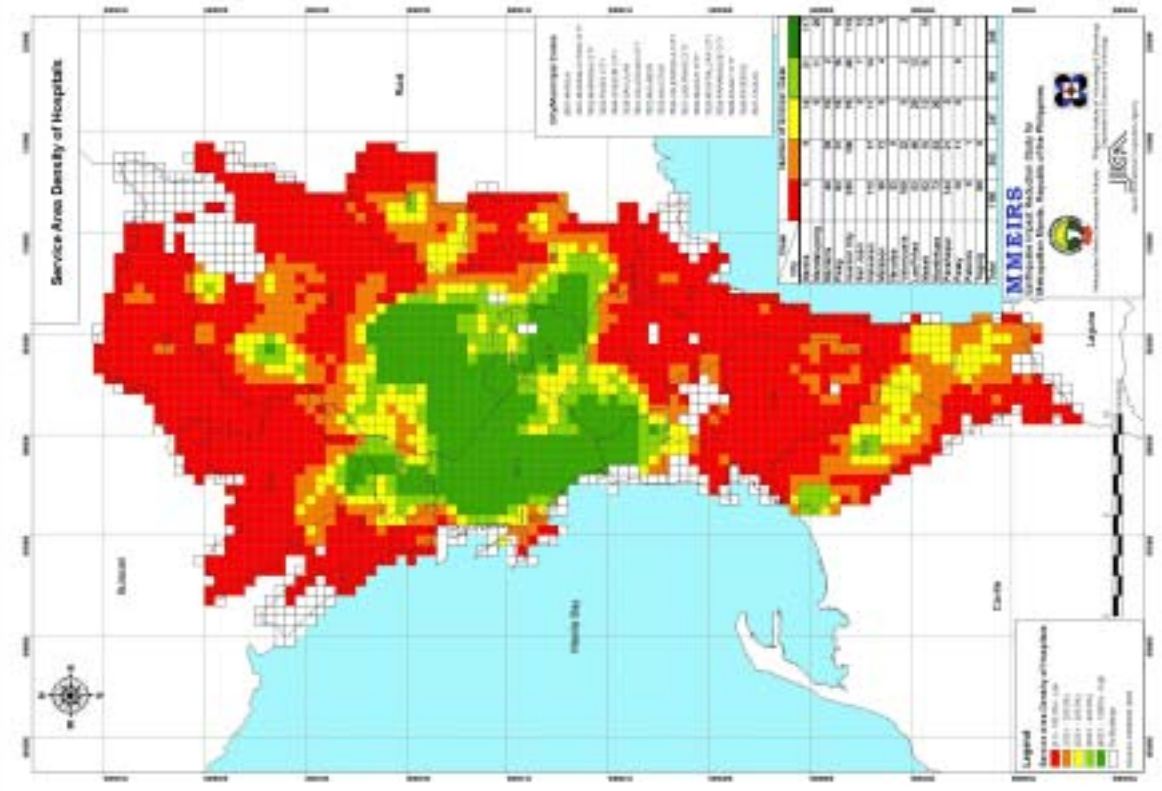


Figure 14.3.7 Density of Hospitals

14.3.5 Evacuation Area Shortage

1) Purpose

Evacuation area shortage seeks to find the most prominent areas with shortage of open space and parks, which will act as evacuation center in the course of emergency response and rehabilitation. Evacuation area shortage is correlated with the number of seriously damaged buildings. It is assumed that more people from those areas will need to evacuate to the open spaces. Result of this evacuation area shortage can be utilized to establish the area with shortage in evacuation areas, and introduce projects that focus on expanding the small areas to be utilized as evacuation area, or provide information on the availability of evacuation area for the community members.

2) Method of Calculation

Indices used for this evaluation are the followings.

1) Service area density of parks and open spaces.
2) Number of buildings seriously damaged

For the analysis of service area density for parks and open spaces, only the areas larger than 2 hectares were selected, which could be utilized for the evacuation purpose. Service area for individual parks and open spaces is considered to be 2km in radius from its outer lines, and this will be used to determine its capacity.

The second index, number of buildings seriously damaged is the result achieved shown in Figure 14.2.9. Calculation method on score and rank is shown in Appendices.

3) Service Area Density of Park and Open Spaces

shows service area density of parks and open spaces. This figure illustrates that the service area density of parks and open spaces are rather high in the fringe areas, such as Valenzuela and Kalookan North, the intersection of Marikina-Quezon-Pasig area, and Las Pinas-Paranaque-Muntinlupa south area. According to our land use map of 2003, only 1.7% and 9.2% of the whole Metropolitan Manila are comprised of parks and open spaces.

4) Evacuation Area Shortage

Based on the result of service area density of parks and open spaces, and the number of buildings seriously damaged, Figure 14.3.9 shows the evacuation area shortage. The figure points out that there are mainly 3 portions within the Metropolitan Manila which are especially short in evacuation area, as listed below.

1) Along Manila Bay
- Navotas Bay Area
- Manila North Port Area
- South Eastern Manila City Area

2) Along West Valley Fault System

- Northern Pasig City Area
- Pateros Municipality Area
- Southern Taguig Area
- Muntinlupa Laguna Bay Area

3) North Eastern Quezon City Area

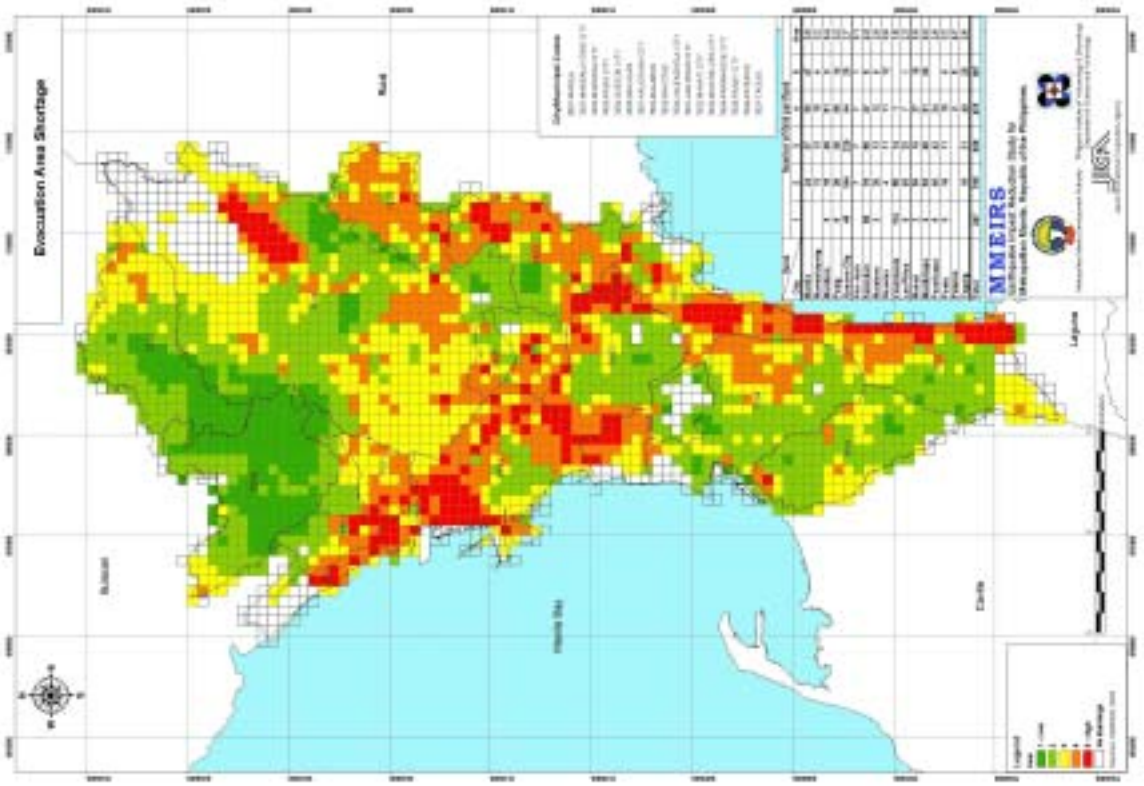


Figure 14.3.9 Evacuation Area Shortage

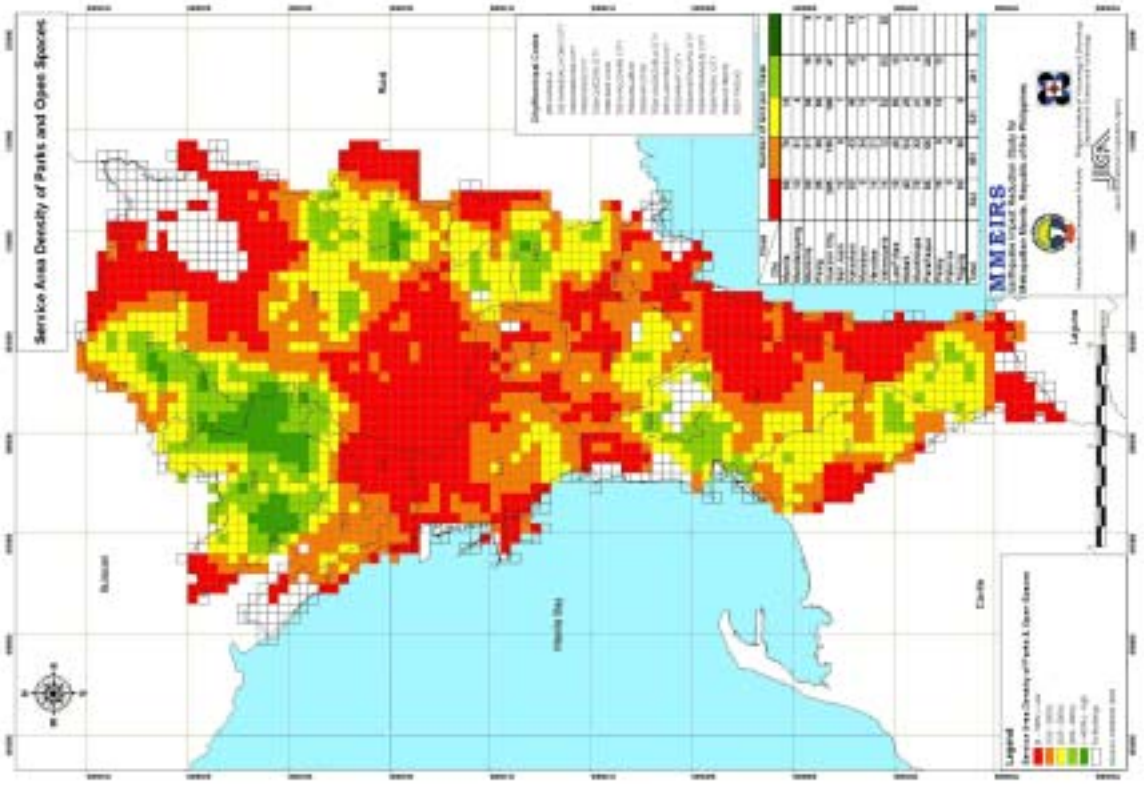


Figure 14.3.8 Service Area Density of Parks and Open Spaces

Chapter 15. Earthquake Damage Scenario

CHAPTER 15. EARTHQUAKE DAMAGE SCENARIO

This chapter will expound on an earthquake damage scenario for Metropolitan Manila.

15.1 Summary of Earthquake Damage

Summary of earthquake damage for Model08, 13, 18 are shown in Table 15.1.1.

Table 15.1.1 Summary of Earthquake Damage

Scenario Earthquake		Model			Model 08	Model 13	Model 18
		Magnitude			7.2	7.9	6.5
		Fault Mechanism			Inland Fault	Subduction	Unknown
Residential Building 1,325,896		Damage		Heavily	168,300 (12.7%)	1,900 (0.1%)	14,200 (1.1%)
				Partly	339,800 (25.6%)	6,600 (0.5%)	52,700 (4.0%)
Population 9,932,560		Casualty		Dead	33,500 (0.3%)	100 (0.0%)	3,100 (0.0%)
				Injured	113,600 (1.1%)	300 (0.0%)	9,500 (0.1%)
Fire	Outbreak				500	-	-
	Burnt area and building	Wind Speed 3m/s			798 ha 42,100 buildings	-	-
		Wind Speed 8m/s			1,710 ha 97,800 buildings		
	Casualty	Wind Speed 3m/s			7,900 (0.1%)		
		Wind Speed 8m/s			18,300 (0.2%)	-	-
Bridge 213 (with detail inventory and stability analysis 189) Flyover 80 (with detail inventory and stability analysis 38)		Large possibility of falling-off		Bridge	7	0	0
				Flyover	0	0	0
		Moderate possibility of falling-off		Bridge	2	0	2
				Flyover	0	0	0
Water Supply Distribution Pipes Total 4,615km				Break of pipes or joints	4000 points	0 points	200 points
Electric Power Transmission and Distribution Line Total 4,862km				Cut of cables	30 km	0 km	4 km
PLDT Telephone Aerial Cable 9,445 km Underground Cable 3,906 km				Cut of cables	95 km	0 km	11 km
Public Purpose Buildings (Hospital 177, School 1412, Fire Fighting 124, Police 43, MMDCC Organizations and 17 LGU City and Municipal Halls 53)				Heavily Damaged	8 - 10 %	0 - 0.2 %	0 – 1 %
				Partly Damaged	20 – 25 %	0 - 0.3 %	2 - 3 %
Mid-rise and High-rise Buildings	10-30 stories building	981		Heavily Damaged	11 %	0.3 %	2.3 %
				Partly Damaged	27 %	2.8%	9.2 %
	30-60 stories building	119		Heavily Damaged	2 %	0 %	0%
				Partly Damaged	12 %	0.1%	0.5%

Source: JICA Study Team

15.2 Earthquake Damage Scenario During One Week from Occurrence of Earthquake

Earthquake damage scenario for Model 08 is shown in Table 15.2.1

Table 15.2.1 Earthquake Damage Scenario

Basic Condition		**-Scenario earthquake: Model 08 (West Valley Fault, Magnitude 7.2)** **-Occurrence of earthquake: 7PM, wind speed 8m/sec.**				
Items		**0-1 hour**	**1-24 hours**	**1-3 days**	**3-7days**	**7days after**
Buildings	Residential houses	◗ 170,000 heavily damaged or collapsed (13% of total buildings) ◗ 340,000 moderately damaged (26% of total buildings) ◗ 10,000 Liquefaction affected building alongside of Manila Bay ◗ Damage ratio of concrete-made buildings is 9%, wooden-made buildings is 16% ◗ Damage ratio in squatter building is 27%. ◗ These figures include damaged caused by aftershocks	• Aftershock causes further building damage • 1,260,000 people lost their residential house (people living in collapsed or heavily damaged residential buildings)			• Debris removal
	Hospital, school, fire fighting, police, government	• 8 – 10% heavily damaged or collapsed • 20-25% moderately damaged	• Residents begin to evacuate to slightly damaged public buildings • Official function severely limited	• Public buildings are occupied with refugees • Staffs can not reach to the Buildings • Official function severely limited		• Temporary repairs initiated • Debris removal
	Mid-rise and High-rise	• 11% heavily damaged or collapsed, 27% moderately damaged for total of 1000 10-30 stories building • 2% heavily damaged or collapsed, 12% moderately damaged for total of 100 30-60 stories building	• Many people are trapped in elevators by electric power failure • Damage expands by aftershocks	• Collapse of moderately damaged buildings by series of aftershocks • No power and water supply in not severely damaged buildings • Habitation impossible in high-rise residences		
Casualties	Dead	• 34,000 dead, 90% of dead from pressure of collapsed building • This figure includes trapped persons who are not rescued from collapsed buildings and die. • Number of dead is small in squatter area	• 20,000 trapped in damaged building burnt to death • Burnt to death in squatter area occurs • Building Collapse by aftershocks make further dead people		• Persons trapped in the collapsed building are all dead. • Some dead bodies are dug out • Absolute limitation of burial • Death of heavily injured persons as to limitation of appropriate medical treatment	• More dead bodies are dug out
	Injured	• 110,000 people with non-life-threatening injuries • Trauma, fracture of a bone, visceral cleft caused by collapsed building and falling furniture • Non structural elements fall from mid-rise and high-rise buildings	• Non structural elements fall from mid-rise and high-rise buildings	• Many crush syndromes occur to the rescued from collapsed building	• Limitation of clean water • Patients increasing by contamination, unsanitary living conditions, especially in infants • Wounds become infected	

Items		0-1 hour	1-24 hours	1-3 days	3-7days	7days after
Fire	Outbreak of Fire	• Total 500 fire outbreak by electricity short circuit • 70 in Manila, 60 Quezon, 50 in Pasig • Fire from Factories, Hospitals, Residential Kitchens • Petroleum leakage from storage tank • LPG leakage from storage tank	• Explosion of LPG and petroleum and tanks by spreading of fire around • Magnification of fire spreading		• New fire outbreaks occur by short circuit of resuming of power supply	
	Spread of Fire	• Not occurred yet	• Fire hydrants incapable • Fire engine unreachable to the fire areas because of congested or debris-blocked roads • Fire fighting system incapable • 100,000 (7%) residential building in 1,700 hector area burned out • Heavy smoke causes respiratory illnesses		•	• Fire almost extinguished
Lifelines	Water Supply	• Failure of water supply caused by damage to water supply pipe at 4,000 points	• Failure of water supply over the whole city		• Damages to Angat reservoir and water purification plant causes stopping of water supply for long term	
	Electricity Supply	• Electric transmission facilities, electric transformer substation on the fault is damaged • Total 30km snapping of cables • Many snapping of cables caused by building collapse	• Power failure over the whole city • Damaged area expands by spread of fire	• Partially recovering in area of building damage is not severe	• Damages to transformer substation is not recovered • Power failure continues over the whole city	
	Telephone	• Total 100km snapping of cables • Many snapping of cables caused by building collapse • Cellular phone broken off as results of damages to base transceiver station • Telephone and cellular phone service is congested and out of use	• Telephone services suspended over the whole city • Suspended area expands by spread of fire	• Partially recovering applying emergency backup generators • Limitation of available fuel for the generator • Limited time of telephone		
Transportation	Airports	• Runway slightly damaged • Some loss of function in airport facilities	• Closure of runway • Only helicopter available • Poor visibility by fire haze	• Runway reopening • Incapable Instrumental landing system by electricity problem • Only daytime visual flight		
	Ports and Harbors	◦ Wharfs in Northport, Southport and Container terminal are damaged and tilted by liquefaction ◦ Damages to cargo-handling machine	• General shipping impossible to come alongside the pier • Incapable loading and unloading			
	Roads and Bridges	• Total of 9 bridges damaged • One in Pasig River, One in Marikina River, One in Manggahan Floodway	• Fire occurs from vehicles left on roads	◦ Almost all roads are occupied with vehicles ◦ Almost all roads are disabled ◦ Many people having difficulty in returning to their residence		
Central Government		• Residential buildings around the Maracanang Palace, the Upper House are severely damaged • Liquefaction around The Lower House area • MMDA building severely damaged	• Danger to fire spreading to the Maracanang Palace	• Public buildings are occupied with refugees • Staffs can not reach to the Buildings • Official function stopped		

15.3 Earthquake Damage Script during One Week from Occurrence of Earthquake

Damage amount and situation are presented Section 15.1 and 15.2. These are translated into a script for better understanding. Lynn Paladio-Melosantos of PHIVOLCS developed the script based upon damage data. Script contents were discussed with the Study Team before being finalized. The same scenario was used during the tabletop exercise held last August 26.

15.3.1 Day 1

Evening. August 26, 2003 is a typical Tuesday, the traffic, the crowd, the sunset at 6:14 as announced by PAGASA. Except that today you are not coming home from work, but from the WORKSHOP at Shangrila Hotel. You are almost home; looking forward to a simple *tinolang manok* that you know is stewing in your kitchen.

You get off from the bus and navigate your village road. As you are walking the last few meters to your gate, you feel a sudden jolt. It sort of pushes you forward. At first you don't know what it is. But the ground continues shaking, up and down, sideways, getting stronger every second. You fall to the ground, unable to keep standing. You hear a booming sound. You hear screams from people inside their homes. You hear breaking glasses. Telephone and power poles sway violently. Then the power goes off. In front of you, the village road is heaving, as if you are riding waves. The strong ground shaking goes on for 50 seconds. It is the longest 50 seconds of your life.

The ground shaking has stopped but you remain on the ground, still feeling dizzy. You try to get up, your knees shake under you. People start pouring out of their homes. Panic and confusion are everywhere. Occasional cries and wails add to the confusion. Around you are toppled poles and fences, collapsed houses, cracked roads, broken water pipes.

You got home as quickly as you can. You recognize your family amongst the crowd on the village street. They are all home, shaken but unhurt. You let out a sigh of relief and say a prayer of thanks. But your family refuses to enter your home. A barangay leader gives instructions to you and your neighbors to move to the basketball court to keep away from objects that may fall or topple.

You move your family as instructed. You try to make a call to other relatives but your mobile phone has no signal. Still you dialed a number. It didn't work. You finally walked back to check your home. But home is something you barely recognize. Everything seems to be piled up on the floor – appliances, shelves, books, lighting fixtures, family portraits, clothes, your prized Jollibee collectibles, even the *tinola* dinner.

Among the pile of mess on the floor, you pick up the old battery-operated transistor radio that your mother-in-law refuses to part with. You turn it on. At first you only get static. You play with

the dials and catch this piece of news: PHIVOLCS issued a bulletin that says a devastating earthquake, with magnitude 7.2 generated by the nearby West Valley Fault, hit Metropolitan Manila. The ground shaking was felt at PEIS VIII in Metropolitan Manila. Weak to strong aftershocks are expected.

You rummage for blankets and go back to the basketball court. You try to think happy thoughts knowing this would be a very long night. You stay tuned in to the radio. News trickles in.

- There is a major power outage in Metropolitan Manila as well as in the neighboring provinces in Luzon.
- Telephone lines, including cellular networks, are down.
- Many residential houses are heavily damaged and collapsed
- Some school buildings collapsed.
- A few hospitals are heavily damaged, ICU patients need to be transferred, and other patients need to be evacuated.
- Fires broke out in several residential clusters, chemical plants, and few other factories and hospitals.
- Hundreds, if not thousands, are estimated trapped dead or injured from collapsed or burning houses, buildings and factories.
- Abandoned cars, some damaged by falling objects, littered the streets of Metropolitan Manila.

Within the next few hours after the earthquake, the National Disaster Coordinating Council convened. Not all the member agencies have representatives immediately available.

15.3.2 Day 2-3

You are one of the more fortunate. No one is injured in your household. But your house is damaged and you are not sure if it will survive the next strong aftershock. Also, food and drinking water are becoming scarce. The barangay leaders and community members work together to provide for everyone.

Overnight you felt several moderate to weak after shocks. There is still no electricity, telephone communication, and water. Haze from burning buildings darkens the horizon. Fires still spread unabated.

News reports give more dismal picture of the extent of damage brought by the earthquake:

The President declares a state of calamity. She mobilizes the Armed Forces of the Philippines for rescue, clearing of debris, and construction of temporary shelters. She suspends schools and offices.

Philippine flags fly at half-mast.

PHIVOLCS confirms movement of the West Valley Fault after it conducted an aerial survey over Metropolitan Manila.

Volunteer rescue groups from Olongapo and Baguio City coordinate with the NDCC.

Back-up power generators are available only in critical public and private offices.

There are more reports of collapsed houses, now numbering in the thousands, mid- to high-rise buildings, and major bridges

Many roads are impassable.

The LRT and MRT railways remain standing but not operational.

Reports of casualties continue to rise to several thousands.

Several thousand families have lost their homes and begin to occupy open spaces.

People rescued from collapsed buildings show crush syndromes and given medical attention on site in temporary medical shelters. They cannot be transferred immediately to hospitals because ambulances cannot get through the roads littered with debris and cars.

The police contain random acts of looting.

15.3.3 Day 4-7

You continue to occupy the basketball court. There is still no power, communication and water supply.

In the tent clusters that sprouted in parks and other open spaces, the lack of clean water supply makes the outbreak of infectious diseases a threat.

In hospitals, injured patients are lined up even along corridors. Again, the lack of clean water is a major problem.

Many people, especially children, suffer from shock, traumatized by the strong ground shaking, the sight of destruction, or being temporarily trapped.

Bodies exhumed from rubbles are lined up along the streets. The air has the distinct smell of decay.

International volunteer rescue teams coordinate with the NDCC. Rescue will continue in the next few days.

Clearing of debris will continue for several weeks to months. Bodies will continue to be recovered among building debris.

Relief goods are distributed in evacuation centers. Some evacuation centers receive more relief goods than others.

Neighboring Asian countries pledge and extend technical, medical and other forms of support.

The Government appeals to those with capabilities to join forces in responding to the disaster. Recovery and rehabilitation will take years and years.