Background

Myanmar is exposed to range of natural hazards such as floods, cyclone, earthquakes, drought, tsunami etc due to its geophysical location. In particular, Myanmar lies in one of the two main earthquake belts of the world with a complex seismotectonic processes (Le Dain et al., 1984). At least nineteen earthquakes of $M_s > 7$ have occurred in the region. The great Arakan earthquake of 1762 caused extensive geo-morphological changes in Myanmar (Burma) coast. The 1878 earthquake caused uplift of 6 m on the west coast of Ramree Island, while another island has disappeared. Another event in 1843 was associated with the eruption of mud volcanoes (GSHAP).

While the main active tectonics characteristics are the subduction zone of Indian plate and Burma (Myanmar) plate in the West of Myanmar and the collision zone of Indian plate and Eurasia plate in the North West there are several fault lines traversing across the country. The major seismotectonically important faults in Myanmar are some unnamed major thrust faults in north-western Myanmar, Kabaw Fault along the Kabaw Valley in western Myanmar, the well-known Sagaing Fault, and the Kyaukkyan Fault situated west of Naungcho. The Sagaing fault is the most prominent active fault in Myanmar which extends from north of Lake Indawgyi southward along the Ayeyarwaddy River north of Mandalay and along the eastern margin of the Bago Yoma to the Andaman Sea (Hazard Profile of Myanmar, Sato, 2009). According to a recent study, on relocation of historical earthquakes since 1918 along the Sagiang Fault, there exist two seismic gaps: one between 19.2°N and 21.5°N in central Myanmar, and another south of 16.6°N in the Andaman Sea. Considering the length of the first seismic gap (~260 km), a future earthquake of up to M ~7.9 is expected to occur in central Myanmar (Nobuo Hurukawa and Phyo Maung Maung, 2011).

The Deterministic Seismic Hazard Zonation Map of Myanmar developed in 2005, classifies Myanmar into five seismic zones, Zone I (Low Zone), Zone II (Moderate Zone), Zone III (Strong Zone), Zone IV (Severe Zone), and Zone V (Destructive Zone). Among the other regions Taungoo – Bago, and Sagaing – Tagaung (Zone V) did not experience any major seismic activity over the past half a century and 2011 Tarlay earthquake in Shan State highlighted the vulnerability of building stock in Myanmar. Considering the majority of the building stock in both urban and rural areas comprising of non-engineered structures such as timber, brick, reinforced concrete there is an increasing concern on the potential damage to major urban areas such as Yangon, Bago, Taungoo and Sagaing, Meikhtila, Taunggyi along the Sagaing fault.

While Disaster Risk Reduction is a nascent stage, efforts are underway to reduce the vulnerabilities through specific interventions such as multi-hazard risk assessment, the earthquake risk assessment for Mandalay city, development of Myanmar National Building Code; community based DRR etc in the country.

Sagaing city is lying on the Sagaing Fault, however no studies have been carried out to assess their earthquake related risk. In addition, Sagaing has undergone recent urban developments with the construction of higher storey buildings. In this regard, earthquake related risk assessment in Sagaing is carried out to estimate the damages. The findings from this report can lead to develop comprehensive risk reduction programs addressing the specific vulnerabilities as well as guiding the future development in the cities along with UN-Habitat's Myanmar Comprehensive Disaster Risk Reduction Programme and also with broader DRR-WG activities and those of initiatives by the local and national Government.

Research Methodology

The current research adopted methodology from the HAZUS-MH Earthquake Loss Estimation Model developed by Federal Emergency Management Agency (FEMA), USA.The framework of the methodology includes Potential Earth Science Hazard (PESH), Direct Physical Damage, Induced Physical Damage, Direct Economic/Social Loss and Indirect Economic Loss. Inventory for general building stock and essential facilities are used as input data. Direct damage data of building and essential facilities, casualties, and economic losses are developed as output result of HAZUS analysis because of limited resources. The earthquake loss estimation methodology can produce the preliminary estimation of damages to prepare before disaster situation and to plan and stimulate efforts how to reduce probable risk from earthquake. The flow chart of the methodology is shown in Figure1.

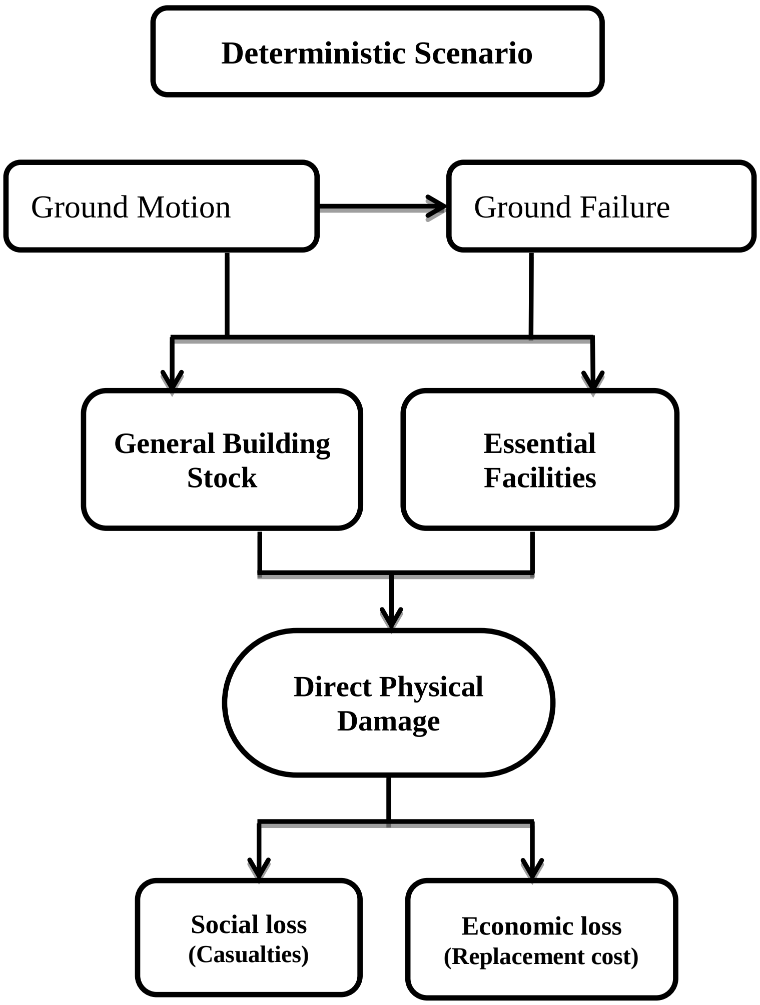

Figure (1) Flowchart of the Earthquake Loss Estimation Methodology adopted by HAZUS

Sagaing City

Sagaing city is situated in the middle part of Myanmar and it lies on the west bank of Ayeyarwady River. The geographical size of Sagaing is 10.84 square miles and contains 18 wards. There are over 15 thousand households in the region with a total estimated population of 77619 people whereas demographic data from government administration office is slightly lower than that number. As per city development plan in Sagaing, five more wards are proposed to be added in existing wards to make the city wider. Some parts of the wards are connected to sloping ground which tends to landslide susceptibility whereas some are in lower land which can be affected by flooding. The location map of Sagaing city is shown in Figure 2.

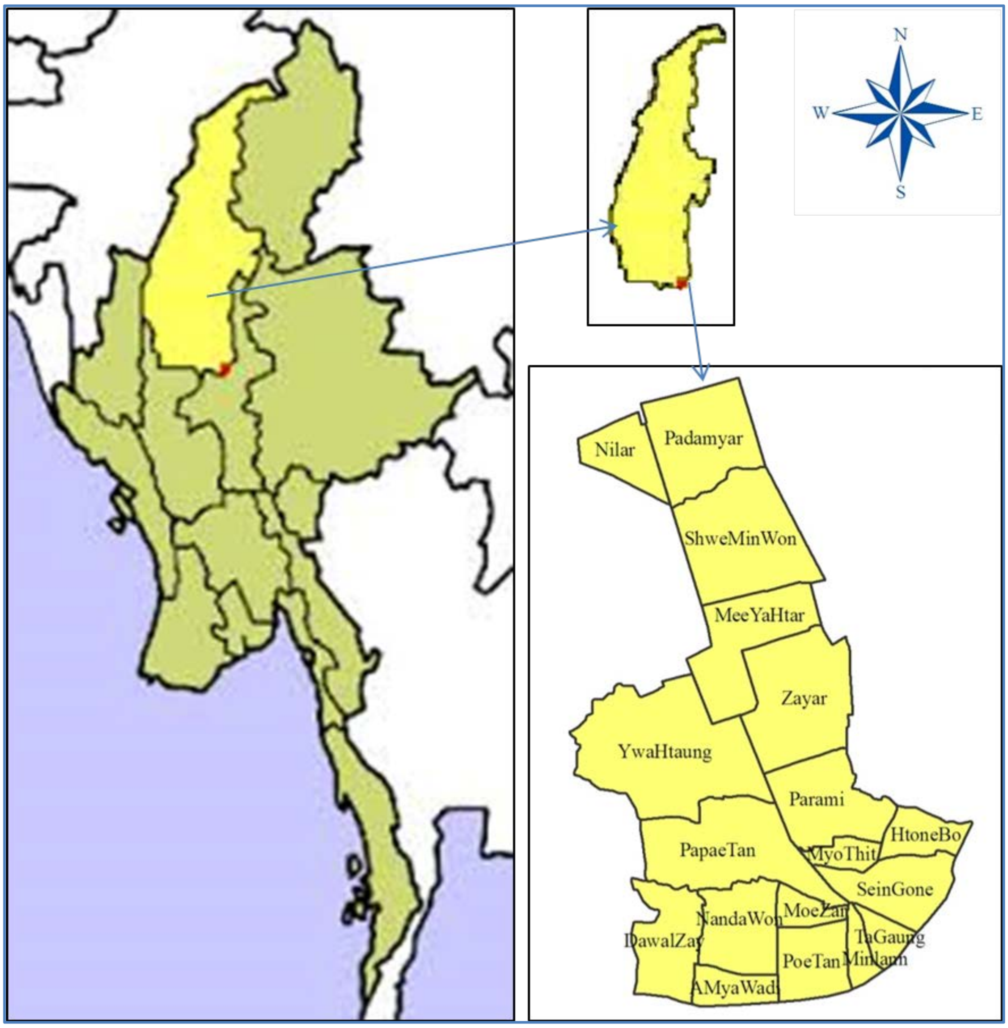

Figure (2) Location Map of Sagaing City

The eastern part of Sagaing is Mandalay city, which is located on the other bank of Ayeyarwady river. Along with the Ayeyarwaddy River, there are the Myatheintan Pagoda, the Mingun Pahtodawgyi and the Largest Ringing bell known as Mingun Bell. Sagaing and Min Won hills are close to Sagaing city and are kind of important places for Buddhist study and meditation. Many famous pagodas and monasteries are scattered on the hills. These places can keep tourist attraction. One of the largest stupas in Myanmar, the Kaunghmudaw Pagoda in Sagaing is also the tourist destination (Figure 3).

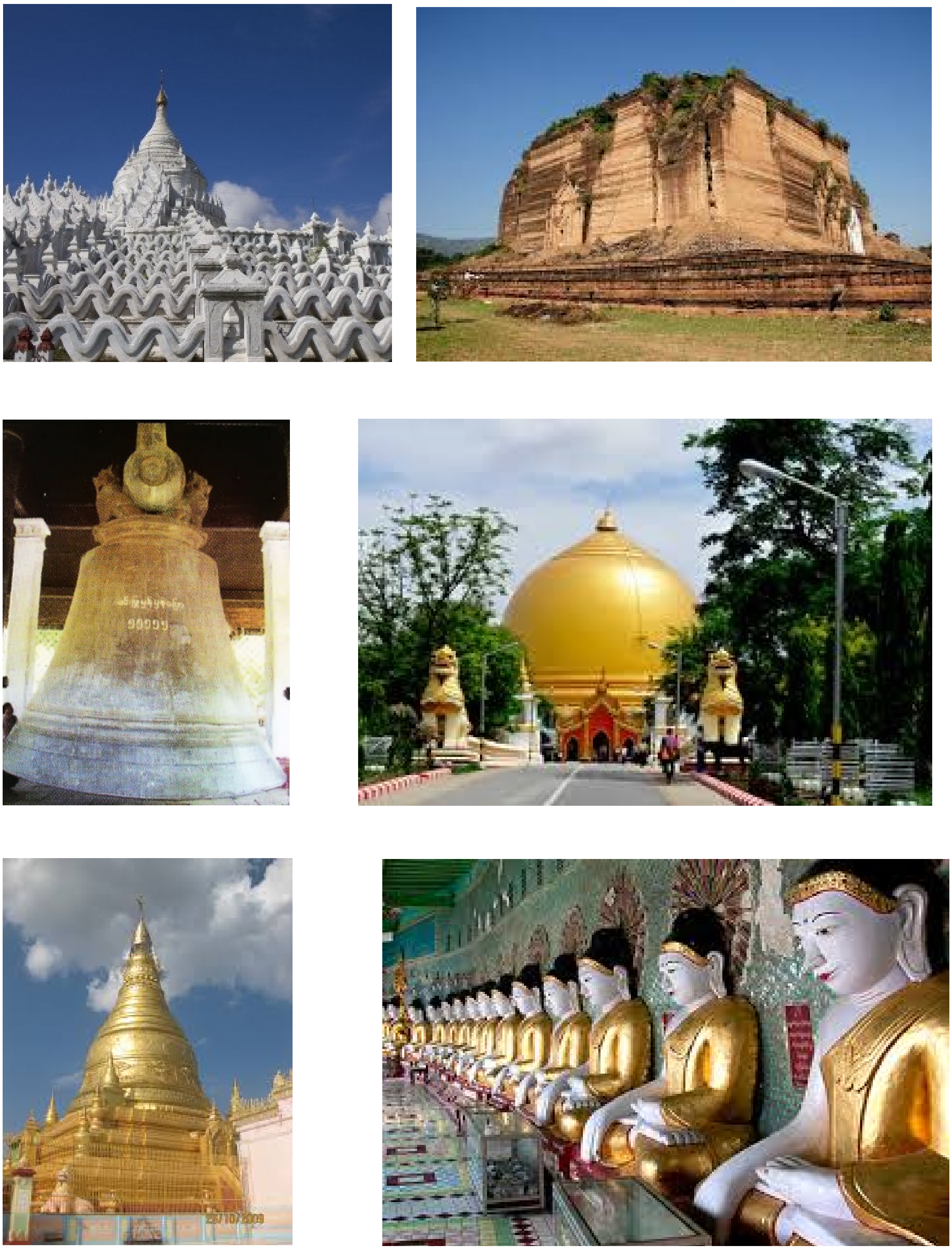

Figure (3) Famous Pagodas near Sagaing City

Livelihood in Sagaing

As per demographic data, Shwe Min Won Ward has the highest population whereas Nilar ward has the lowest one. Among all other data in the livelihood, the highest number of building, population, and households are in Shwe Min Won ward. Zayar ward is the second populated area in Sagaing in which Ywa Htaung is in the third place. Padamyar ward is the industrial area, and it includes the second lowest number of livelihood. Shwe Min Won (7917), Zay Yar (6904), and Ywa Htaung (6624) have got the highest population among any other wards in Sagaing whereas Nilar (1142) have got the lowest population. Population is just above 25% of highest population in Parami, Htone Bo, Moe Zar, and Min Lann wards (Figure A-1). The highest population density (population per area-km^2) among any other wards is in Myothit. Through Myothit ward, pagodas in Sagaing hill can be visited. The wards in a higher population density are in the developed part of the city, near market (Figure A-2).

As Shwe Min Won ward has got the highest population amongst any other wards, the total number of children/youngster under 18 is also the highest. Younger population in Min Lann (466) and Nilar (485) are the lowest (Figure A-3). In Poe Tan ward, population aged over 18 is 4.6 times higher than young population (Figure A-4). The ratio of female to male is higher than one in every ward, which is telling that the number of female is higher than the number of male for the whole city. In Shwe Min Won ward, female population is 1.56 times greater than male population (Figure A-5). The number of households in Shwe Min Won, Zayar, Ywa Htaung, and PapaeTan are the largest as population distribution. Thewider the ward is, the higher the household is (Figure A-6).Most of the wards have got the building count around 1000. Among all wards, Nilar ward has the lowest building count 254 (Figure A-7). In the above map, Myothit and Tagaung wards have got the biggest building density in any other wards in Sagaing (Figure A-8).

Inventory Data for general building stock and essential facilities

Inventory data includes general building stock, essential facilities, and its related replacement cost. The former two inventory data deal with direct damage data whereas the latter will provide additional information to calculateeconomic loss. Three groups of wards in Sagaing are classified depending on levels of economic condition; rich, medium, and poor, to take rapid visual screening survey. The main idea of dividing three groups is to get the different types of building and its use because of the interdependency between building type and income of the family. There are mainly six structure types which can be found in Sagaing. These are timber, brick nogging, reinforced concrete, brick masonry, steel, and bamboo (Figure 4 to 8). Timber building types are the most common type in Sagaing.

Figure (4) Timber Building Type

Figure (5) Brick Nogging Building Type

Figure (6) Reinforced Concrete Building Type

Figure (7) Brick Masonry Building Type

Figure (8) Steel Building Type

General Building Stock Inventory

Inventory data for general building stock, which includes residential, commercial, industrial, agricultural, religious, government, and educational buildings, is prepared as per HAZUS requirement. There are 15 thousand of estimated buildings in the Sagaing city with an aggregated replacement cost of 174 millions of dollars. Approximately 86% of the buildings (55% of the building value) are associated with residential housing. In terms of structural types found in the region, timber frames construction makes up 61% of the building inventory. The remaining percentage is distributed between the other general building types (Figure 9). Distribution of structure type for each ward is listed down inTable 1 and described in Figure (A-9). Total number of building by occupancy in each ward is shown in Table 2 and Figure (A-10). Percent distribution of building by occupancy type in Sagaing is shown in Figure 10.

Estimated building count data by occupancy class for the whole city is directly collected from the field visiting the ward level officer through General Administration Department. Square footage by occupancy is the total floor area (per 1000 ft2) in which estimated floor area is multiplied by the number of story and is divided by 1000. Replacement value (per $1000) by occupancy is calculated by the estimated local PAE rate ($ per ft2) of specific structure type, which is multiplied by square footage for each occupancy class and divided by 1000, which can be done by using occupancy matrix. Content value (per $1000) by occupancy is the percentage of replacement cost. Demographic data is obtained from local government office and prepared as per HAZUS attribute format, which provides housing and population statistics for the study region.

The inventory information required for the analysis to evaluate the probability of damage to occupancy classes is the relationship between the specific occupancy class and the model building types. That occupancy mapping is created from the statistical distribution of on-street survey data.The entire composition of the general building stock within a given tract is lumped at the centroid of the tract.Probability of the general building stock in different damage states is calculated at the centroid of each tract.

$$\text{Square Footage } (\text{ft}^2 \text{ per } 1000) = \frac{\text{Estimated Floor Area} * \text{ No of Story}}{1000}$$

$$\text{Replacement cost } (\$ \text{ per } 1000) = \frac{\text{Estimated PAE rate} * \text{ square footage}}{1000}$$

$$\text{Content cost } (\$ \text{ per } 1000) = \% \text{ of Replacement Cost}$$

Table(1) Distribution of Structure Type in Sagaing

Ward Name	Timber	Brick Nogging	Reinforced Concrete	Brick Masonry	Steel	Total
TaGaung	573	271	46	9	0	899
Minlann	290	163	35	4	0	492
PoeTan	595	348	65	15	0	1023
MoeZar	303	174	39	5	0	521
AMyaWadi	332	172	48	13	0	565
DawalZay	662	307	50	4	0	1023
NandaWon	657	314	48	4	1	1024
PapaeTan	753	375	87	6	0	1221
YwaHtaung	815	401	90	9	0	1315
Nilar	164	78	11	1	0	254
Padamyar	192	133	86	7	11	429
ShweMinWon	944	515	146	58	0	1663
MeeYaHtar	636	290	44	4	0	974
Zayar	1016	474	78	5	0	1573
Parami	250	154	31	11	1	447
MyoThit	547	269	54	14	0	884
SeinGone	771	369	66	12	0	1218
HtoneBo	221	114	30	12	0	377
Total	9721	4921	1054	193	13	15902

Table (2) Distribution of Occupancy Type in Sagaing

Ward Name	Residential	Commercial	Medical	Industrial	Religious	Government	Education
TaGaung	838	12	1	0	36	11	1
Minlann	369	104	7	0	6	2	4
PoeTan	817	80	10	12	25	53	26
AMyaWadi	466	15	11	0	36	1	36
DawalZay	947	58	1	2	11	0	4
NandaWon	962	25	0	14	16	0	7
MoeZar	351	155	2	0	12	1	0
PapaeTan	1018	176	5	0	14	7	1
YwaHtaung	1160	59	3	18	27	4	44
Nilar	230	12	0	9	2	0	1
Padamyar	246	10	0	103	6	7	57
ShweMinWon	1275	50	5	19	308	0	6
MeeYaHtar	937	14	2	1	10	10	0
Zayar	1463	79	3	0	17	2	9
SeinGone	1115	25	0	0	55	9	14
HtoneBo	302	9	0	0	65	0	1
MyoThit	796	12	1	2	71	0	2
Parami	336	20	0	31	27	29	4

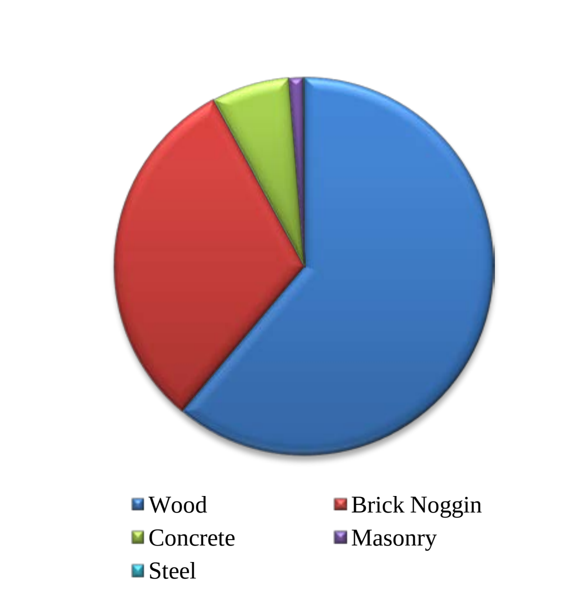

Figure (9) Structure Type Distribution

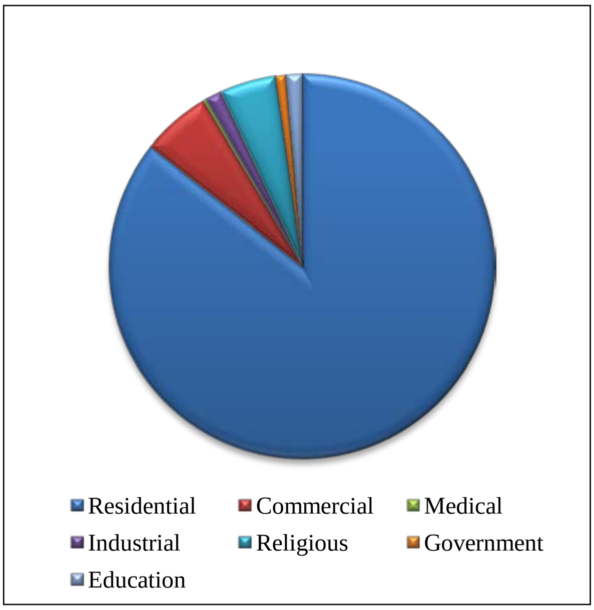

Figure (10) Occupancy Type Distribution

Essential Facilities Inventory

Essential facilities in Sagaing contain 3 hospitals, 2 police stations, 3 fire stations and 30 schools with a specific location of each building. The number of beds in hospital and the number of fire trucks at fire station are collected and applied. The ground motion parameters will be used on a site-specific location of the facility. Design level used for these facilities is pre-code design. Economic losses associated with these facilities are calculated by specific building type as per square footage area.

There are 30 schools in the region with a total 174 school buildings. 24 schools are dropped within the coverage area out of 30 schools and others are out of the study region. Although there are 3 hospitals, one regional hospital is under the submission process to open and remaining two are in the same yard in Poe Tan ward. No (1) police station is in Poe Tan ward and No (2) is in Padamyar ward. Every ward has at least one fire station but every fire station does not have fire engine. All of three fire stations shown in Figure (A-11) have got fire engine in some cases.

Seismic Hazard

For computation of seismic ground motion demand, there are three options: (1) a deterministic calculation, (2) probabilistic maps, and (3) user-supplied maps. Deterministic calculation is used in this research. If all the required data are available to use probabilistic maps, it will be the best choice to estimate the damages of the risk. For deterministic calculation of ground shaking, a scenario earthquake magnitude and location are required to specify. The earthquake scenario data used in this research is with the maximum probable magnitude which can happen along Sagaing fault in the future.

Earthquake Scenarios

There are five segments divided along with Sagaing fault. These are Segment-1 (Putao - Indawgyi Segment), Segment-2 (Tagaung - Sagaing Segment), Segment-3 (Thazi - Pyinmana Segment), Segment-4 (Taungoo - Bago Segment), and Segment-5 (Mottama Gulf Segment) which are described in Figure (11). Two scenario earthquakes with the maximum probable magnitude in Sagaing segment (98km long) and Wundwin segment (203km long) are assumed to be occurred. Epicenter location of two earthquake scenarios is shown in Figure 12 and 13, and scenario information is listed in Table 3.

There are sixteen (16) attenuation functions provided by HAZUS methodology. From all of these attenuation functions, Boore, Joyner and Fumal (1997) for Strike-Slip fault type is chosen to use because Sagaing fault is Strike-Slip fault.

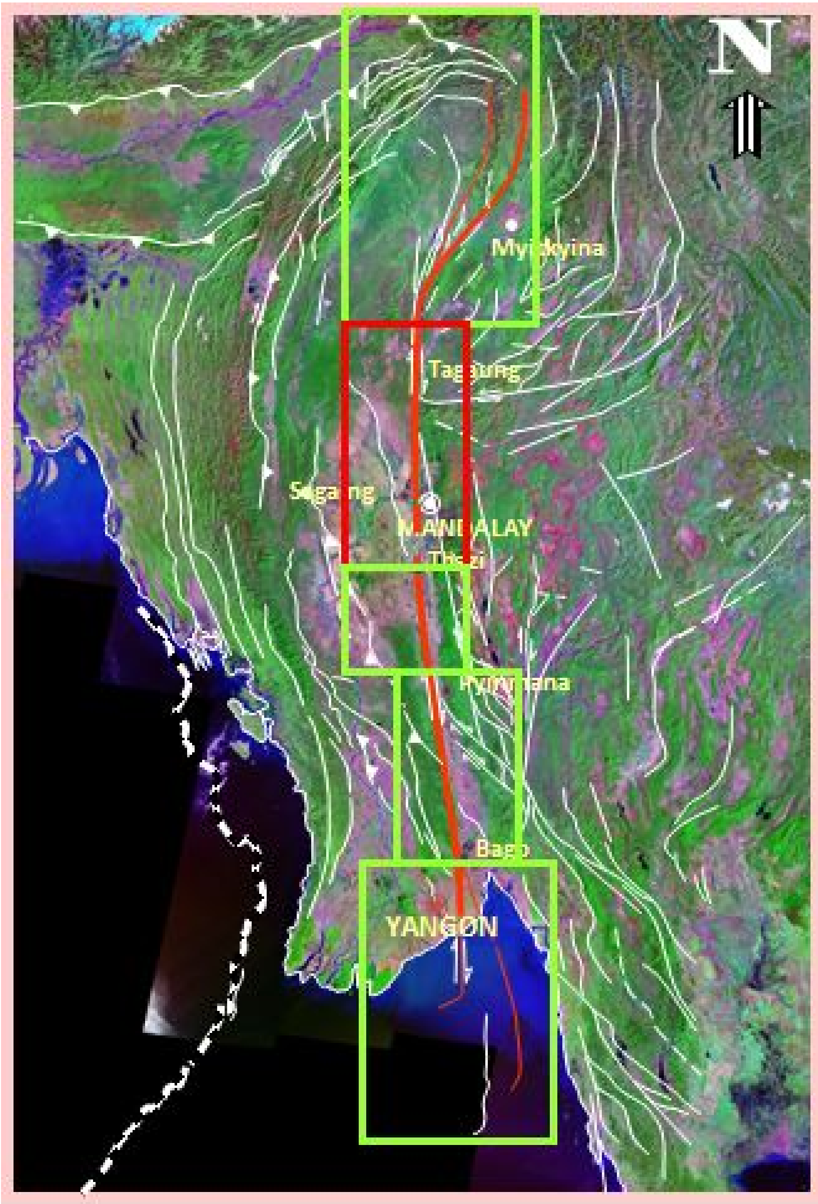

Figure (11) Five Segments along with Sagaing Fault

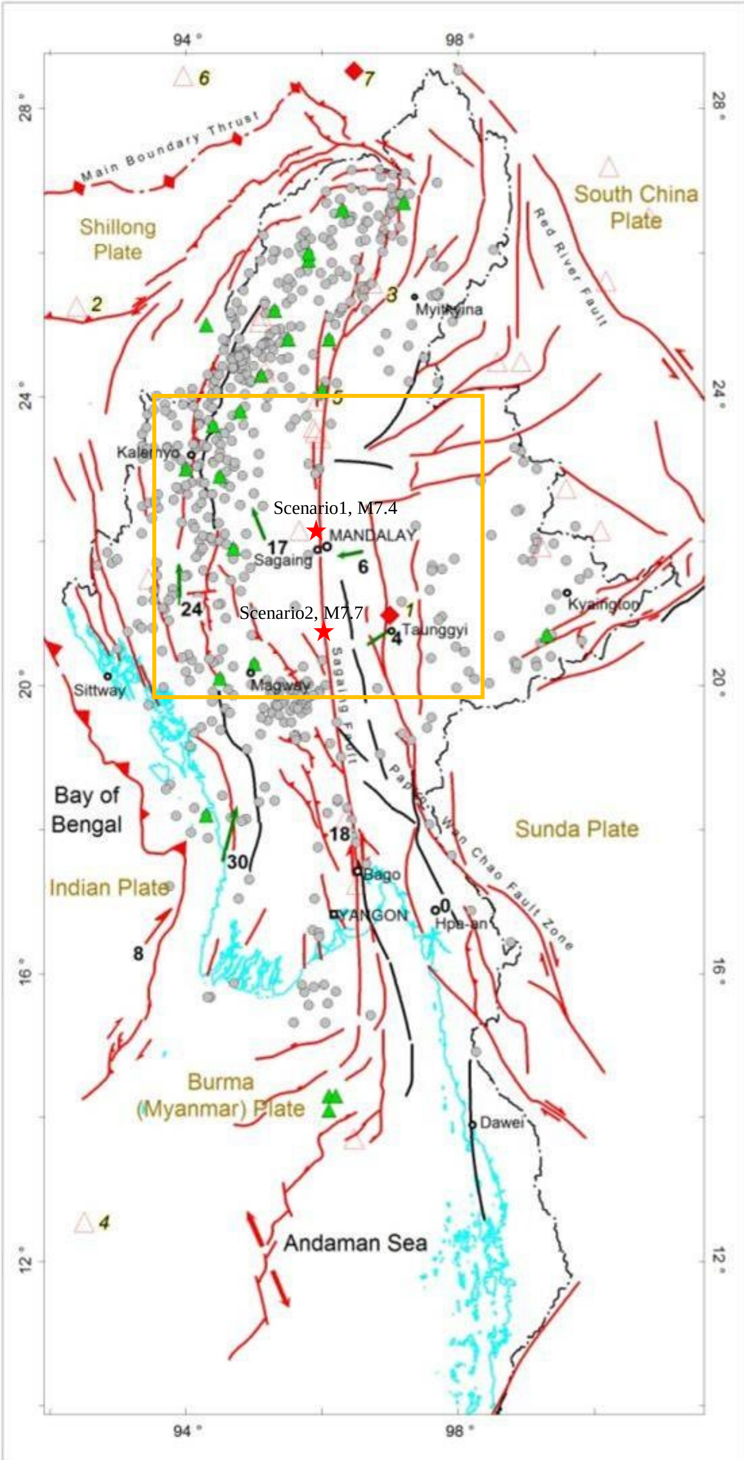

Figure (12) Tectonic Map of Myanmar

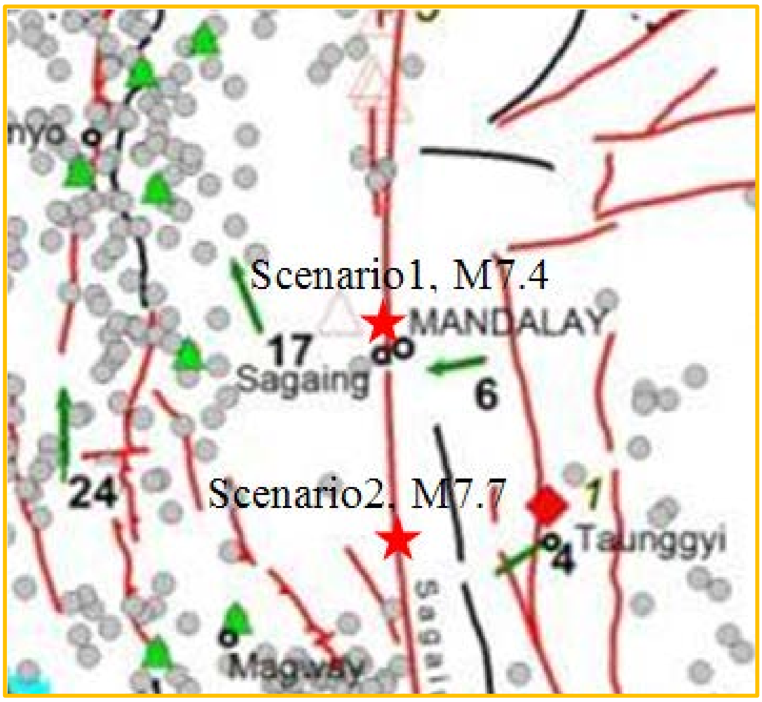

Figure (13) Epicenter Location for Maximum Probable Earthquake along Sagaing Fault

Table (3) Two Scenarios with the Maximum Probable Magnitude along Sagaing fault

	Scenario 1 (Sagaing)	Scenario 2 (Wundwin)
Segment along Sagaing Fault	Sagaing Segment	Wundwin Segment
Max. Expected Magnitude	M7.4	M7.7
Epicenter location	95˚58'12"E 22˚8'49.2"N	96˚1'55.2"E 20˚46'22.8"N
Depth (km)	12	12
Rupture Width (km)	17.2	21.4
Rupture Orientation (degree)	0	0
Dip Angle (degree)	90	90
Seismic Hazard Type	Deterministic Hazard (Arbitrary event)	
Fault Type	Strike-Slip fault	
Attenuation Function	Boore, Joyner and Furnal (1997)	

Definition of Damage States

Damage states are defined separately for structural and nonstructural systems of a building. Damage is described by one of four discrete damage states: slight, moderate, extensive, and complete. Description of damage states for each structural type is listed in Table3.Loss functions relate the physical condition of the building to various loss parameters (i.e., direct economic loss, casualties, and loss of function).

Table (4) Description of Damage States for each structure type

Damage State	Timber	Steel	Reinforced Concrete	Brick Masonry	Brick Nogging
Slight	Small cracks at corners of door and window openings	Minor deformations in connections or hairline cracks in few welds.	Diagonal (sometimes horizontal) hairline cracks on most infill walls; cracks at frame-infill interfaces.	Diagonal hairline cracks on brick masonry wall surfaces; larger cracks around door and window openings in walls.	Small cracks at corners of door and window openings, Diagonal, stair-step hairline cracks on brick masonry wall surfaces
Moderate	Large cracks at corners of door and window openings	Permanent rotations at connections in yielded steel members, Major cracks in few welded connections, Enlarged bolt holes in few bolted connections.	Larger diagonal cracks in most infill wall. Crushing of brick around beam-column connections in some walls. Diagonal shear cracks in reinforced concrete beams or columns.	Diagonal cracks on most wall surfaces, Larger diagonal cracks on some of the walls.	Large cracks at corners of door and window openings, Diagonal cracks on most wall surfaces, Larger diagonal cracks on some of the walls
Extensive	Permanent lateral movement of floors and roof	Significant permanent lateral deformation in most yielded steel members. Some of the members exceeding their ultimate capacity resulting major permanent member rotations at connections	Most infill walls exhibit large cracks. Few reinforced concrete columns or beams may fail in shear resulting in partial collapse. Structure may exhibit permanent lateral deformation.	Most walls have suffered extensive cracking. Beams may have moved relative to their supports.	Permanent lateral movement of floors and roof, Most walls have suffered extensive cracking.
Complete	Large permanent lateral displacement, may collapse, or the failure of the lateral load resisting system,	Significant structural elements have exceeded their ultimate capacities or some critical structural elements have failed resulting in dangerous permanent lateral displacement, partial collapse or collapse of the building.	A combination of total failure of the infill walls and non-ductile failure of the reinforced concrete beams and columns.	Structure has collapsed due to in-plane or out-of-plane failure of the walls.	Large permanent lateral displacement, Failure of the lateral load resisting system, Structure has collapsed due to in-plane or out-of-plane failure of the walls.

Direct Damage for Maximum Probable Earthquake

According to HAZUS methodology, direct earthquake damage deals with buildings and facilities; the general building stock, essential facilities, and high potential loss facilities. High potential loss facilities are not considered in this research because of limited resources in collecting the inventory data.

Building Damages

Earthquake damage to buildings is influenced by the types of buildings. For Scenario-1, about 13624building are at least moderately damaged, that is over 86% of the total number of buildings in the region. There are an estimated 6566 buildings that is damaged beyond repair. The building damages for earthquake M7.4, Sagaing segment are in figure (B-1 to B-21). Expected damages by occupancy and structure type are listed in Table 5 and 6.

Table (5) Expected Number of Building Damages by Occupancy for M7.4

Occupancy Type	NoneDamage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage	Total No. of Building
Commercial	18	72	168	141	567	966
Education	1	4	11	17	185	218
Government	1	3	8	13	111	136
Industrial	3	11	28	26	143	211
Other Residential	33	127	283	205	367	1015
Religion	6	25	65	73	575	744
Single Family	404	1567	3497	2524	4620	12612
Total No. of Building	466	1809	4060	2999	6568	15902

Table (6) Expected Number of Building Damages by Building Type for M7.4

Structure Type	None Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage	Total No. of Building
Timber	464	1790	3884	2458	1138	9734
Steel	0	0	0	0	13	13
Reinforced Concrete	0	1	10	14	1029	1054
Brick Masonry	0	0	4	14	172	190
Brick Nogging	2	18	162	513	4216	4911
Total No. of Building	466	1809	4060	2999	6568	15902

For Scenario-2, the estimation of building damages is about 2,901 buildings, which are at least moderately damaged. This is over 18% of the total number of buildings in the region. An estimated 168 buildings is damaged beyond repair. Figure (B-22to B-42) is the damage distribution of buildings in each ward for the earthquake M7.7 in Wundwin segment. Expected damages by occupancy and structure type are listed in Table 7 and 8.

Table (7) ExpectedNumber of Building Damages by Occupancy for M7.7

Occupancy Type	None Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage	Total No. of Building
Commercial	493	213	165	74	21	966
Education	84	49	49	27	8	217
Government	58	31	29	13	4	135
Industrial	103	47	39	18	5	212
Other Residential	632	221	121	33	8	1015
Religion	338	164	149	74	19	744
Single Family	7850	2718	1499	442	104	12613
Total No. of Building	9558	3443	2051	681	169	15902

Table (8) Expected Number of Building Damagesby Building Type for M7.7

Structure Type	None Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage	Total No. of Building
Timber	7076	1946	648	61	5	9736
Steel	1	2	4	4	2	13
Reinforced Concrete	228	202	308	243	72	1053
Brick Masonry	106	40	31	10	2	189
Brick Nogging	2147	1253	1060	363	88	4911
Total No. of Building	9558	3443	2051	681	169	15902

Essential Facilities Damage

Essential facilities are facilities which provide services to public and should be functional after an earthquake. The essential facility includes medical care facilities, emergency response facilities, and schools. Police station and fire station should also be functional to prevent fire following earthquake and to serve in search and rescue after earthquake. Before the earthquake, the region had 220 hospital beds available for use.

For Scenario-1, no hospital beds are available to use by patients already in the hospital and those injured on the day of the earthquake until one week after earthquake because all hospital buildings are more than 50% complete damage (Table 9). Only 7 beds will be operational after a month.

For Scenario-2, on the day of the earthquake, the estimation is only 77 hospital beds (35%) are available for use by patients already in the hospital and those injured by the earthquake. Only 4 out of 15 buildings are at least moderate damage (Table 9). After one week, 56% of the beds will be back in service. By 30 days, 80.00% will be operational.

Table (9) Expected Damage to Essential Facilities

EQ	Classification	Total Building	At Least Moderate damage >50%	Complete damage >50%	With Functionality > 50% on day1
Scenario 1 (M7.4)	Hospitals	15	15	15	0
	Schools	178	178	167	0
	Police Stations	42	42	8	0
	Fire Stations	3	3	2	0
Scenario 2 (M7.7)	Hospitals	15	4	0	1
	Schools	178	3	0	14
	Police Stations	42	1	0	35
	Fire Stations	3	2	0	1

Induced Earthquake Damage-Debris Generation

The amount of debris generated by the earthquake is also estimated. The debris is divided two general categories: (a) Brick/Timber and (b) Reinforced Concrete/Steelbecause of the different types of material handling equipment required to handle the debris.

For Scenario-1, a total of 0.580 million tons of debris isgenerated (Table 10). Of the total amount, Brick/Timber comprises 41.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 23200 truckloads (at 25 tons/truck) to remove the debris generated by the earthquake M7.4 in Sagaing segment.

For Scenario-2, in the total debris of 0.06 million tons, brick/timber comprises 38% of the total and the remaining 62% is the debris of reinforced concrete/steel. The estimated number of 2400 truckloads (at 25 tons/truck) is required for the remove of debris (Table 10).

Table (10) Debris and Total Truckloads for Earthquake Scenarios (at 25Tons/Truck)

Scenario Name	Brick/Timber		RC/Steel		Total Debris (Million Tons)	Total Number of Trucks
	Debris (Million Tons)	Number of Trucks	Debris (Million Tons)	Number of Trucks		
Scenario1 , M7.4	0.2378 (41%)	9512	0.3422 (59%)	13688	0.58	23200
Scenario2 , M7.7	0.0228 (38%)	912	0.0372 (62%)	1488	0.06	2400

Casualties

The number of people that will be injured and killed by the earthquake is estimated. The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial. For the casualties at 5:00 PM, the estimation is based on commuting population. The estimated number of casualty is listed down in Table 11.

The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level-1 : Injuries will require medical attention but hospitalization is not needed.
Severity Level-2 : Injuries will require hospitalization but are not considered life-threatening
Severity Level-3 : Injuries will require hospitalization and can become life threatening if not promptly treated.
Severity Level-4 : Victims are killed by the earthquake.

Table (11) Estimated Number of Casualty Population

Scenario Name	Level 1			Level 2			Level 3			Level 4		
	2AM	2PM	5PM	2AM	2PM	5PM	2AM	2PM	5PM	2AM	2PM	5PM
Scenario1 , M7.4	1750	6886	2697	463	2208	857	44	338	130	79	651	250
Scenario2 , M7.7	93	487	191	19	126	49	2	20	8	4	38	15

Building Related Economic Losses

The economic loss estimated for the earthquake is expressed by millions of kyats which include building and lifeline related losses based on the region's available inventory.The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. The estimated economic losses are listed in Table 12 and 13.

Table (12) Building Related Economic Losses in Millions of Kyats (M7.4)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	1930	14850	1060	11470	29310
	Capital-Related	0	840	7630	640	3360	12480
	Rental	19410	6950	8880	480	5060	40790
	Relocation	65390	3520	14580	1820	45360	130670
	Subtotal	84800	13240	45940	4010	65250	213250
Capital Stock Losses	Structural	9790	860	8590	1290	4410	24950
	Non_Structural	30380	4620	17600	5840	21140	79590
	Content	10550	970	9420	4020	10770	35720
	Inventory	0	0	5220	5060	0	10280
	Subtotal	50720	6460	40820	16220	36320	150550
Total		135520	19700	86760	20230	101580	363800

Table (13) Building Related Economic Losses in Millions of Kyats (M7.7)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	350	2350	190	1790	4680
	Capital-Related	0	150	1160	120	510	1940
	Rental	1790	740	1870	80	760	5260
	Relocation	6620	340	3400	320	7040	17720
	Subtotal	8410	1580	8780	720	10100	29590
Capital Stock Losses	Structural	870	80	1440	170	570	3140
	Non_Structural	1940	310	1690	380	1620	5930
	Content	690	70	820	250	720	2550
	Inventory	0	0	420	330	0	750
	Subtotal	3500	450	4370	1130	2910	12370
Total		11920	2040	13150	1840	13010	41960

CONCLUSION

The outcome of this paper isthe estimation result of damages and casualties for the maximum probable earthquake and it is very useful for urban planners, decision makers and government officials who are responsible for disaster prevention and disaster preparedness in Sagaing city. Priorities for urban planning, land-use planning, and building regulations can be decided by the use of the estimated damage result. These are the results to prepare an improvement plan for existing urban structures such as reinforcement (retrofitting) of vulnerable buildings and infrastructure, securing of open spaces and emergency roads. Besides, preparation for emergency activities such as life saving, firefighting, and emergency transportation can be carried out.

According to the damage result, at least 41% of the total numbers of building are collapse for scenario-1, in which 26% of complete damages are brick nogging buildings and the remaining are other types. For scenario-2, around 1% of total buildings are collapsed and 61% of that makes no damage. The meaning is that when the hazard and the vulnerability meet, the damages can produce. The higher the hazard and vulnerability happen, the bigger the damages appear.

In this research, the numbers of people who get injuries and die are the highest when the earthquake comes at 2 pm. Those are in industrial, educational and commercial buildings. In this case, the numbers of people are collected in specific places. As the disaster is not prevented, the preparedness like awareness raising for the people in those specific area can be done to know how to act in disaster situation.

For the essential facilities; school buildings, hospital buildings, fire station, police station, most of the buildings damage completely more than 50% for scenario-1 and lack of service in the day of earthquake. As a result, delay can be high in terms of emergency response like search and rescue, and preventing fire following earthquake. Besides, all of the school buildings will severely damage and most of the students will get injury and some even die. Furthermore, the existing patients and earthquake related patients in hospital will require more free space like shelter to get treatment. For scenario-2, some of the buildings damage moderately more than 50%, and some of them can be back in service.

The collapse or heavy damage of buildings is considered as the main cause of death and injury during an earthquake. HAZUS casualty estimation does not take into account of casualty (Death and Injury) from non-structural hazards. The entire process of carrying out casualty simulation is to reach an understanding of how many people will require medical attention. It also gives better insights into the requirements of emergency services for response planning and the hospital authorities for developing hospital contingency plan.

In Sagaing, although the population and building inventory inShwe Min Won, ZayYar, and YwaHtaung wards are the highest, their density is lower than in compare with other wards. Thus, more evacuation spaces are available in these wards. In contrast, the numbers of population and building in Myothit ward are lower; its density is higher as less evacuation place is obtained.

The results in this report are the estimation of damages to make the communities aware. Understanding the vulnerability of the area where they live, to understand how to behave in case of an earthquake, and participating in preparing plans for disaster prevention are the prior effectiveness for the communities. The building damage distribution maps highlight the areas of vulnerable building stock. And it offers a window of opportunity to reduce the vulnerability of the people by implementing specific risk reduction measures such as retrofitting of buildings and have effective response plan to deal with.

APPENDIX - A

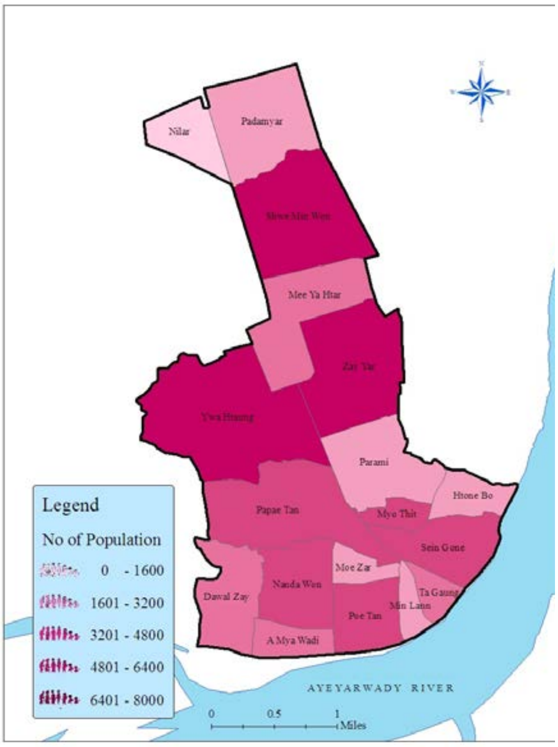

Figure (A-1) Total Population

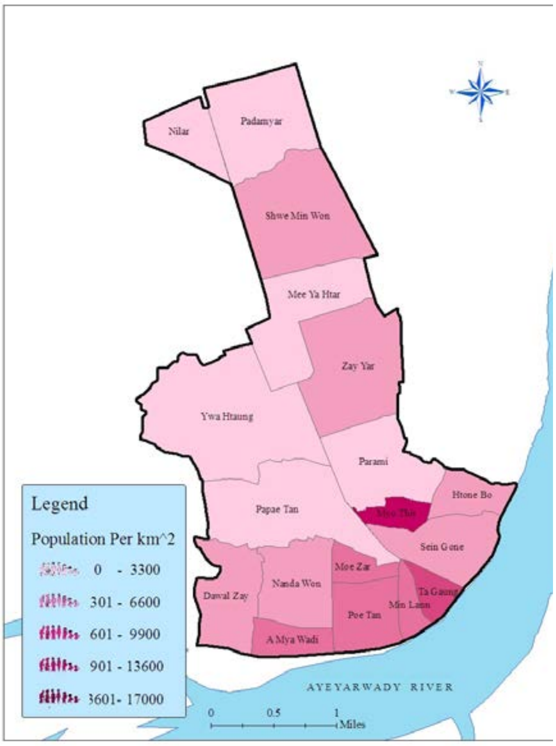

Figure (A-2) Population Density

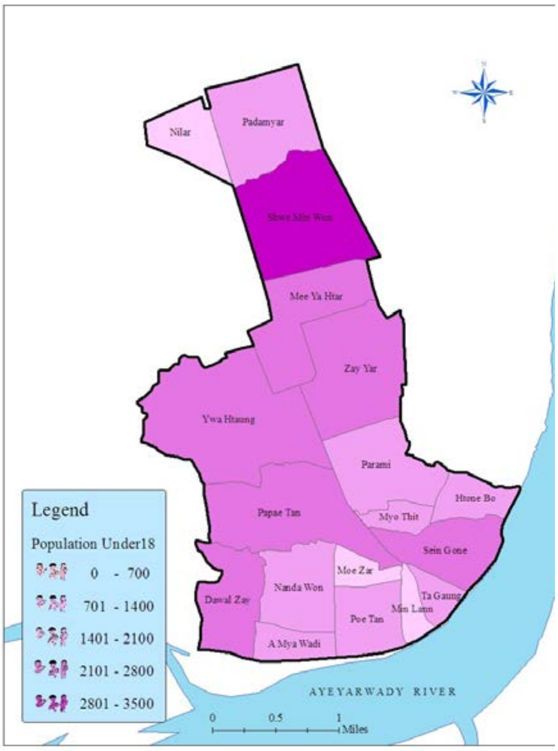

Figure (A-3) Age Under-18Population

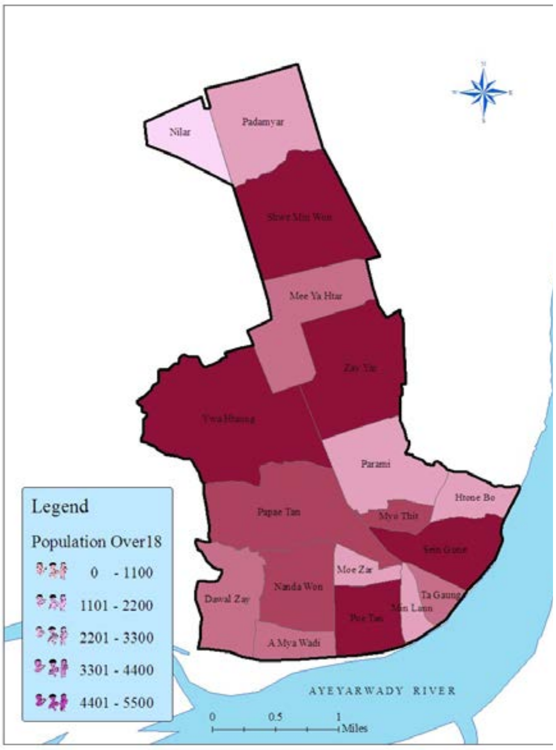

Figure (A-4) Age Over-18 Population

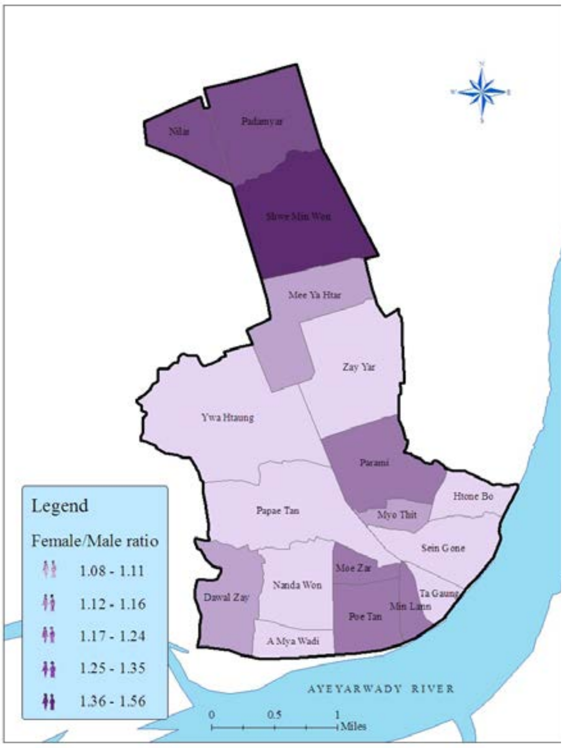

Figure (A-5) Female to Male ratio

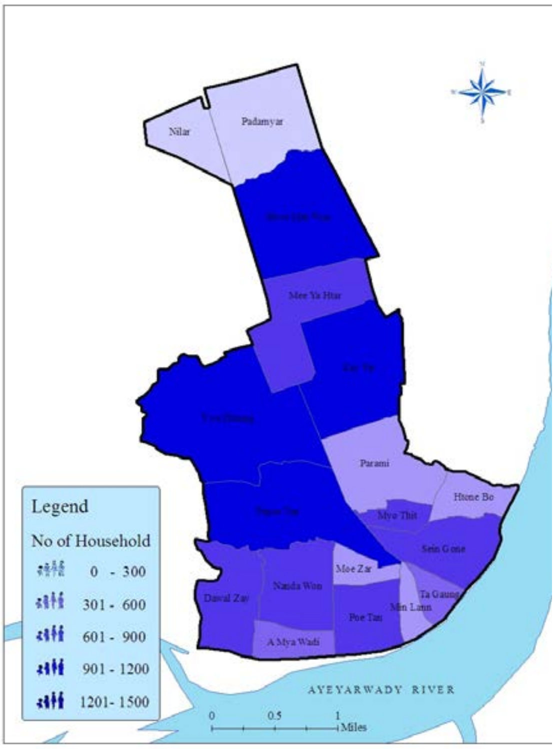

Figure (A-6) Number of Household

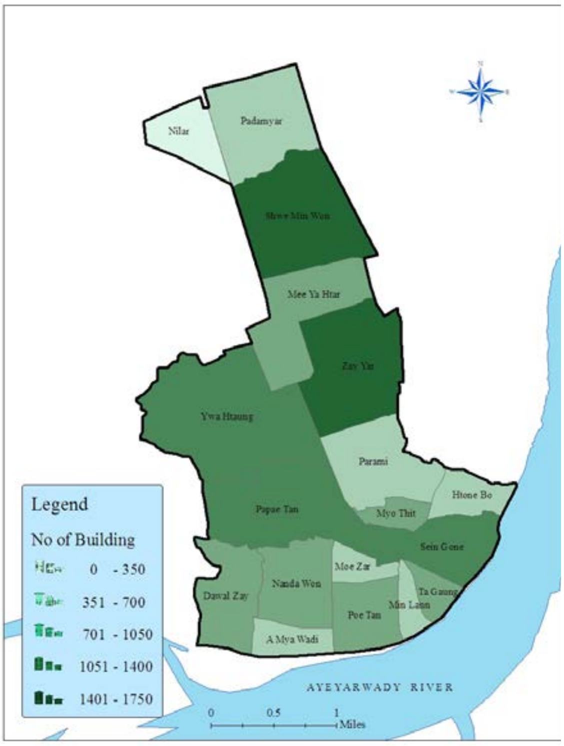

Figure (A-7) Total Number of Buildings

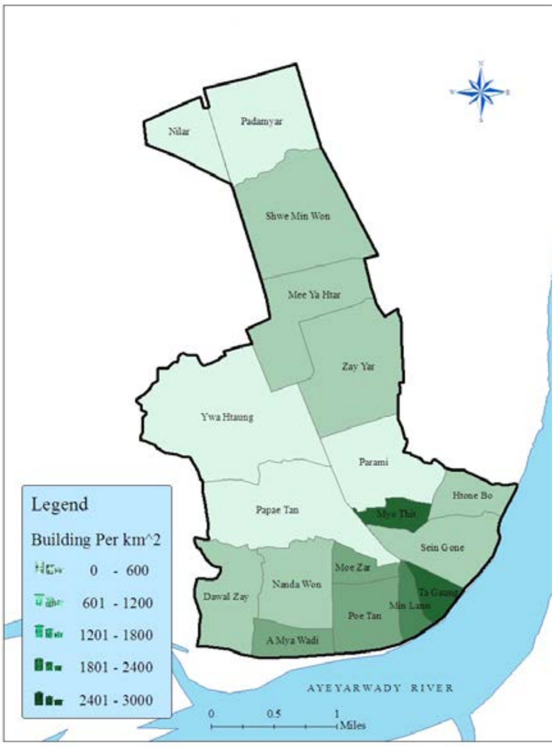

Figure (A-8) Building Density

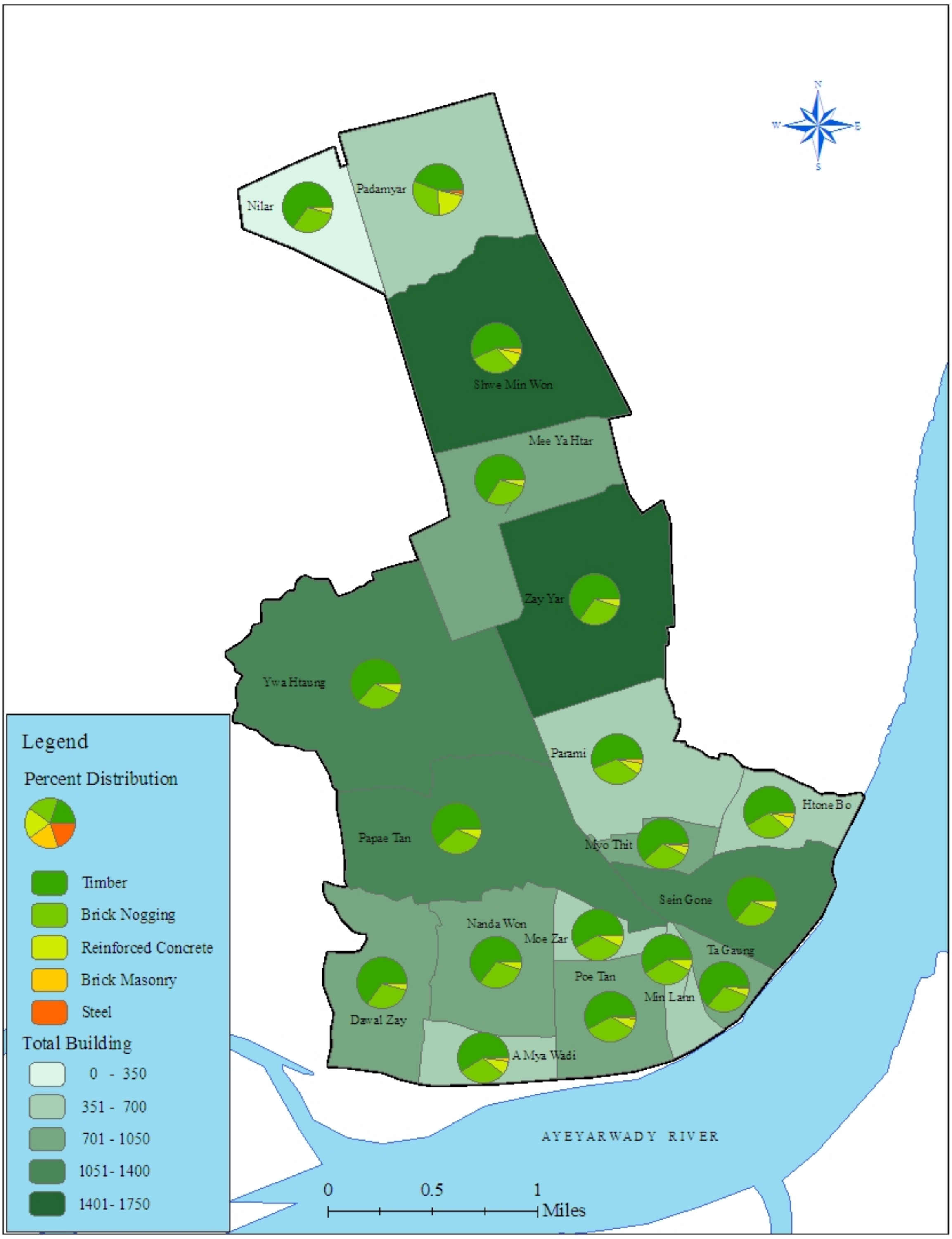

Figure (A-9) Total Number of Building by the Percent Distribution of Structure Type

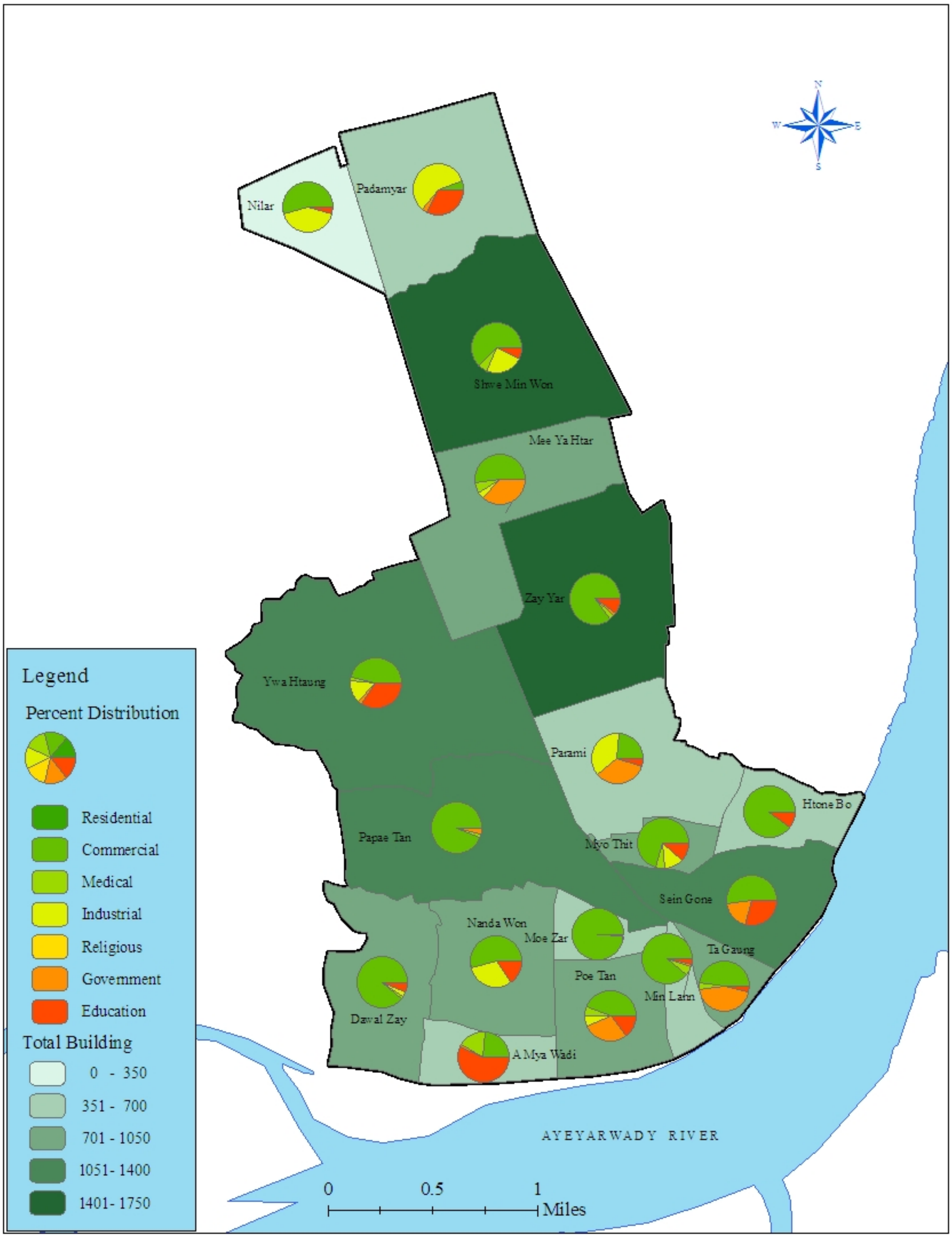

Figure (A-10) Total Number of Building by the Percent Distribution of Occupancy Type

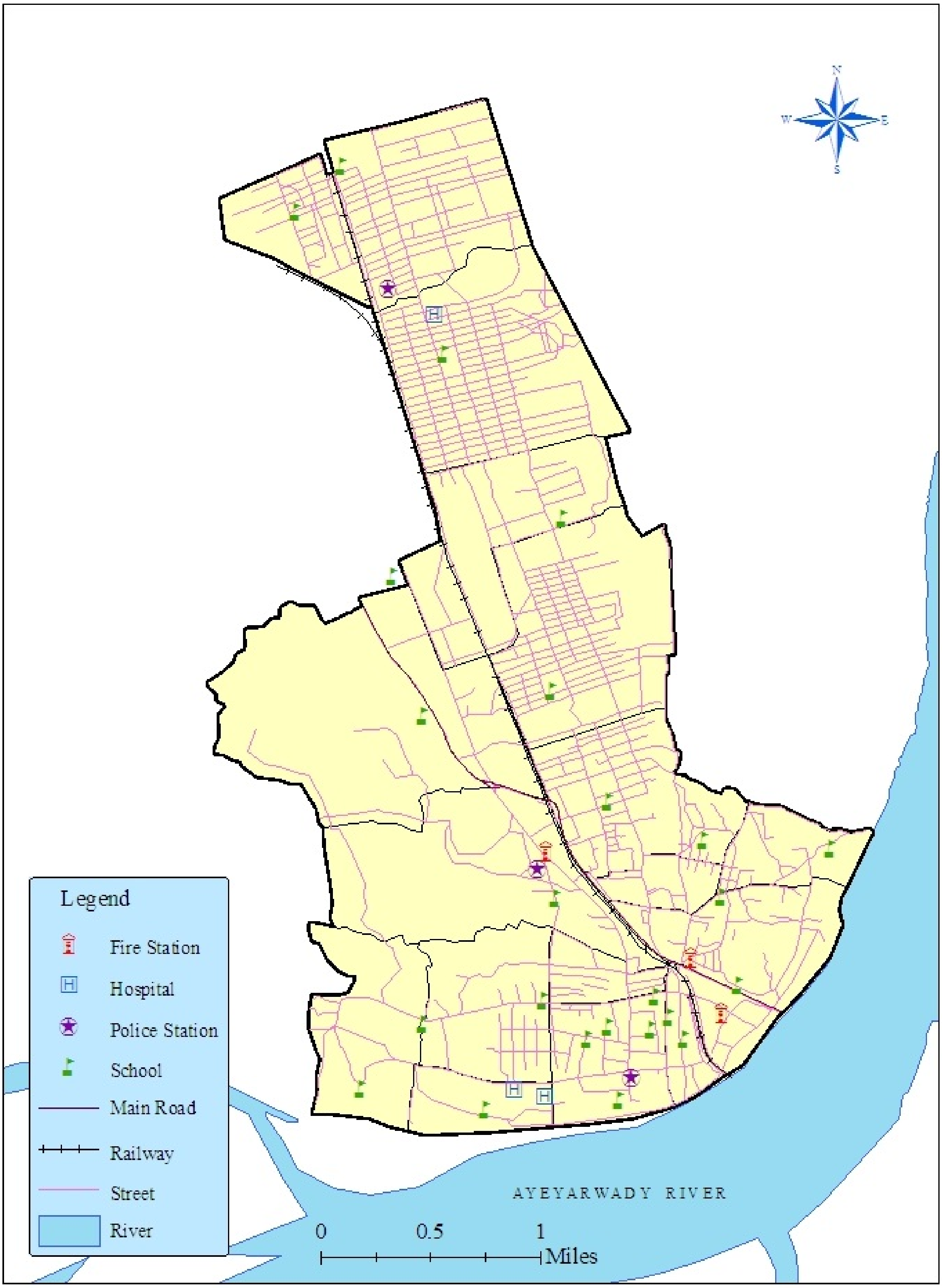

Figure (A-11) Location Map of Essential Facilities in Sagaing

APPENDIX - B

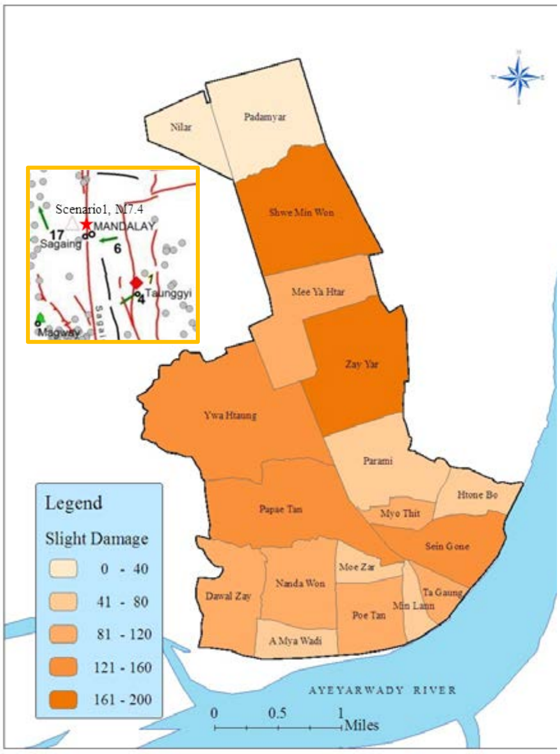

Figure (B-1) Timber Building Damages in Slight Damage State, M7.4

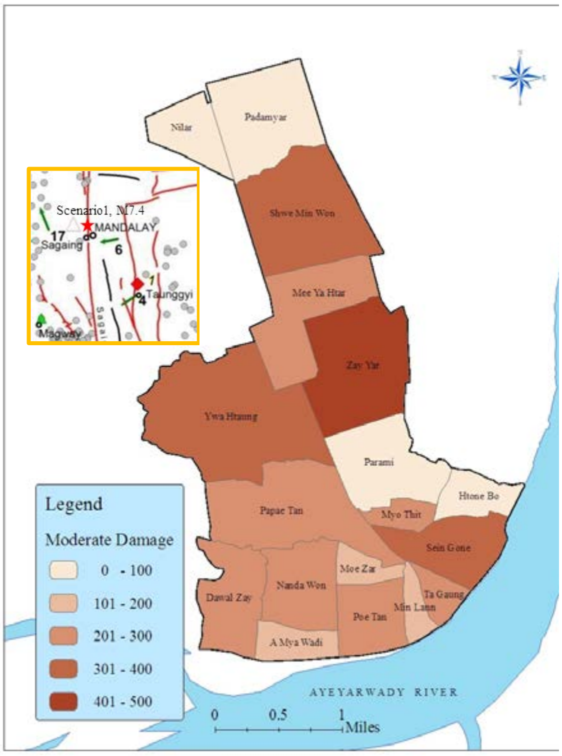

Figure (B-2) Timber Building Damages in Moderate Damage State, M7.4

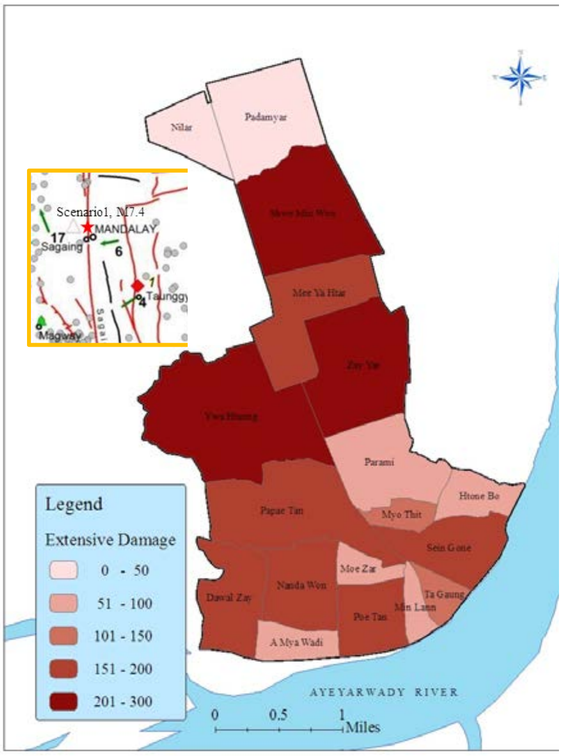

Figure (B-3) Timber Building Damages in Extensive Damage State, M7.4

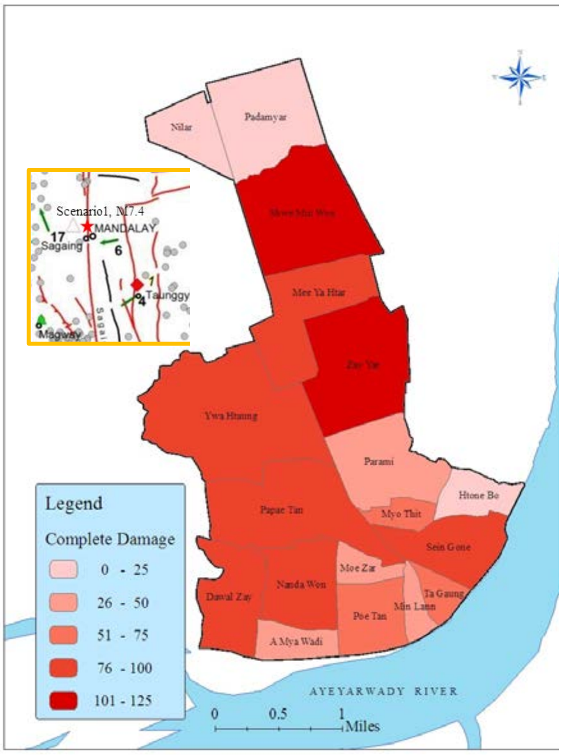

Figure (B-4) Timber Building Damages in Complete Damage State, M7.4

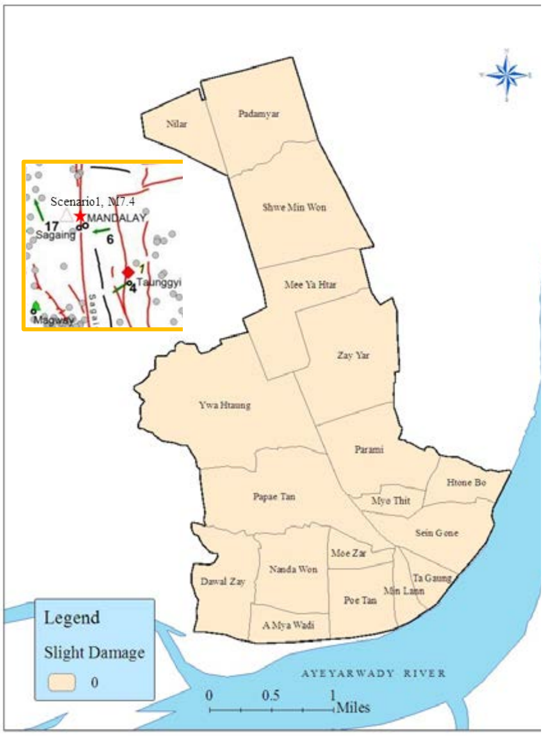

Figure (B-5) Brick Masonry Building Damages in Slight Damage State, M7.4

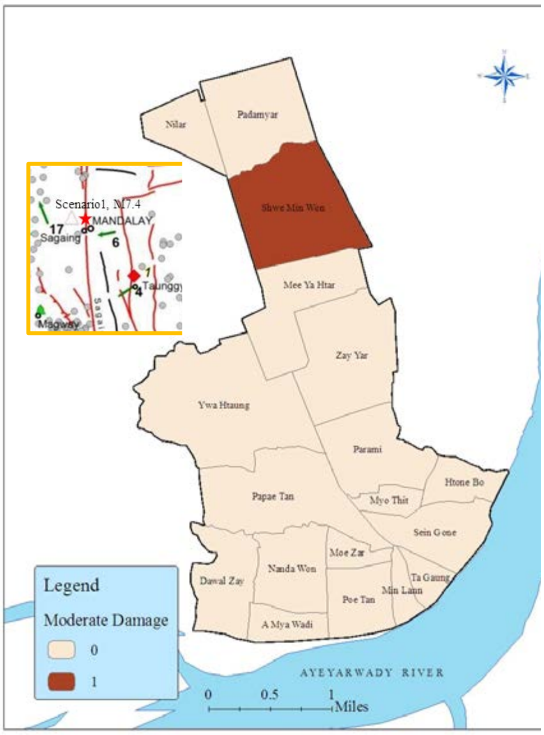

Figure (B-6) Brick Masonry Building Damages in Moderate Damage State, M7.4

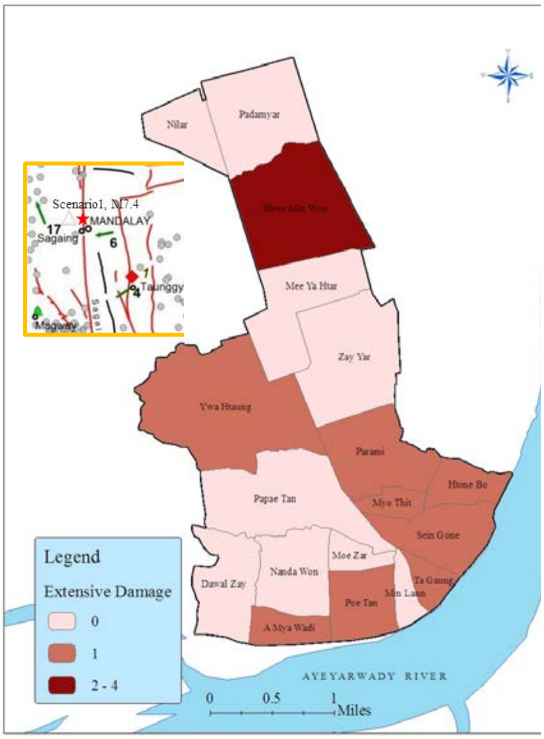

Figure (B-7) Brick Masonry Building Damages in Extensive Damage State, M7.4

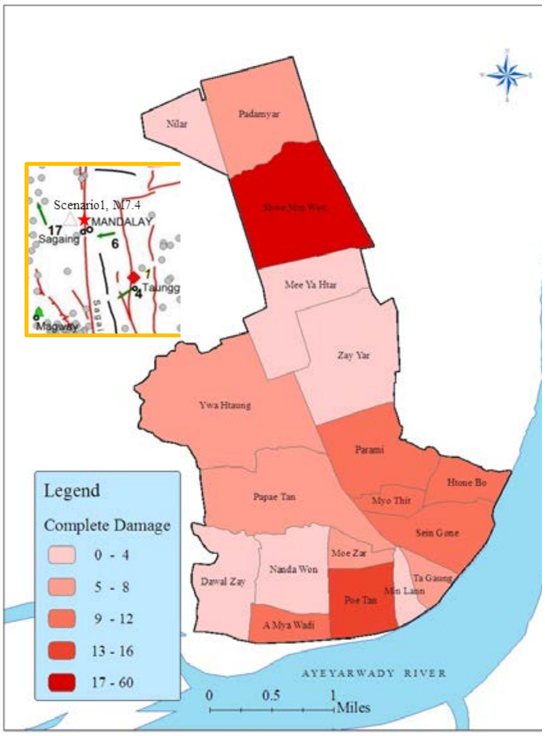

Figure (B-8) Brick Masonry Building Damages in Complete Damage State, M7.4

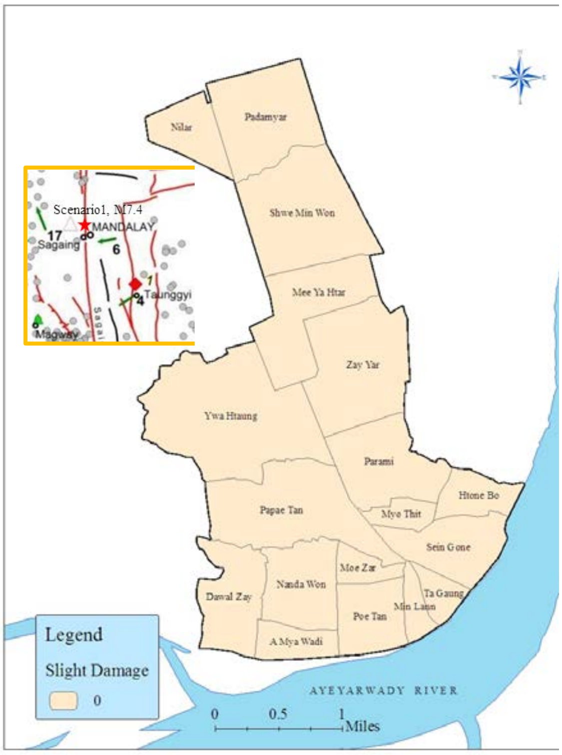

Figure (B-9) Reinforced Concrete Building Damages in Slight Damage State, M7.4

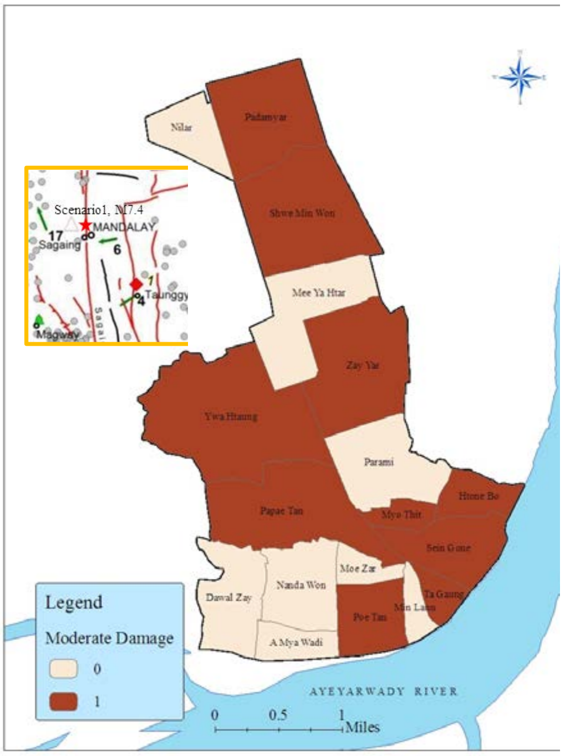

Figure (B-10) Reinforced Concrete Building Damages in Moderate Damage

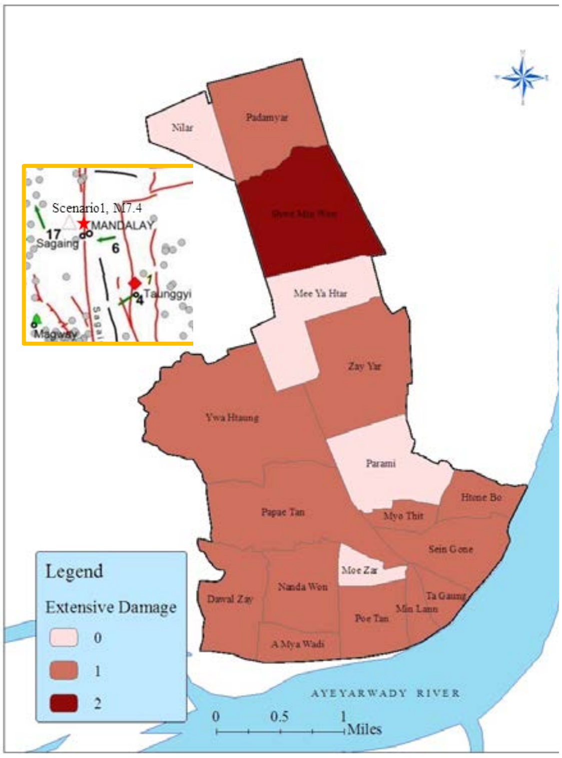

Figure (B-11) Reinforced Concrete Building Damages in Extensive Damage

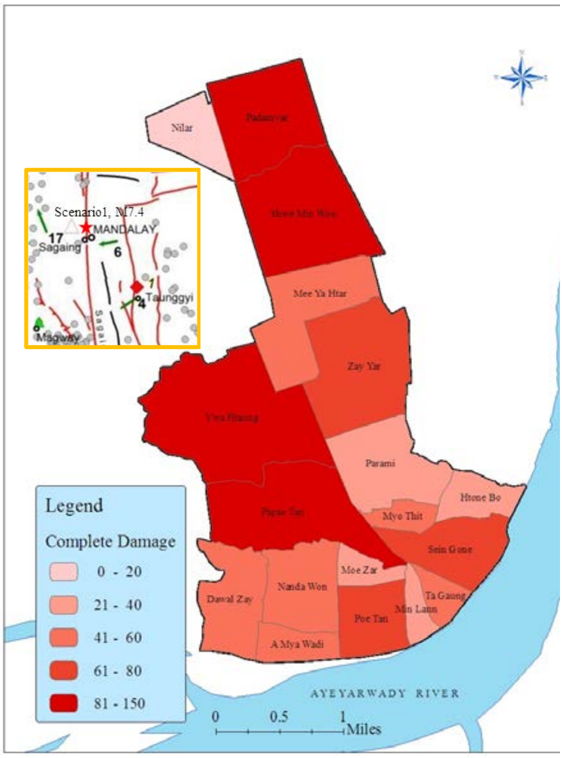

Figure (B-12) Reinforced Concrete Building Damages in Complete Damage

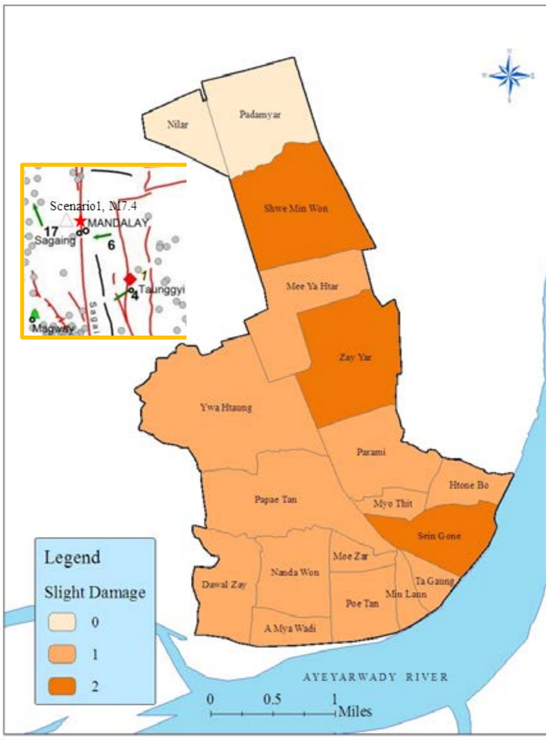

Figure (B-13) Brick Nogging Building Damages in Slight Damage State, M7.4

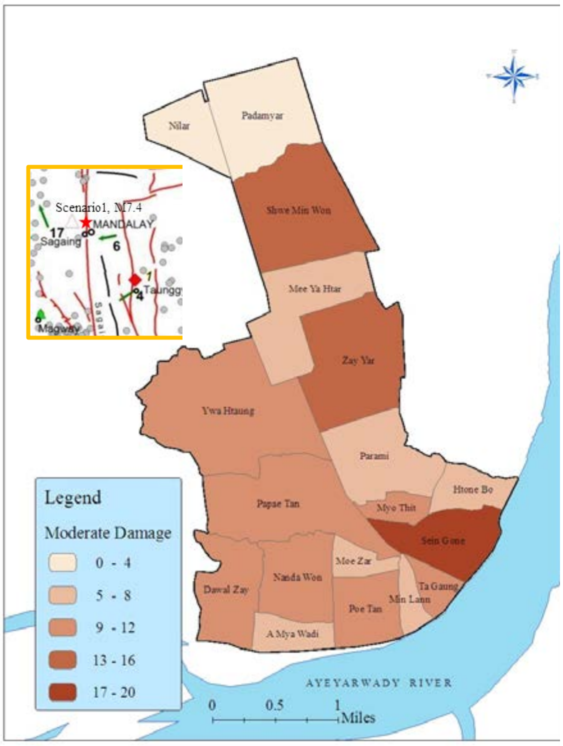

Figure (B-14) Brick Nogging Building Damages in Moderate Damage State, M7.4

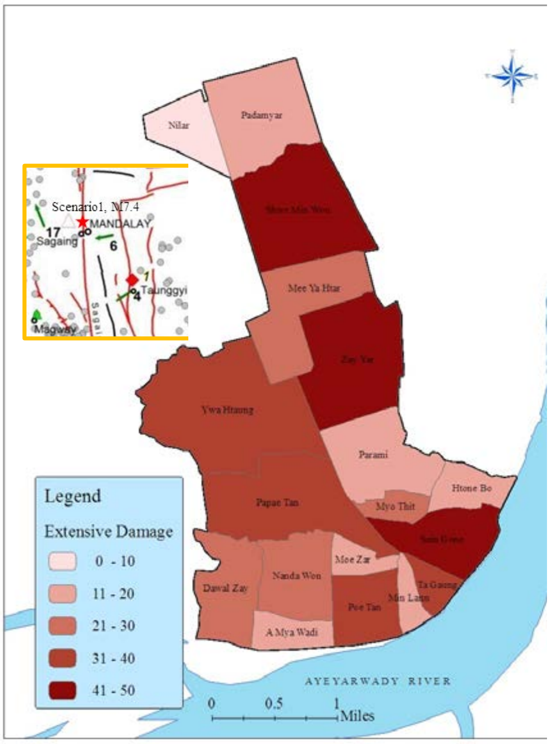

Figure (B-15) Brick Nogging Building Damages in Extensive Damage State, M7.4

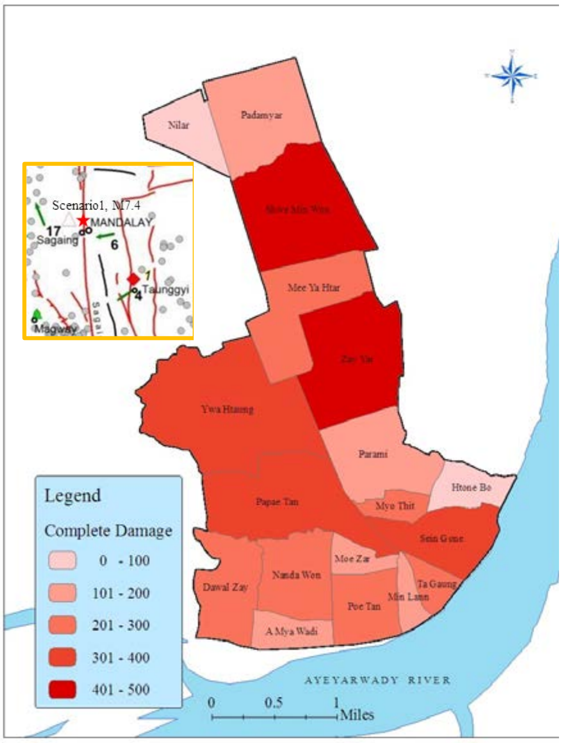

Figure (B-16) Brick Nogging Building Damages in Complete Damage State, M7.4

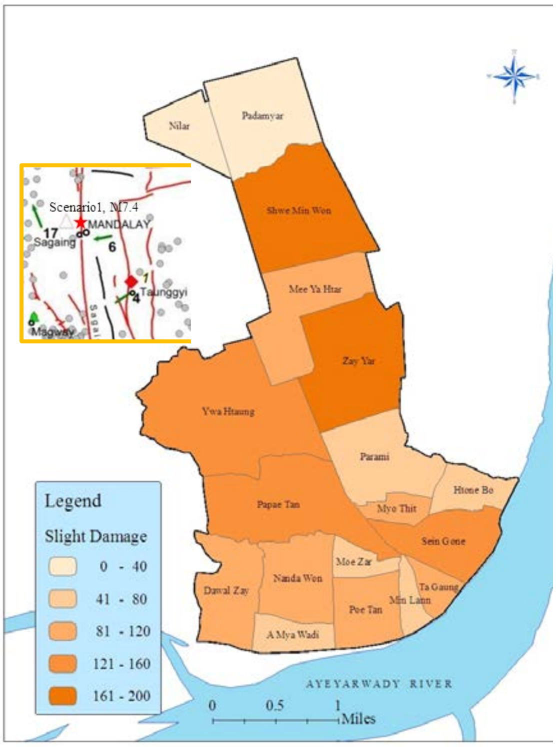

Figure (B-17) Total Building Damages in Slight Damage State, M7.4

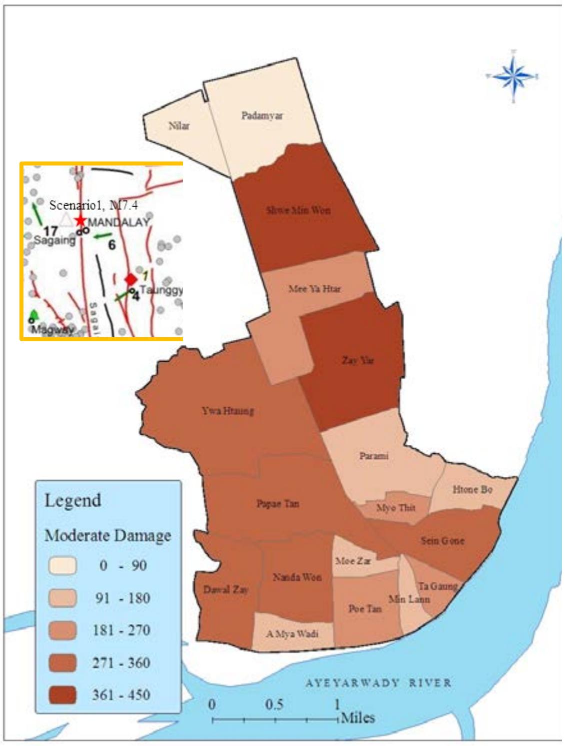

Figure (B-18) Total Building Damages in Moderate Damage State, M7.4

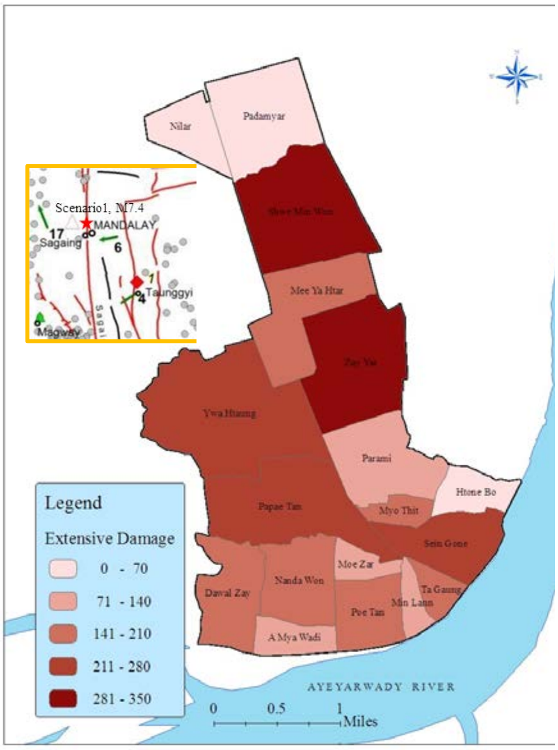

Figure (B-19) Total Building Damages in Extensive Damage State, M7.4

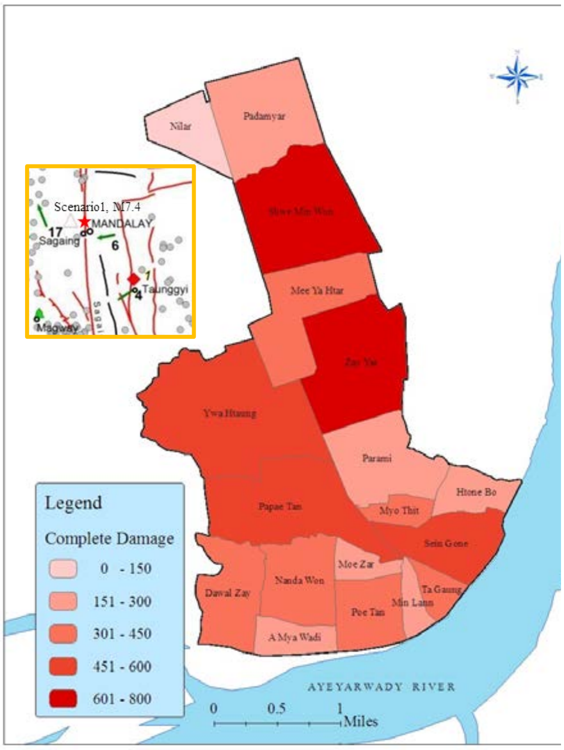

Figure (B-20) Total Building Damages in Complete Damage State, M7.4

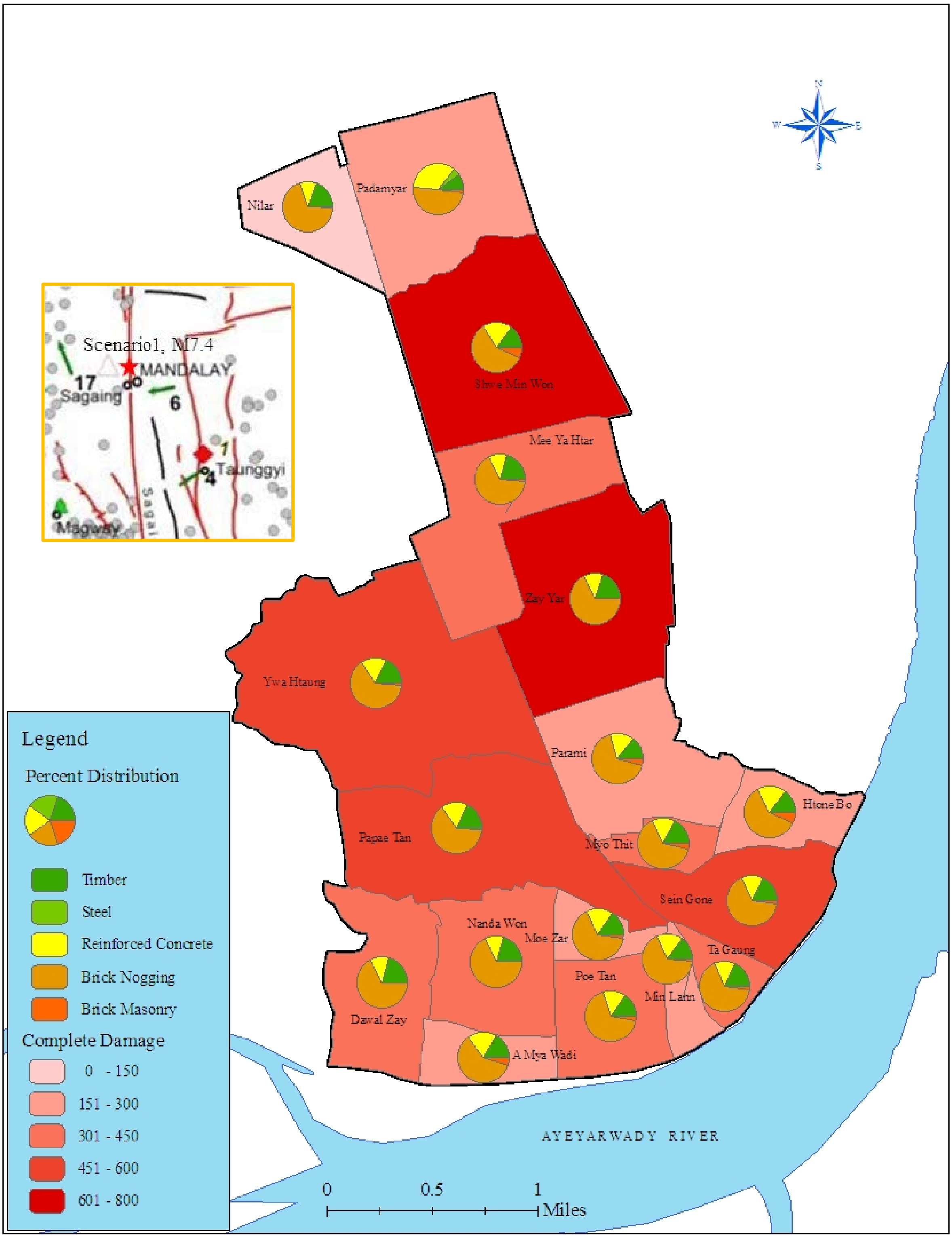

Figure (B-21)Distribution of Complete Damaged Building by Structural Type for Scenario-1, M7.4

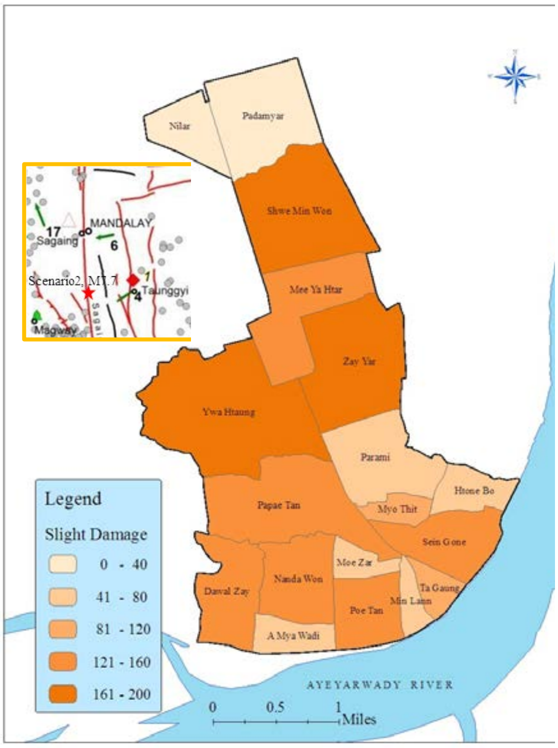

Figure (B-22) TimberBuilding Damages in Slight Damage State, M7.7

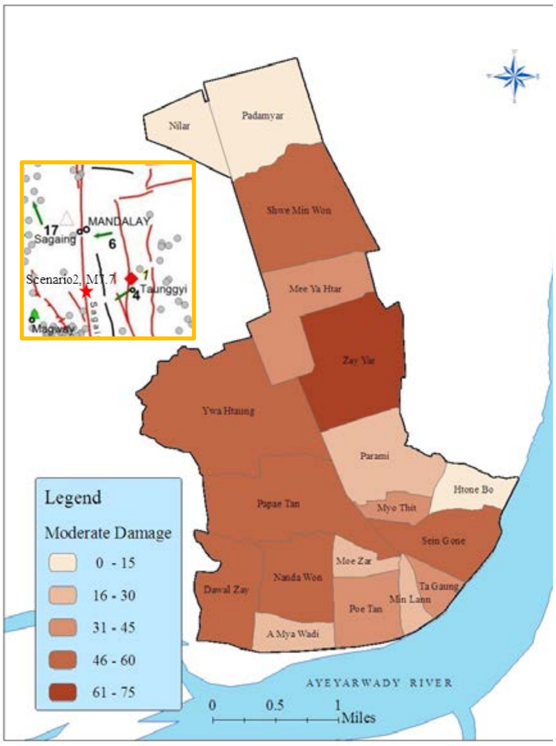

Figure (B-23) Timber Building Damages in Moderate Damage State, M7.7

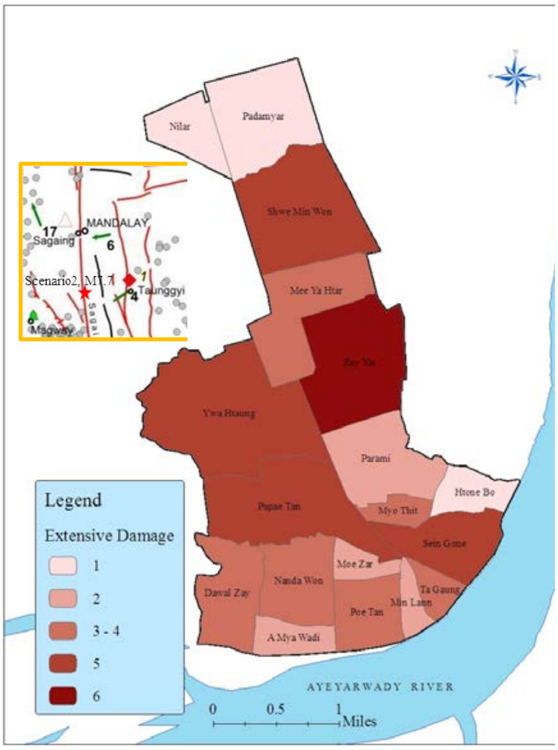

Figure (B-24) TimberBuilding Damages in Extensive Damage State, M7.7

Figure (B-25) Timber Building Damages in Complete Damage State, M7.7

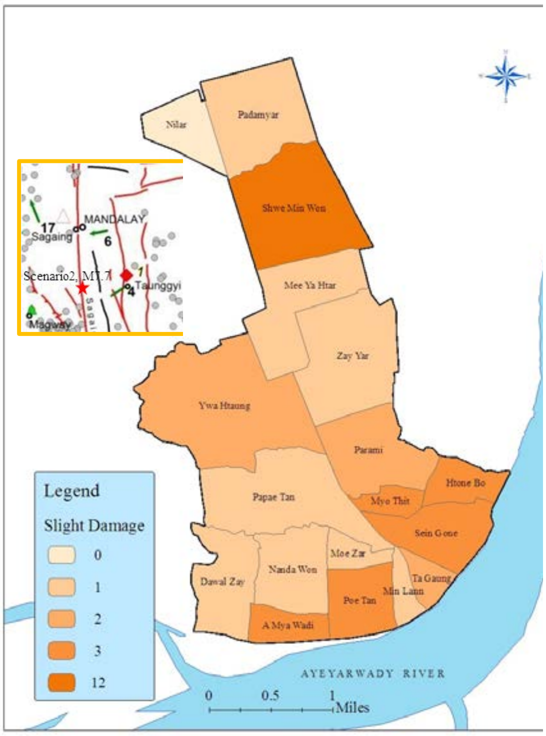

Figure (B-26) Brick Masonry Building Damages in Slight Damage State, M7.7

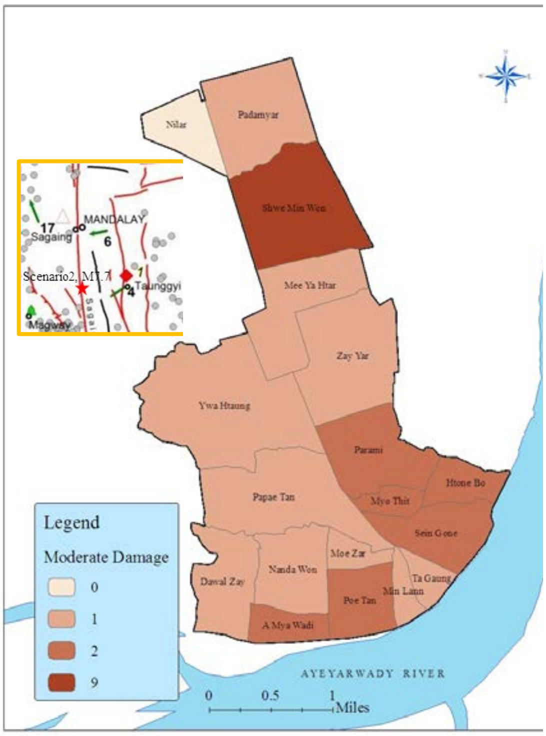

Figure (B-27) Brick Masonry Building Damages in Moderate Damage State, M7.7

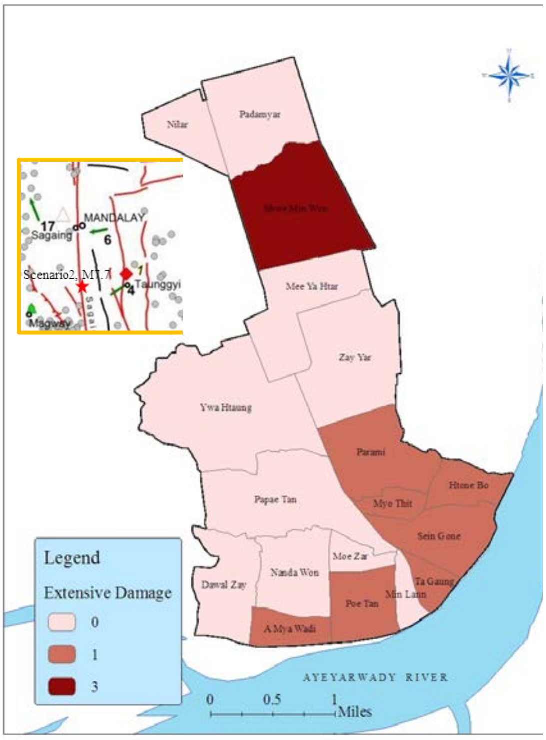

Figure (B-28) Brick Masonry Building Damages in Extensive Damage State,

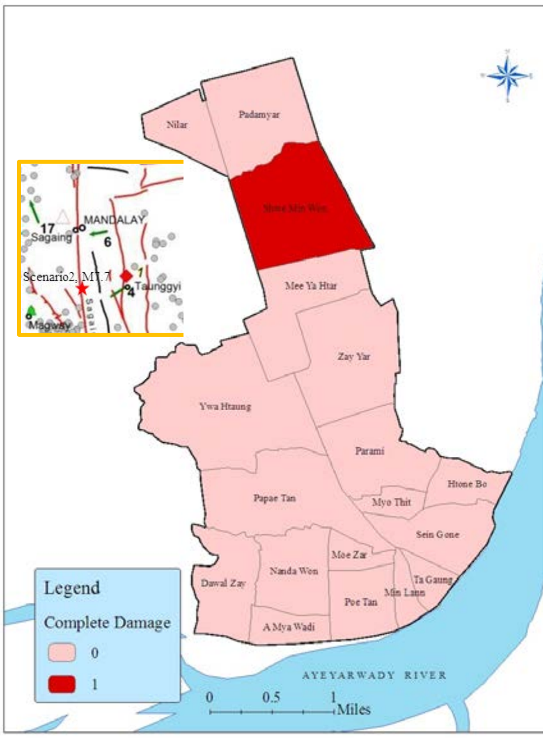

Figure (B-29) Brick Masonry Building Damages in Complete Damage State, M7.7

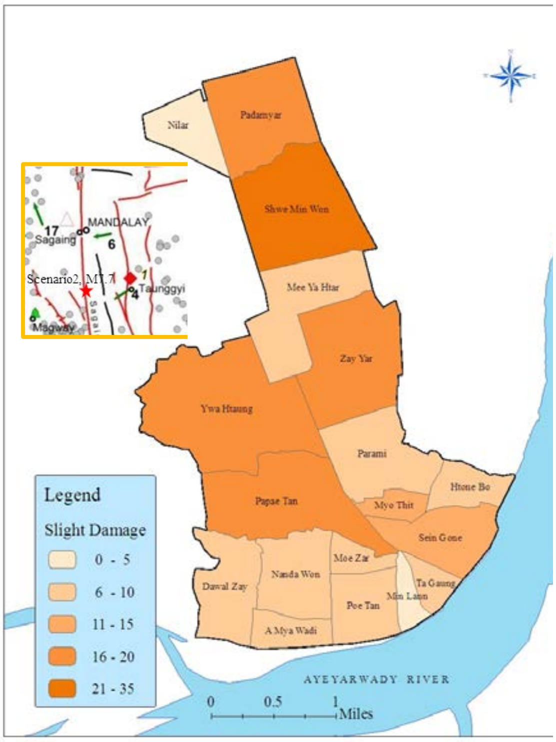

Figure (B-30) Reinforced Concrete Building Damages in Slight Damage State,

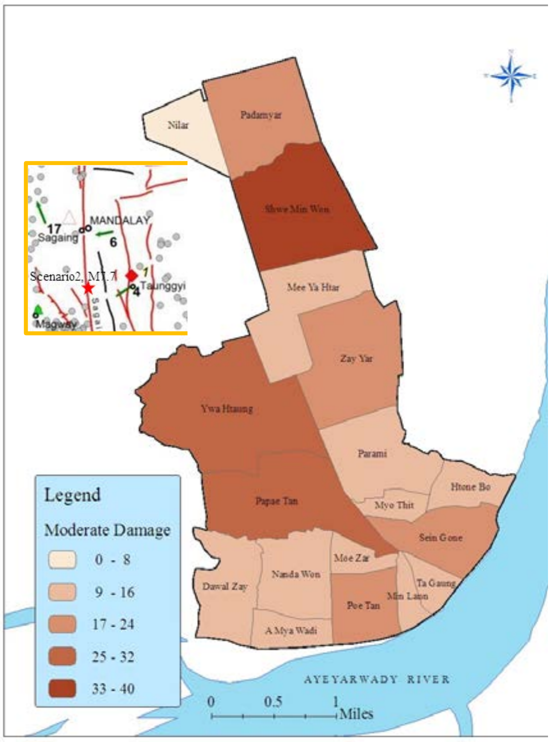

Figure (B-31) Reinforced Concrete Building Damages in Moderate Damage

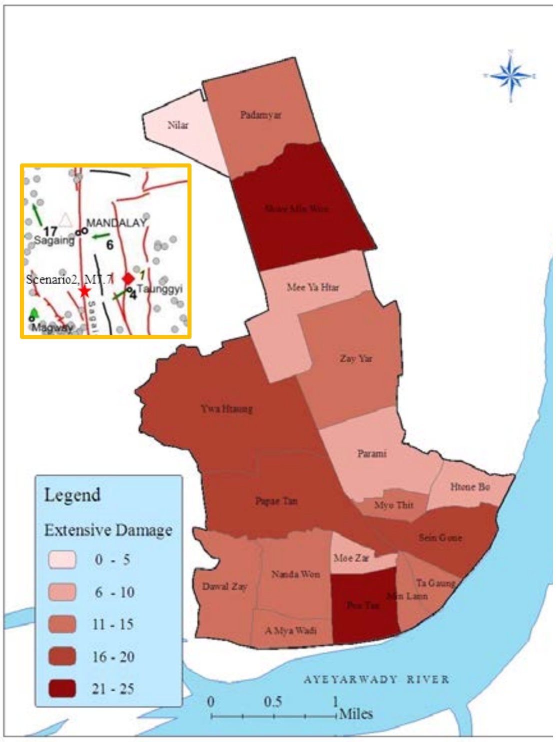

Figure (B-32) Reinforced Concrete Building Damages in Extensive Damage

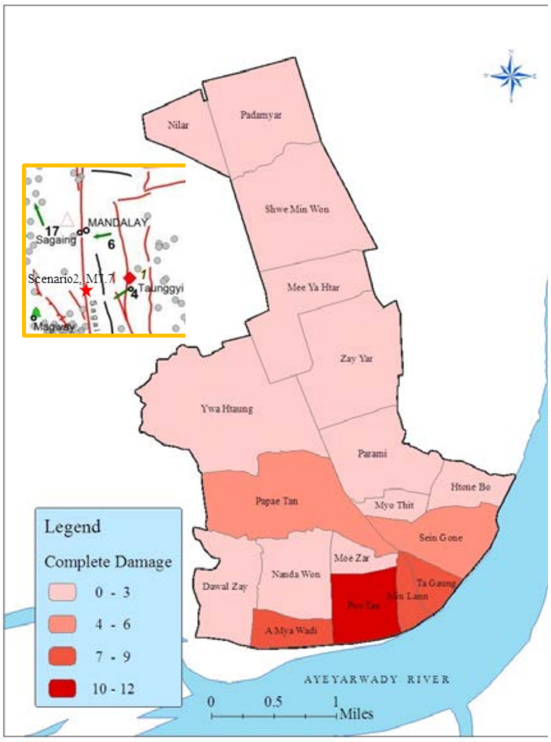

Figure (B-33) Reinforced Concrete Building Damages in Complete Damage

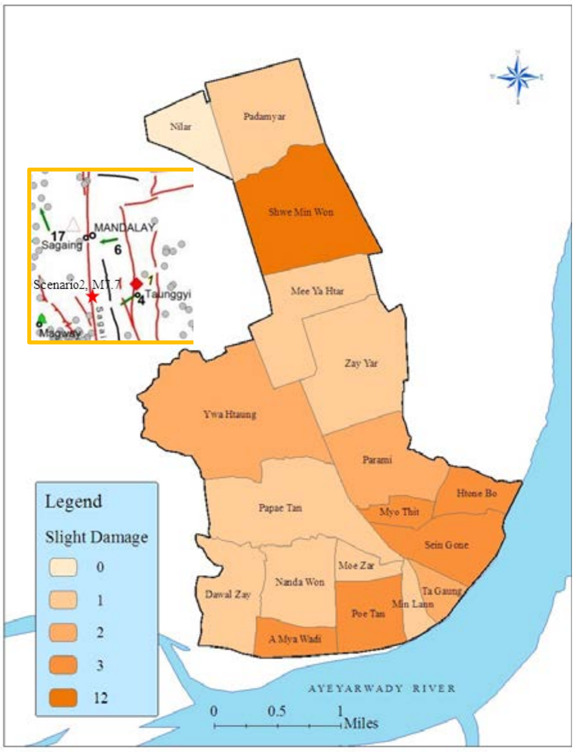

Figure (B-34) Brick Nogging Building Damages in Slight Damage State, M7.7

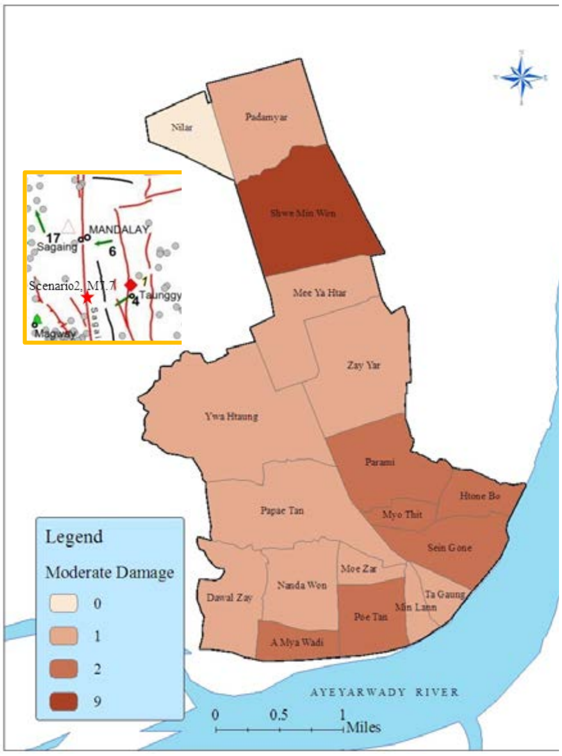

Figure (B-35) Brick Nogging Building Damages in Moderate Damage State, M7.7

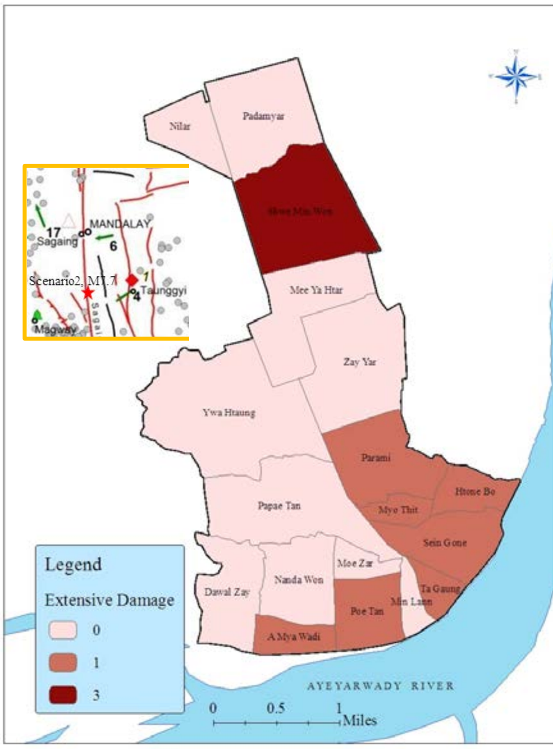

Figure (B-36) Brick Nogging Building Damages in Extensive Damage State, M7.7

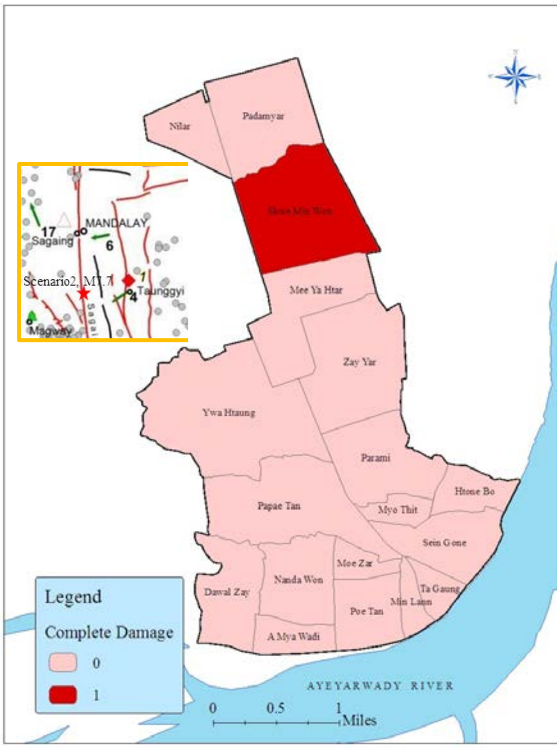

Figure (B-37) Brick Nogging Building Damages in Complete Damage State, M7.7

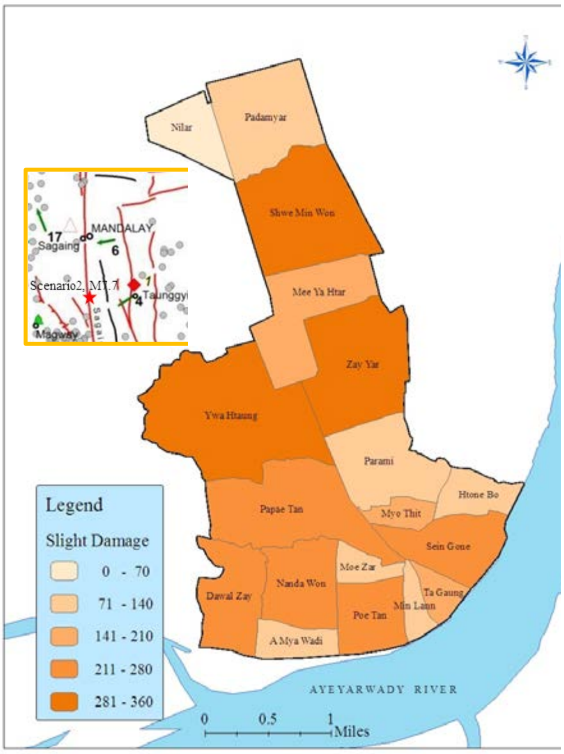

Figure (B-38) Total Building Damages in Slight Damage State, M7.7

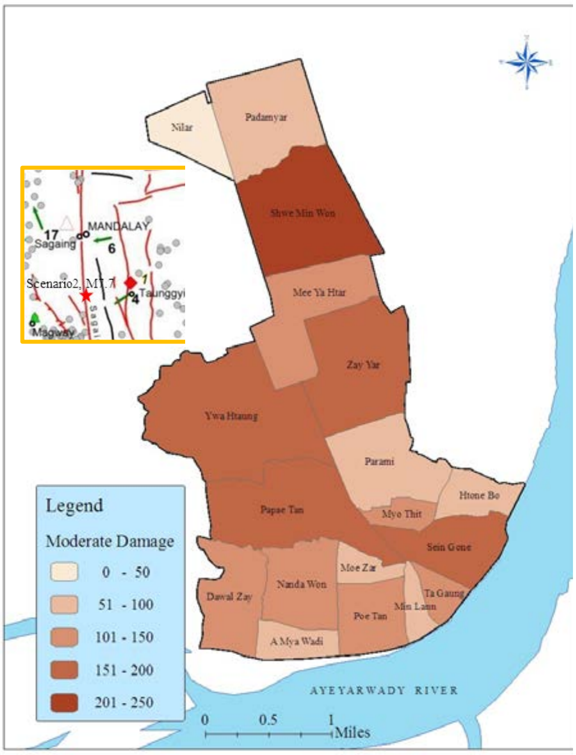

Figure (B-39) Total Building Damages in Moderate Damage State, M7.7

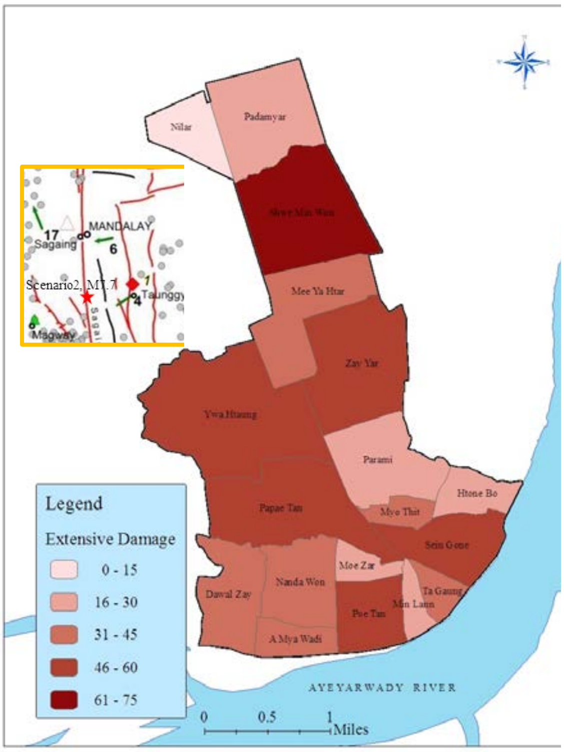

Figure (B-40) Total Building Damages in Extensive Damage State, M7.7

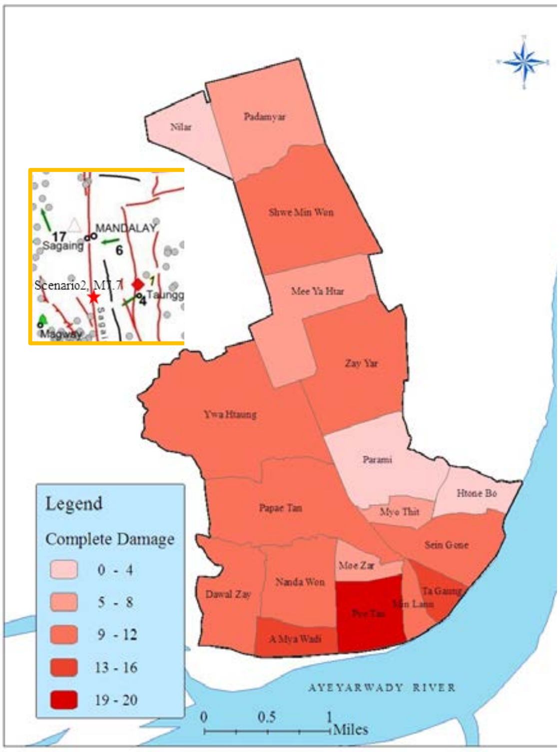

Figure (B-41) Total Building Damages in Complete Damage State, M7.7

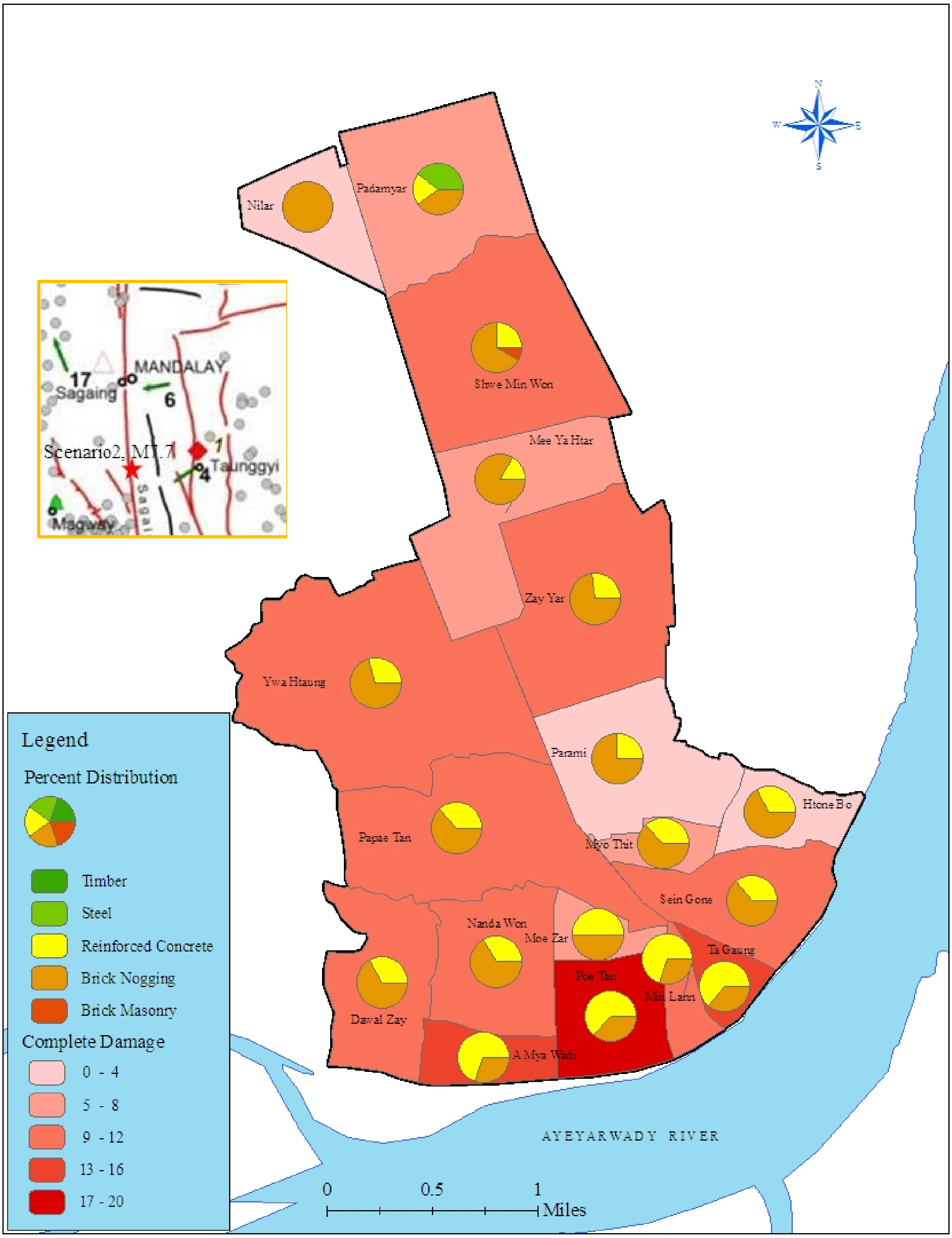

Figure (B-42) Distribution of CompleteDamaged Building by Structural Type

for Scenario-2, M7.7