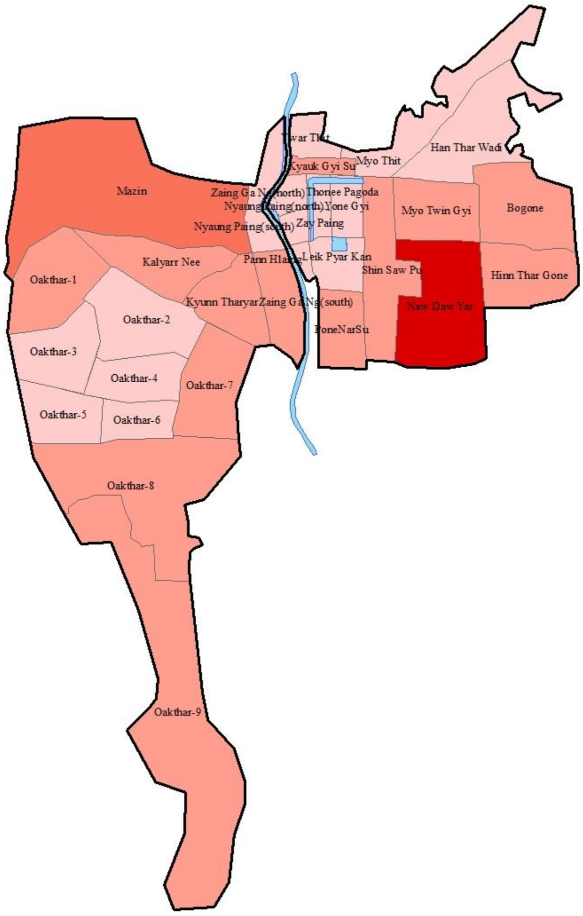
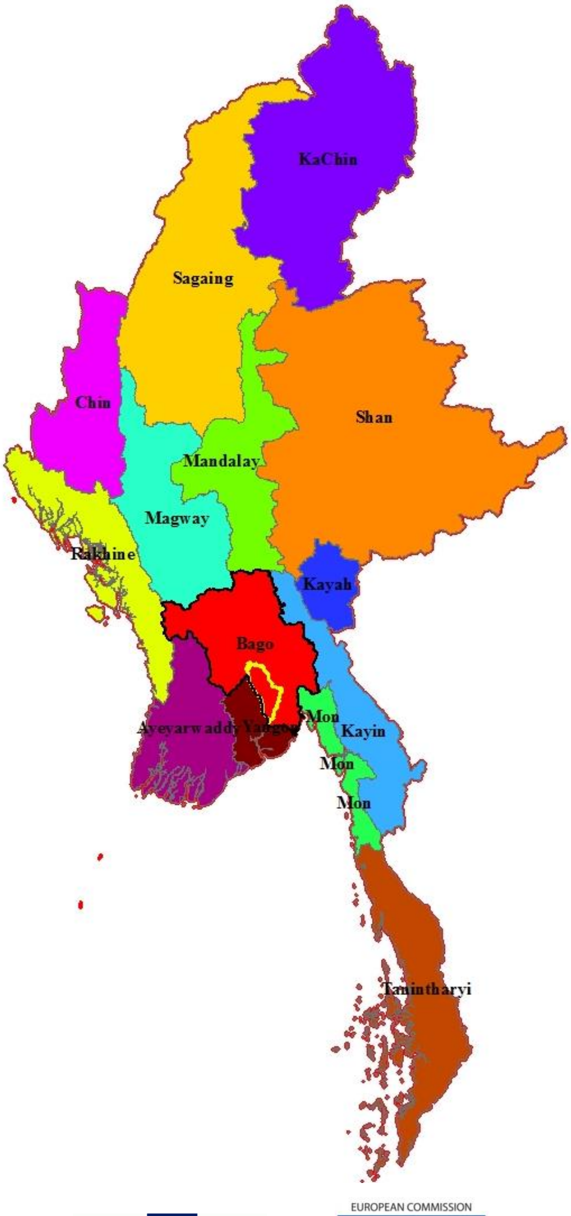
ENHANCING AND DEVELOPING SEISMIC RISK ASSESSMENT FOR BAGO CITY OF MYANMAR





Safer Costal and Urban Communities through Inclusive Disaster Risk Reduction in Myanmar

Project Funded by DIPECHO

December, 2015

Background

Myanmar is prone to earthquakes. It lies on Alphide Belts, one of the two main earthquake belts of the world with a complex seismotectonic processes. The major 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 BagoYoma 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, 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).

Besides, over the past three decades, urbanization in Myanmar has been rapidly increasing. As a result, many of Myanmar's urban cities developed in the proximity of active seismic sources and are at risk of experiencing major earthquake events. Seismic risk cannot be eliminated, but it can be effectively analyzed and possibly reduced by using proper tools and models to produce reliable and meaningful estimates of the seismic risk facing a community, and exposure. Considering the majority of the building stock in both urban and rural areas comprising of non-engineered structures such as made of wood, brick, reinforced concrete, there is an increasing concern on the potential damage to urban areas.In this regard, as a first step it has been proposed to carry out earthquake related risk assessments in three cities of Myanmar: Sagaing, Bago, and Taungoo. All three cities are lying on the Sagaing fault line, however no studies have been carried out assess their earthquake related risk.

In addition, Sagaing, Taungoo and Bago all have a population of more than 100,000 people and have also undergone recent urban developments with the construction of three storey buildings. Furthermore, Sagaing and Bago have a significant socio-economic importance, being the capitals of their respective regions. Therefore, this study tends to develop the seismic risk assessment in Bago City. The study findings will lead to develop comprehensive risk reduction programs addressing the specific vulnerabilities as well as guide 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 Government. The main objective of this paper is to estimate the damages and casualties in Bago City.

Bago City

Bago City is located in Bago Region and it is bounded by Waw (east), Thanatpin (southeast), Kawa (south), Daik-U (north) Townships and Hlegu Township in Yangon Region (west and southwest). The geographic location of the study area is defined by Lat. 17˚14′ to 17˚50′ N and Long. 96˚24′ to 96˚41′E. The area is approximately 1121.66 square miles (2871.449 km^2) and the population is nearly about 300,000 people. The study area is situated on the Major Highway Car Road and Railway of Yangon-Mandalay and Yangon-Mawlamyaing. Since the area is nearly about 50 miles (80 km) from Yangon City, there is easily accessible by car and train. Figure (1) represents the location map of the study area and Famous places in Bago city are as shown in Figure (2).

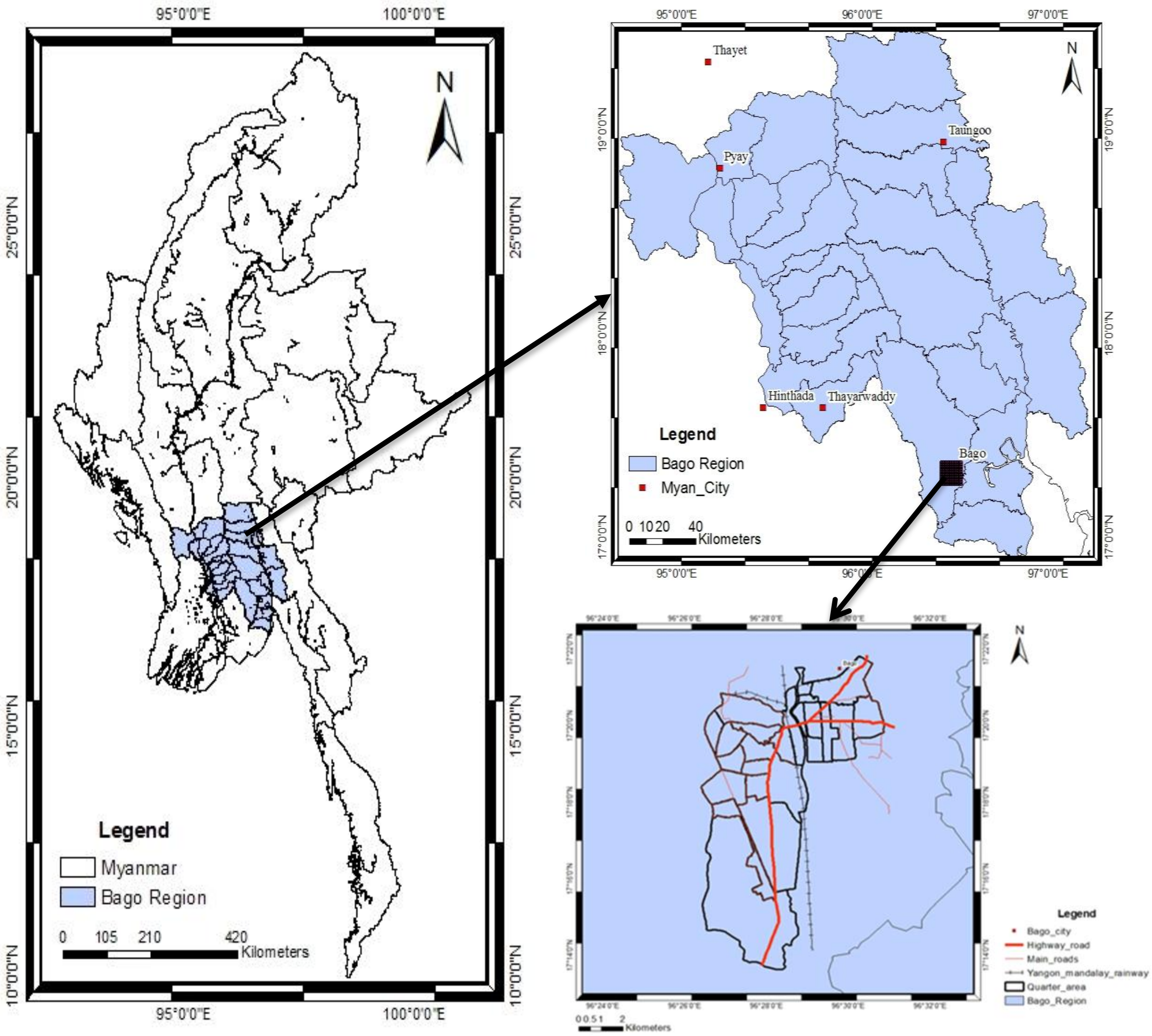


Figure (1) Location Map of the Study Area

Figure (2) Famous Places in Bago City

Active Faults of the Study Area

Bago City is situated in a highly seismically active region which has experienced many disastrous earthquakes during historical time. The well-known Bago earthquake, struck on May 5, 1930 with the magnitude of 7.3, caused 500 casualties and a certain amount of damage in Bago while caused 50 deaths and great damages in Yangon.

Bago region is also bounded by other faults such as Gwegyo Thrust fault and West Bago Yoma fault in the west, Kyaukkyan fault in the east and Papun fault in the south eastern part of the region. Based on the above mentioned, the seismic hazards for Bago City can be expected in the future. Sagaing fault is the north-south trending right-lateral strike-slip fault. The intermittent jerks along this fault caused major earthquakes at (from south to north) Bago (July 5, 1917 - M_w 7) and (May 5, 1930 - M_w 7.3), Phyu (December 3, 1930 - M_w 7.3), Swa (August 8, 1929 - M_w 7), Inwa (March 23, 1839 - M_w > 7?), Amarapura (July 16, 1956 – M_w 7), Bagan (July 8, 1975- M_w 6.8), Sagaing (July 16, 1956 - M_w 7), Tagaung (January 5, 1991 - M_w 7.3), Wuntho (September 13, 1946 - M_w 7.5), Myitkyina (January 27, 1931 - M_w 7.6) and Putao (August 31, 1906 - M_w 7). Sagaing Fault and Other Active Faults around Bago Region and Myanmar are shown in Figure (3).

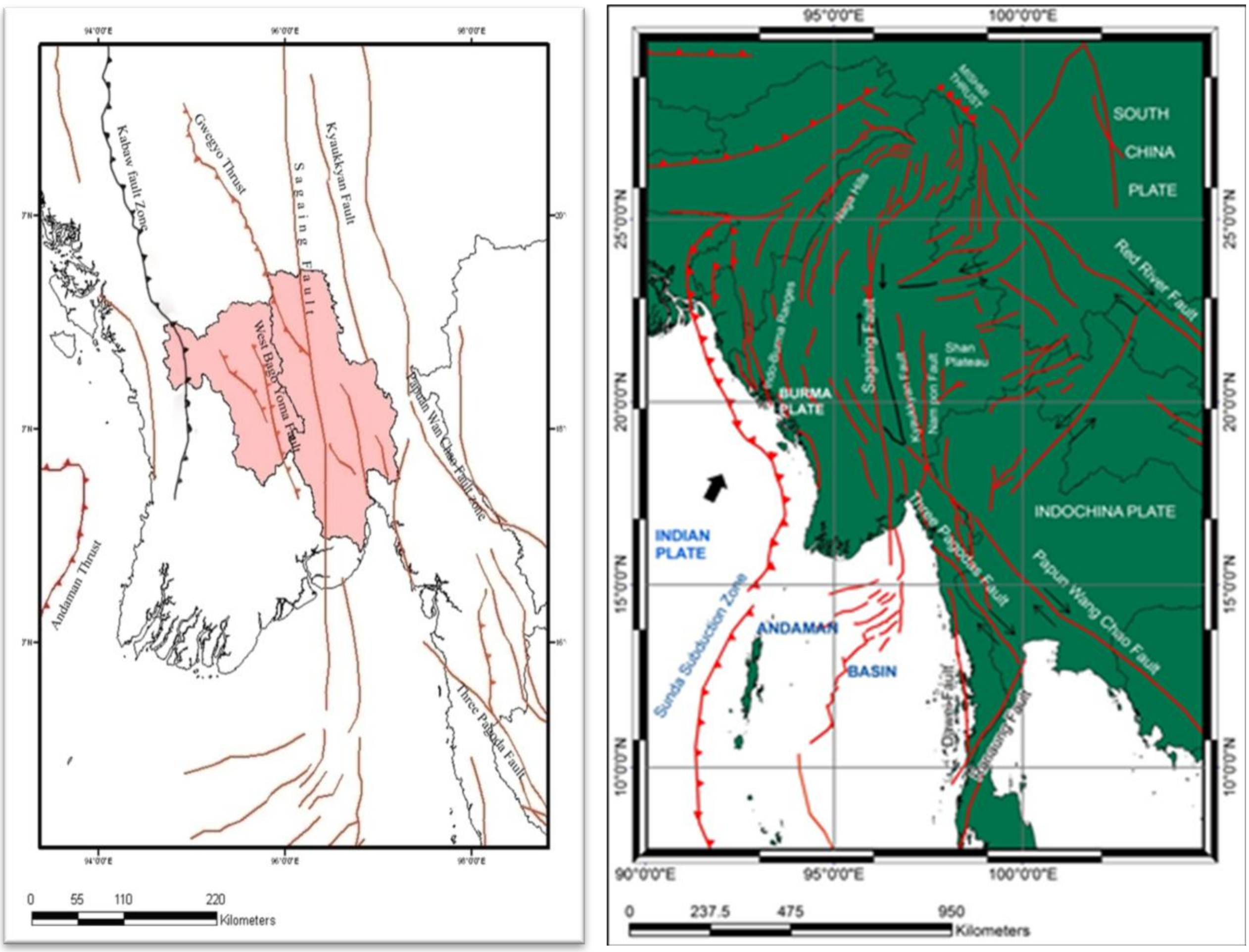


Figure (3) Sagaing Fault and Other Active Faults around Bago Region and Myanmar

Methodology

HAZUS methodology for earthquake loss estimation model is herein used for this project. The earthquake loss estimation methodology can develop the preliminary estimation of damages to prepare before disaster situation and to plan and stimulate efforts how to reduce probable risk from earthquake. Socio-economic profiling and inventory of critical infrastructures of Bago City is undertaken by surveying in the field. Perform 3D and Etabs structural software are used for the analysis of representative building types in Bago City. HAZUS and Arc GIS Softwares are used in the development of probabilistic sesismic hazard map of Bago City.

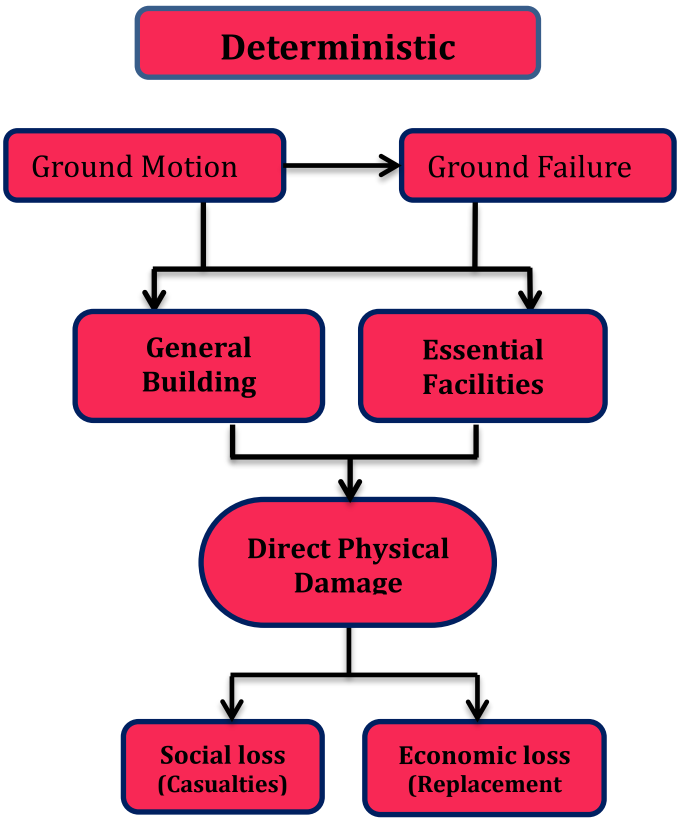


Figure (4) Flow Chart of the Earthquake Loss Estimation Methodology adopted by HAZUS

Building Inventory

This section deals with the general building stock, essential facilities, and high potential loss facilities.

General Building Stock

Inventory data for general building stock are prepared for each occupancy classes as per HAZUS requirement. Building count data by occupancy class for each ward is collected from the field. Square footage is the total floor area (per 1000 ft2) in which estimated floor area multiplied by the number of story and divided by 1000. Replacement value (per $1000) is the estimated local PAE rate ($ per ft2) for specific structure type multiplied by square footage for each occupancy class and divided by 1000, which can be done by using occupancy matrix. Content value (per $1000) is the percentage of replacement cost as per HAZUS. Demographic data is taken from local government office and prepared as per HAZUS attribute format. Occupancy Mapping for this area is developed by the on street survey data.

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

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

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

The general building stock (GBS) includes residential, commercial, industrial, agricultural, religious, government, and educational buildings. The geographical size of the Bago city is 12.56 square miles and contains 31 census tracts (wards). There are over 50 thousand households in the region with a total population of 296,098 people (Ward Level Census data). 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. This can be computed directly from the specific occupancy class square footage inventory. The distribution of Structural and Occupancy Type is provided in Table (2) and (3). There are an estimated 40 thousand buildings in the study area with a total building replacement value (excluding contents) of 803 (millions of dollars). Approximately 90.00 % of the buildings (and 80.00% of the building value) are associated with residential housing. All these data is collected from study area by visiting the ward level officers through General Administrative Department. Estimated PAE rate ($ per sqft) for Replacement cost is collected from City Development Organization and Local construction site. From field survey data, there are five different types based on structural behavior as shown in Table (1).

Table 1 Definition of Structural Type

Timber (W1)	Timber, Light Frame (< 5,000 sq. ft.)
Brick-nogging (RML)	Unreinforced Masonry Bearing Walls with Wood Diaphragms
Brick Masonry (URML)	Unreinforced Masonry Bearing Walls
Reinforced Concrete (RC)	Concrete Frame with Unreinforced Masonry Infill Walls
Mixed-use (MH)	Other Type of Building or Mixed use buildings

Reinforced Concrete Building (RC)

Bricknogging Building (RML)

Mixed-use Building (MH)

Brick Masonry Building (URML)

Timber Building (W1)

Table: 2 Distribution of Structural type in Bago City

Ward	Brick Masonry	Timber	Low-rise RC (C3L)	Mid-rise RC (C3M)	Bricknogging	Mixed-use
Myo Thit	0	318	189	0	482	0
Hinn Thar Gone	0	480	83	0	472	738
Myo Twin Gyi	0	400	106	4	500	262
Yone Gyi	0	59	50	7	311	67
Zay Paing	1	9	105	20	20	25
Thonee Pagoda	2	27	3	0	131	36
Kyauk Kyi Su	0	935	81	0	102	338
Kyunn Tharyar	0	97	300	0	215	1220
PoneNarSu	0	611	242	0	691	380
Mazin	50	1250	500	0	287	1300
Han Thar Wadi	0	176	30	1	212	118
Bogone	0	80	69	0	95	895
Naw Daw Yar	0	1152	466	1	842	2504
Shin Saw Pu	0	809	282	7	204	659
Nyaung Paing(south)	0	18	11	0	117	42
Nyaung Paing(north)	0	50	5	0	71	3
Ywar Thit	0	286	6	0	75	136
Kalyarr Nee	82	444	53	0	1082	494
Pann Hlaing	0	79	87	0	87	5
Leik Pyar Kan	0	103	190	2	310	42
Zaing Ga Ng(north)	0	695	250	0	180	84
Zaing Ga Ng(south)	0	900	9	4	128	367
Oakthar-1	0	1181	0	0	491	591
Oakthar-2	0	34	175	0	700	562
Oakthar-3	0	200	57	0	65	5
Oakthar-4	0	350	78	0	240	0
Oakthar-5	0	606	0	0	76	100
Oakthar-6	0	175	196	0	150	65
Oakthar-7	30	1680	1	0	395	28
Oakthar-8	0	89	100	1	129	2379
Oakthar-9	0	10	16	0	42	1227

Table: 3 Distribution of Occupancy type in Bago City

Ward_Name	Residential	Commercial	Medical	Industry	Religious	Government	Education
Hinn Thar Gone	1722	36	2	1	8	2	2
Myo Twin Gyi	1108	155	6	0	0	1	2
Yone Gyi	448	22	9	1	4	7	3
Zay Paing	57	106	3	0	5	9	0
Kyauk Gyi Su	1388	60	1	3	3	1	0
Nyaung Paing (south)	144	40	1	60	0	1	2
Nyaung Paing (north)	118	5	1	0	1	2	2
PoneNarSu	1885	20	3	0	14	1	1
Mazin	3142	156	2	25	55	2	5
Kyunn Tharyar	1785	33	2	0	11	1	0
Han Thar Wadi	483	29	2	1	13	7	2
Bogone	1110	25	0	3	0	1	0
Naw Daw Yar	3231	1664	25	4	32	3	6
Shin Saw Pu	1845	101	6	1	4	1	3
Thonee Pagoda	188	7	1	0	2	1	0
Myo Thit	901	63	4	5	12	4	0
Ywar Thit	453	31	2	12	3	1	1
Kalyarr Nee	1950	185	0	0	17	1	2
Pann Hlaing	216	29	3	6	1	3	0
Leik Pyar Kan	558	64	5	7	3	7	3
Zaing Ga Ng (north)	1033	161	4	1	5	3	2
Zaing Ga Ng (south)	1265	132	8	0	0	1	2
Oakthar-1	2170	44	1	0	47	0	1
Oakthar-2	1350	96	4	2	13	3	3
Oakthar-3	306	13	1	2	4	1	0
Oakthar-4	640	18	2	0	4	2	2
Oakthar-5	733	23	0	1	24	1	0
Oakthar-6	547	20	1	1	1	16	0
Oakthar-7	2067	52	1	0	11	1	2
Oakthar-8	2612	45	5	1	29	3	3
Oakthar-9	1270	11	1	1	10	0	2

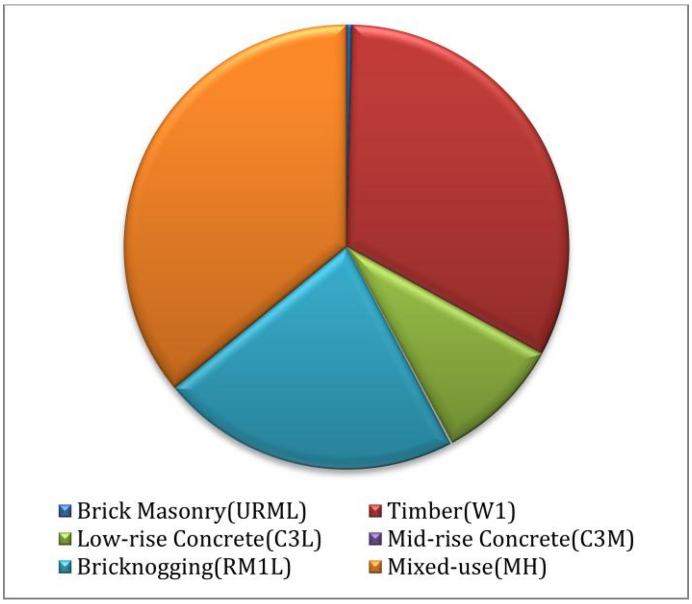


Figure (5) Number of Building in term of structural Type

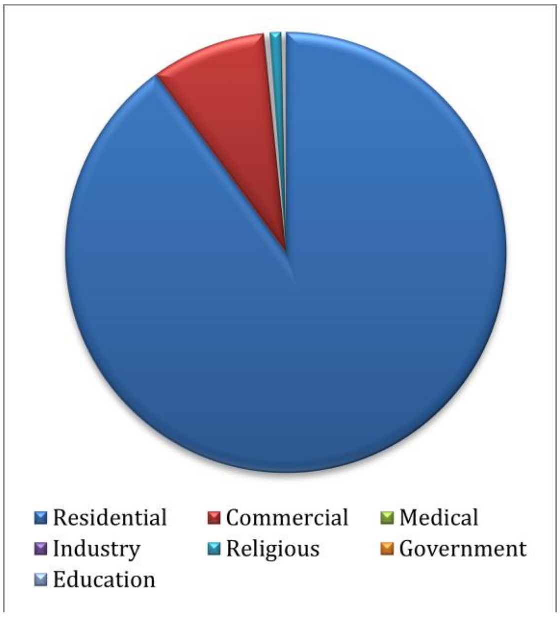


Figure (6) Number of Building in term of Occupancy Type

- **Square footage by occupancy.** These data are the estimated floor area by specific occupancy (e.g., COM1). For viewing by the user, these data are also rolled up to the general occupancies (e.g., Residential).
- **Full Replacement Value by occupancy.** These data provide the user with estimated replacement values by specific occupancy (e.g., RES1). For viewing by the user, these data are also rolled up to the general occupancies (e.g., Commercial).
- **Building Count by occupancy.** These data provide the user with an estimated building count by specific occupancy (e.g., IND1). For viewing by the user, these data are also rolled up to the general occupancies (e.g., Government).
- **General Occupancy Mapping.** These data provide a general mapping for the GBS inventory data from the specific occupancy to general building type (e.g., Wood).
- **Demographics.** This table provides housing and population statistics for the study region.

Essential Facilities

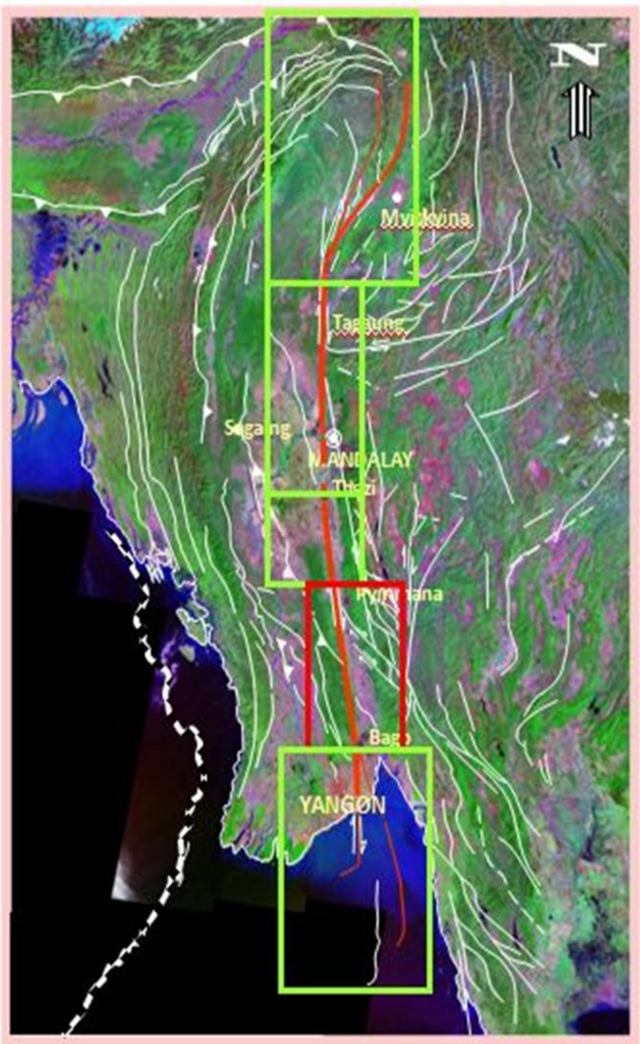
Essential facilities are facilities which provide services to public and should be functional after an earthquake. Essential facilities include hospitals, police stations, fire stations and schools and specific location of each building. The number of beds in hospital and the number of fire trucks at fire station are collected and used. 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.

Replacement Cost

The economic loss estimated for the earthquake is expressed by millions of dollars which includes building and lifeline related losses based on the region's available inventory.

Earthquake Scenario

In this section, two maximum probable earthquake scenarios on Taungoo-Bago Segment had been considered. Scenario one is on Payagyi segment with magnitude M 7, scenario two is on Bago segemnt with magnitude M 7.4.



Segment 1:

Putao - Indawgyi Segment

Segment 2:

Tagaung – Sagaing Segment

Segment 3:

Thazi – Pyinmana Segment

Segment 4:

Taungoo – Bago Segment

Segment 5:

Mottama Gulf Segment

Figure(7) Five Segment on Sagaing Fault

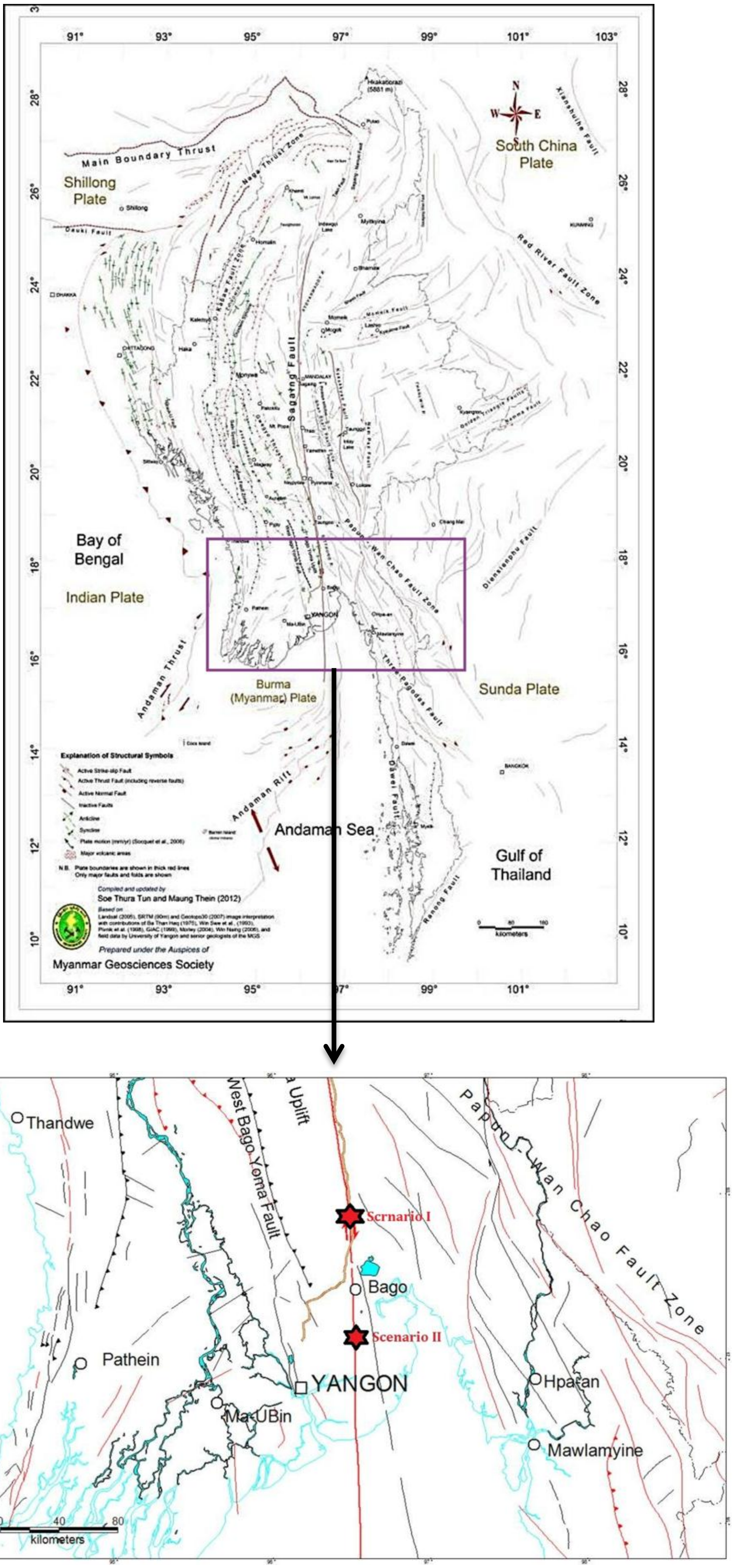


Figure (8) Tectonic Map of Myanmar and Two scenarios on Sagaing Fault

Scenario 1 (Payagyi Segment)

Scenario Name	Scenario I
Type of Earthquake	Strike Slip Fault
Epicentral Distance	22 km
Earthquake Magnitude	7.0
Depth(km)	10
Rupture Width	13.4
Rupture Orientation (Degrees)	0
Dip (Deg)	90
Attenuation Function	Boore. Joyner and Fumal (1997)

Scenarios 2 (Bago Segment)

Scenario Name	Scenarion II
Type of Earthquake	Strike Slip Fault
Epicentral Distance	53 km
Earthquake Magnitude	7.4
Depth(km)	10
Rupture Width	17.7
Rupture Orientation (Degrees)	0
Dip (Deg)	90
Attenuation Function	Boore. Joyner and Fumal (1997)

In this analysis, Attenuation equation we used is Boore.Joyner and Fumal(1997). This equation was confirmed by Department of Meteorology and Hydrology (Nay Pyi Daw) that based on geological condition of Myanmar.

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. All Damage States for different type of structure are as shown in table A-1.

Essential Facilities Damages

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.

Table 4 Essential Facilities Damages in Two Earthquake Scenario

	Classification	Total	At Least Moderate damage >50%	Complete damage >50%	With Functionality > 50% on day1
Scenario 1	Hospitals	10	4	0	0
	Schools	86	12	0	1
	Police Stations	3	0	0	0
	Fire Stations	3	0	0	0
Scenario 2	Hospitals	10	10	0	0
	Schools	86	86	83	0
	Police Stations	3	3	0	0
	Fire Stations	3	3	0	0

Direct Earthquake Damage for Maximum Probable Earthquake

Direct earthquake damage deals with buildings and facilities; the general building stock, essential facilities, and high potential loss facilities. Earthquake damage to buildings is influenced by the types of buildings. For an effective estimation of damage to buildings, a building classification is necessary. Capacity curves that are used to determined building response and Fragility curves that describe damage state for each structural building type have been assumed HAZUS format. HAZUS estimates that buildings will be at least moderately damaged. This is over of the total number of buildings in the region. There are estimated buildings that will be damaged beyond repair.

Table 5 Building Damage by Building Type (Maximum Estimated Magnitude M7)

	None	Slight	Moderate	Extensive	Complete	Total
Timber	6,679	4152	2,229	354	38	13452
Brick-nogging	2,391	2373	2,526	1,049	296	/'8635
Brick Masonry	44	38	45	26	13	166
Reinforced Concrete	570	614	1,069	923	277	3453
Mixed-use	3,390	3312	4,337	2,709	1,377	15125
Total	13,074	10,488	10,207	5,060	1,999	**40828**

Table 6 Building Damage by Building Type (Maximum Estimated Magnitude M7.4)

	None	Slight	Moderate	Extensive	Complete	Total
Timber	402	1780	4,733	3,918	2,619	13452
Brick-nogging	18	129	757	1,693	6,038	8635
Brick Masonry	1	3	12	26	124	166
Reinforced Concrete	8	22	153	269	3,001	3453
Mixed-use	52	241	1,091	2,426	11,315	15125
Total	480	2,174	6,745	8,332	23,097	**40828**

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/Wood and (b) Reinforced Concrete/Steel because of the different types of material handling equipment required to handle the debris.

For Scenario-1, a total of 0.278 million tons of debris will be generated. Of the total amount, Brick/Timber comprises 37.00% of the total, with the remainder being Reinforced Concrete/Steel of 63%. If the debris tonnage is converted to an estimated number of truckloads, it will require 11,130 truckloads (at 25 tons/truck) to remove the debris generated by the earthquake M7 in Payagyi segment.

For Scenario-2, a total of 1.35 million tons of debris will be generated. Of the total amount, Brick/Timber comprises 41.00% of the total, with the remainder being Reinforced Concrete/Steel comprises 59%. If the debris tonnage is converted to an estimated number of truckloads, it will require 54,156 truckloads (at 25 tons/truck) to remove the debris generated by the earthquake M7.4 in Bago segment.

Table 7 Debris and Total Truckloads for Two Earthquake Scenarios

Scenario Name	Brick/Timber and Others		RC/Steel		Total Debris (Million Tons)	Number of Truckload
	Debris (Million Tons)	Truckload	Debris (Million Tons)	Truckload		
Scenario I, M7.0	0.102 (37%)	4,119	0.176 (63%)	7,011	0.278	11,130
Scenario II, M7.4	0.557 (41%)	22,204	0.796 (59%)	31,952	1.353	54,156

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. 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.

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 sector loads are maximum and 5:00 PM represents peak commute time.

Table 8 Summary of the casualties estimated for Scenario I

Time	Level 1	Level 2	Level 3	Level 4
2 AM	974	224	25	48
2 PM	723	167	19	36
5 PM	543	125	14	27

Table 9 Summary of the casualties estimated for Scenario II

Time	Level 1	Level 2	Level 3	Level 4
2 AM	8612	2643	383	740
2 PM	6352	1948	288	544
5 PM	4790	1459	215	402

Building Related Economic Losses

The economic loss estimated for the earthquake is expressed by millions of dollars which includes 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.

Table 10 Building-Related Economic Losses in Millions of Kyats (Maximum Estimated Magnitude M7)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	1,160	35,980	100	6,200	43,440
	Capital- Related	0	500	15,960	60	2,450	18,970
	Rental	36,930	60,011,550	65,060	50	3,960	60,117,550
	Relocation	132,630	43,560,160	99,570	230	38,700	43,831,290
	Subtotal	169,560	103,573,370	216,570	440	51,300	104,011,240
Capital Stock Losses	Structural	15,650	3,230	4,240	140	1,560	24,820
	Non-Structural	33,170	12,450	6,380	370	3,900	56,270
	Content	7,510	2,590	3,320	250	1,790	15,460
	Inventory	0	0	12,170	170	0	12,340
	Subtotal	56,330	18,260	26,120	940	7,260	108,910
	Total	225,900	103,591,640	242,690	1,380	58,560	104,120,170

Table 11 Building-Related Economic Losses in Millions of Kyats (Maximum Estimated Magnitude M7.4)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	5700	173,080	330	24,490	203,600
	Capital-Related	0	2460	72,820	200	9,710	85,190
	Rental	166,370	299,000,000	234,090	170	18,230	299,418,860
	Relocation	550,220	189,000,000	335,130	670	170,830	190,056,850
	Subtotal	716,590	488,000,000	815,120	1,370	223,270	489,756,350
Capital Stock Losses	Structural	75,920	15,830	20,610	570	7,430	120,360
	Non-Structural	229,410	87,860	45,510	2,550	26,160	391,490
	Content	50,990	18,050	23,580	1,740	11,820	106,180
	Inventory	0	0	86,040	1,250	0	87,290
	Subtotal	356,320	121,730	175,730	6,110	45,420	705,310
	Total	1,072,910	488,000,000	990,850	7,490	268,690	490,339,940

Thematic Map of Bago City

According to the Population map, the population of Bago City is found the highest in NanDawYar Ward and the number of population is 10 % of the City population. See figure (A-1). In Population Density map, the population density of Bago City is the highest in Kyauk Kyi Su and Pann Hlaing Wards. Although The area of these two wards is not big enough, population is very crowded and Pann Hlaing ward is in downtown. See figure (A-2)

According to the Age map, Age under 18 in NandawYar and Zaing Ga Naing ward are higher than any other wards in Bago. NanDawYar wards have the most highest population in both under 18 and over 18 because of its total population. Mazin and NewOakthar 8 also have higher population in over 18. See figure (A-3 and A-4). NanDawYar and Mazin wards have the most highest household and building. See figure (A-6 and A-7)

Total Building Damages

The damage maps show two earthquake scenarios in term of building damage with respect to building types and damaged state. Two earthquakes destroyed the city but the effect of earthquake on Bago Segment is the most significant.

In Scenario I, HAZUS estimates that about 17,265 buildings will be at least moderately damaged. This is over 42.00 % of the total number of buildings in the region. There are an estimated 1,998 buildings that will be damaged beyond repair.

In Scenario II, HAZUS estimates that about 38,174 buildings will be at least moderately damaged. This is over 93.00 % of the total number of buildings in the region. There are an estimated 23,097 buildings that will be damaged beyond repair.

Conclusion

The results of this paper are very useful to decision makers and government officials who are responsible for disaster prevention and disaster preparedness in Bago city. Priorities for urban planning, land-use planning, and building regulations can be decided by the use of above results. 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, fire-fighting, and emergency transportation can be carried out. The results are also useful to communities. 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 progress 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.

HAZUS tool gives the exact number of casualties (death and injury) during scenario earthquakes which highlight how many people will require medical attention. 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.

APPENDIX- A

Table (A-1) Four Damaged state in term of structural Type

	Timber (W)	Bricknogging (RML)	Reinforced Concrete (C3)	Brick Masonry (URM)	Mixed-use (MH)
Slight	Small timber-board cracks at corners of door and window openings and wall-ceiling intersections	Diagonal hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; minor separation of walls from the floor and roof diaphragms.	Diagonal (sometimes horizontal) hairline cracks on most infill walls; cracks at frame-infill interfaces.	Diagonal, stair-step hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; movements of lintels; cracks at the base of parapets.	Small timber-board cracks at corners of door and window openings and wall-ceiling intersections. Diagonal hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; minor separation of walls from the floor and roof diaphragms.
Moderate	Large timber-board cracks at corners of door and window openings.	Most wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities indicated by larger diagonal cracks. Some walls may have visibly pulled away from the roof.	Most infill wall surfaces exhibit larger diagonal or horizontal cracks; some walls exhibit crushing of brick around beam-column connections. Diagonal shear cracks may be observed in concrete beams or columns.	Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; masonry walls may have visible separation from diaphragms; significant cracking of parapets; some masonry may fall from walls or parapets. some masonry may fall from walls or parapets.	Large timber-board cracks at corners of door and window openings. Most wall surfaces exhibit diagonal cracks.
Extensive	Large cracks at plywood joints; splitting of wood sill plates and/or slippage of structure over foundations; small foundations cracks.	In buildings with relatively large area of wall openings most walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks and visibly buckled wall. The wood diaphragms may exhibit cracking and separation along wood joints. Partial collapse of the roof may result from failure of the wall-to-diaphragm anchorages or the connections of beams to walls.	Most infill walls exhibit large cracks; some bricks may dislodge and fall; some infill walls may bulge out-of-plane; few walls may fall partially or fully; few concrete columns or beams may fail in shear resulting in partial collapse. Structure may exhibit permanent lateral deformation.	Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; masonry walls may have visible separation from diaphragms; significant cracking of parapets; some masonry may fall from walls or parapets.	Large cracks at plywood joints; splitting of wood sill plates and/or slippage of structure over foundations; small foundations cracks. The wood diaphragms may exhibit cracking and separation along wood joints. Partial collapse of the roof may result from failure of the wall-to-diaphragm anchorages or the connections of beams to walls.
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks. Approximately 3% of the total area of W1 buildings with complete damage is expected to be collapsed.	Structure has collapsed or is in imminent danger of collapse due to failure of the wall anchorages or due to failure of the wall panels. Approximately 13% (low-rise) or 10% (mid-rise) of the total area of RM1 buildings with complete damage is expected to be collapsed.	Structure has collapsed or is in imminent danger of collapse due to a combination of total failure of the infill walls and non-ductile failure of the concrete beams and columns. Approximately 15% (low-rise), 13% (mid-rise) or 5% (high-rise) of the total area of C3 buildings with complete damage is expected to be collapsed.	Structure has collapsed or is in imminent danger of collapse due to in-plane or out-of-plane failure of the walls. Approximately 15% of the total area of URM buildings with complete damage is expected to be collapsed.	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks. Approximately 3% of the total area of buildings with complete damage is expected to be collapsed.

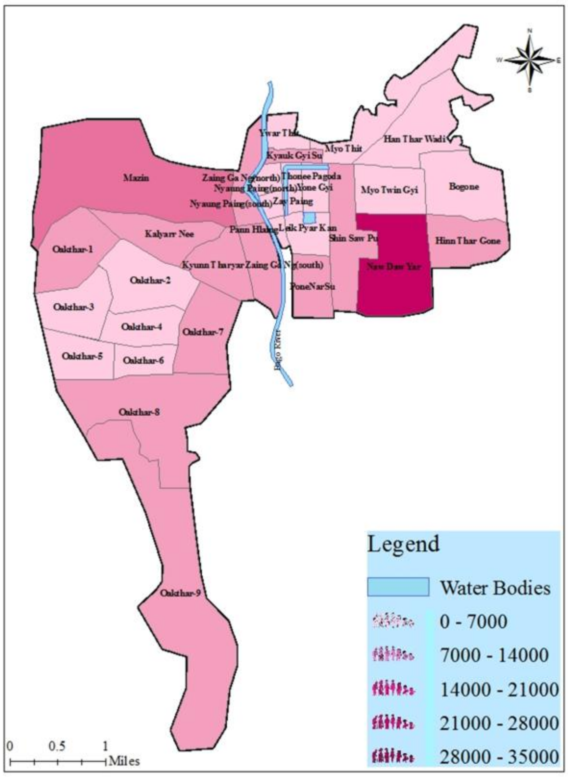


Figure (A-1) Population in Bago

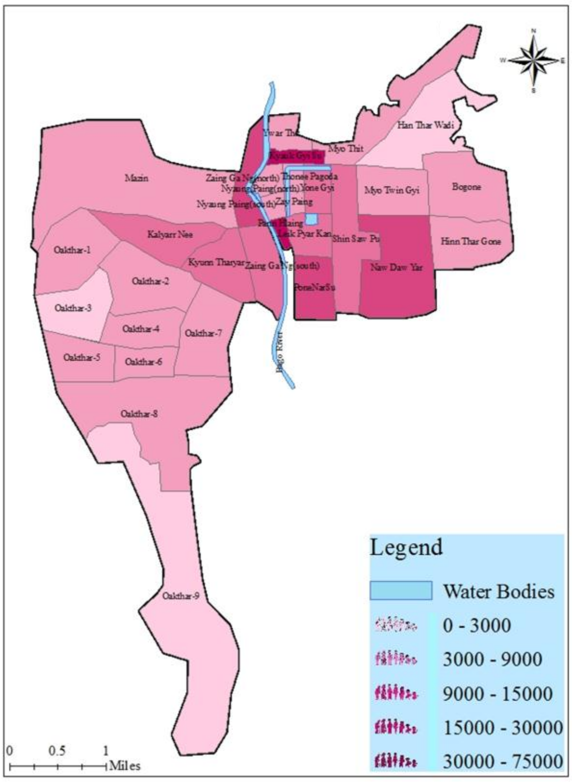


Figure (A-2) Population Density in Bago

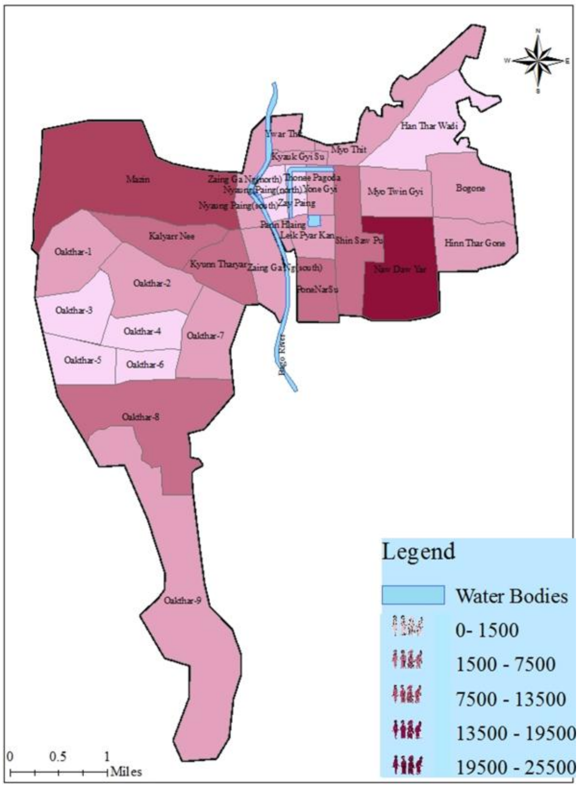


Figure (A-3) Age Over 18 in Bago

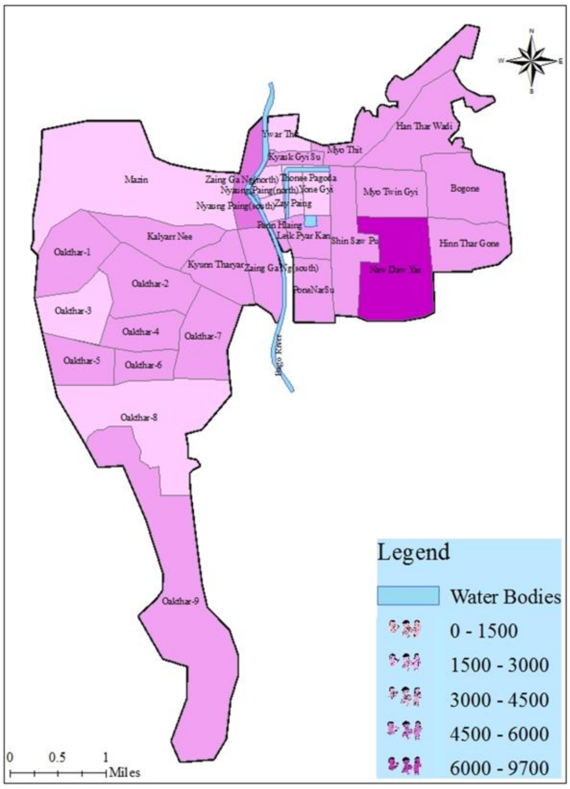


Figure (A-4) Age Under 18 in Bago

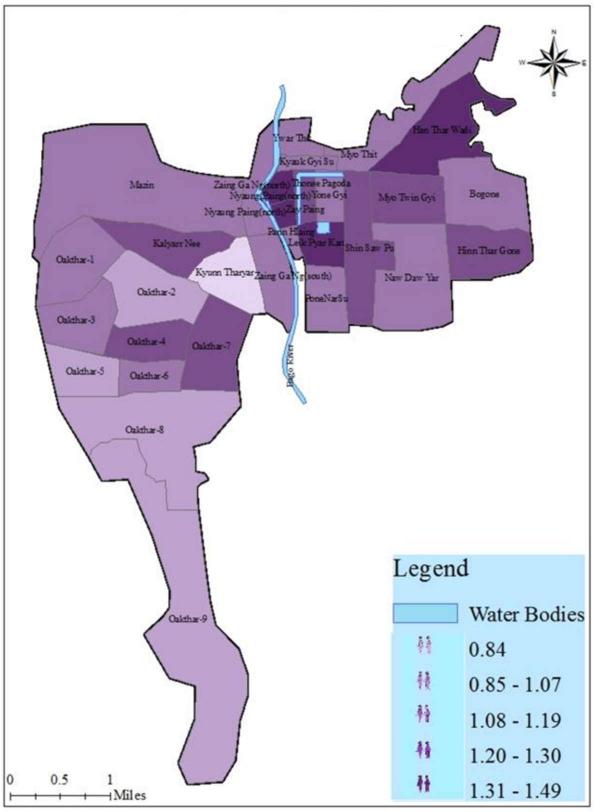


Figure (A-5) Female to Male Ration in Bago

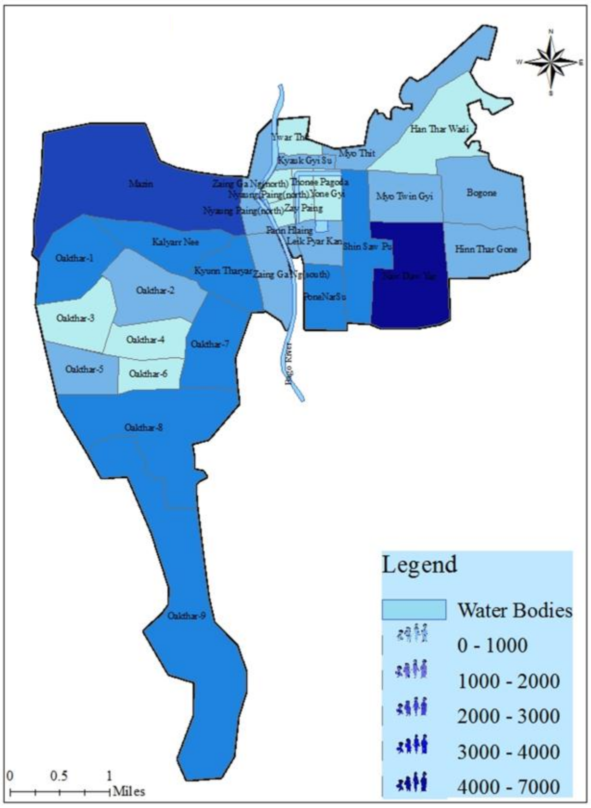


Figure (A-6) Household in Bago

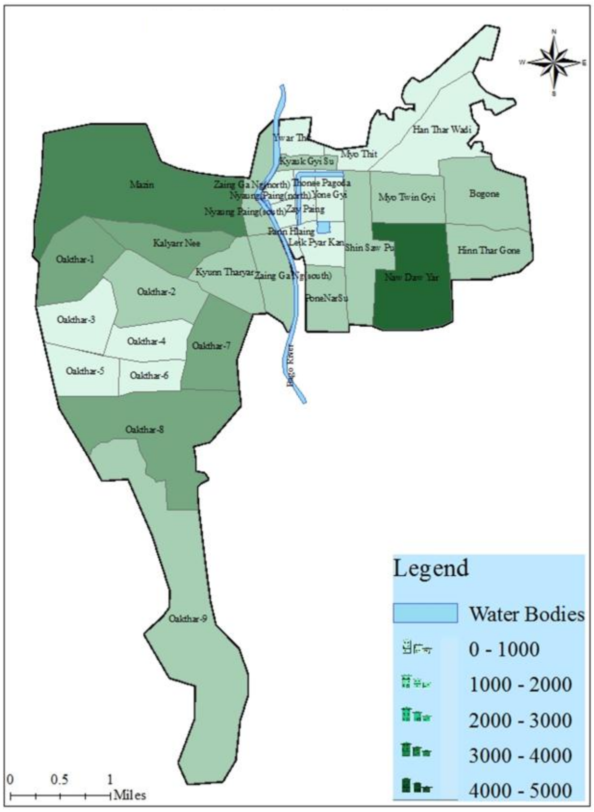


Figure (A-7) Building Count in Bago

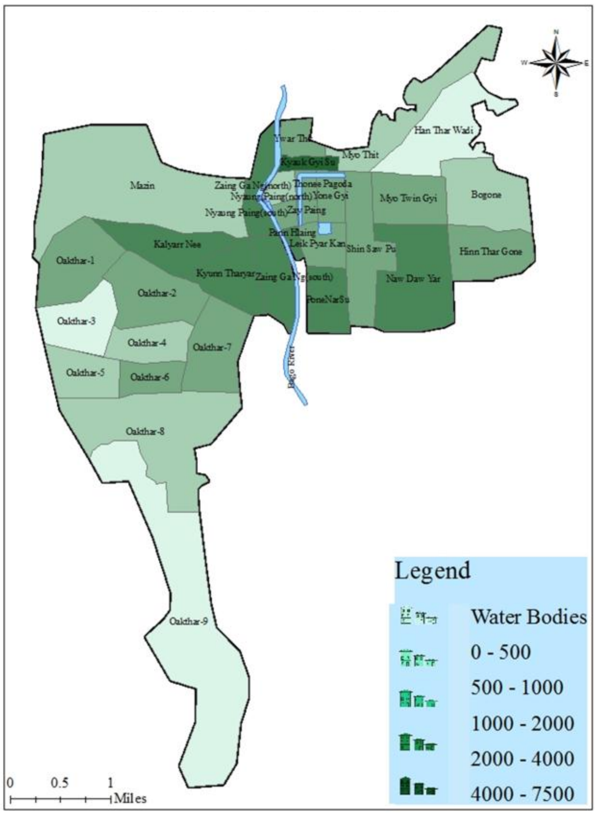


Figure (A-8) Building Density in Bago

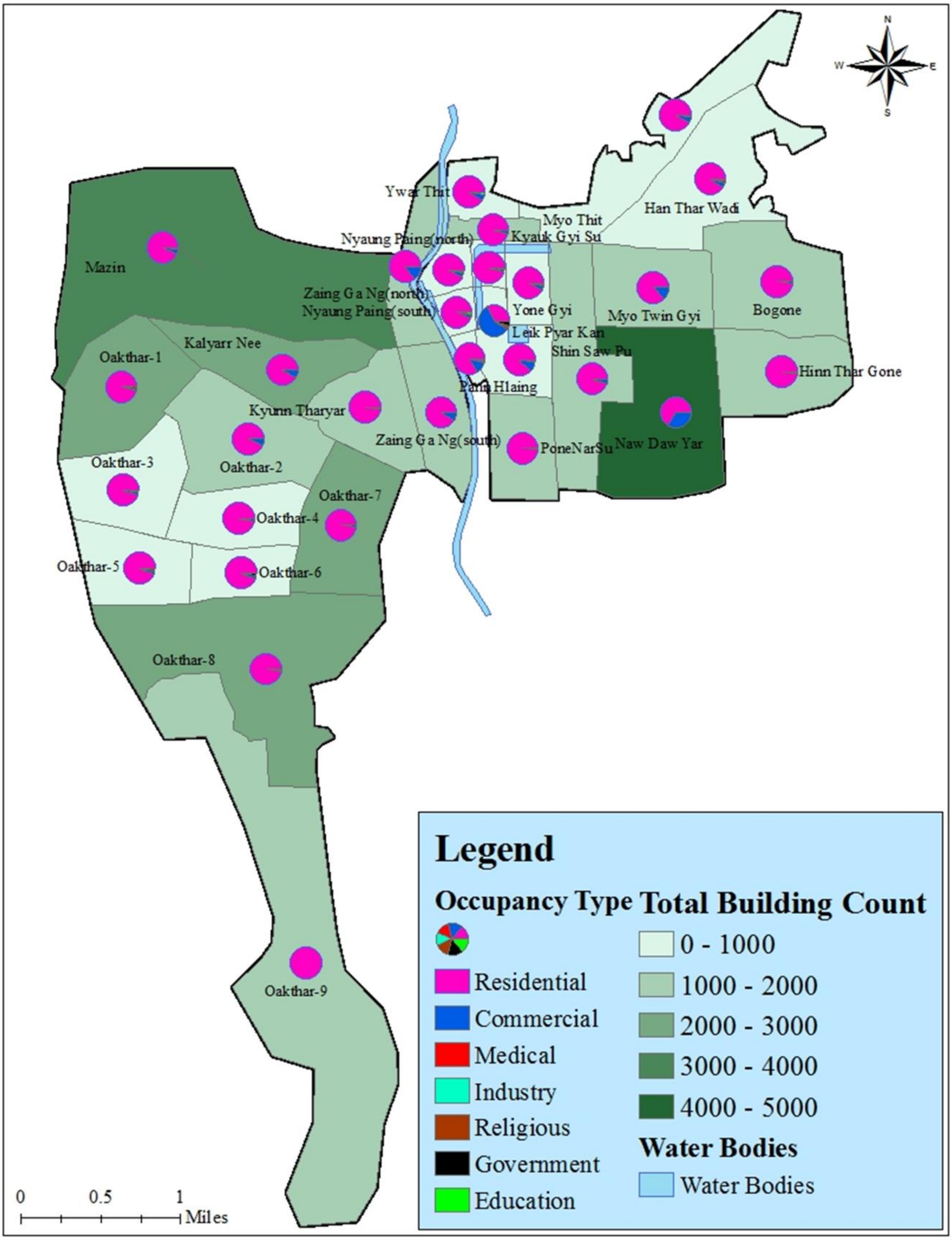


Figure (9) Distribution of Occupancy Type on Total Building Count

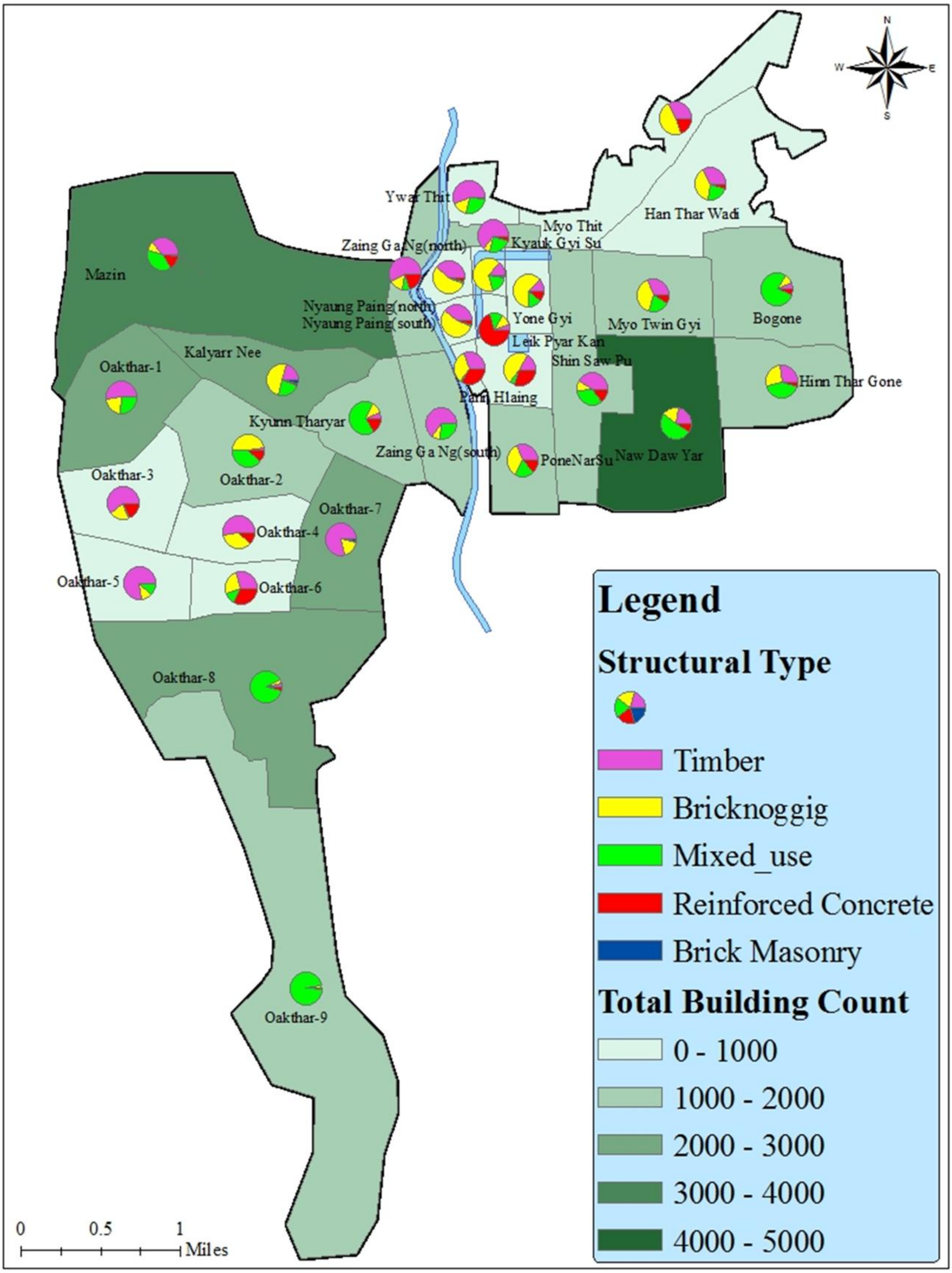


Figure (10) Distribution of Structural Type on Total Building Count

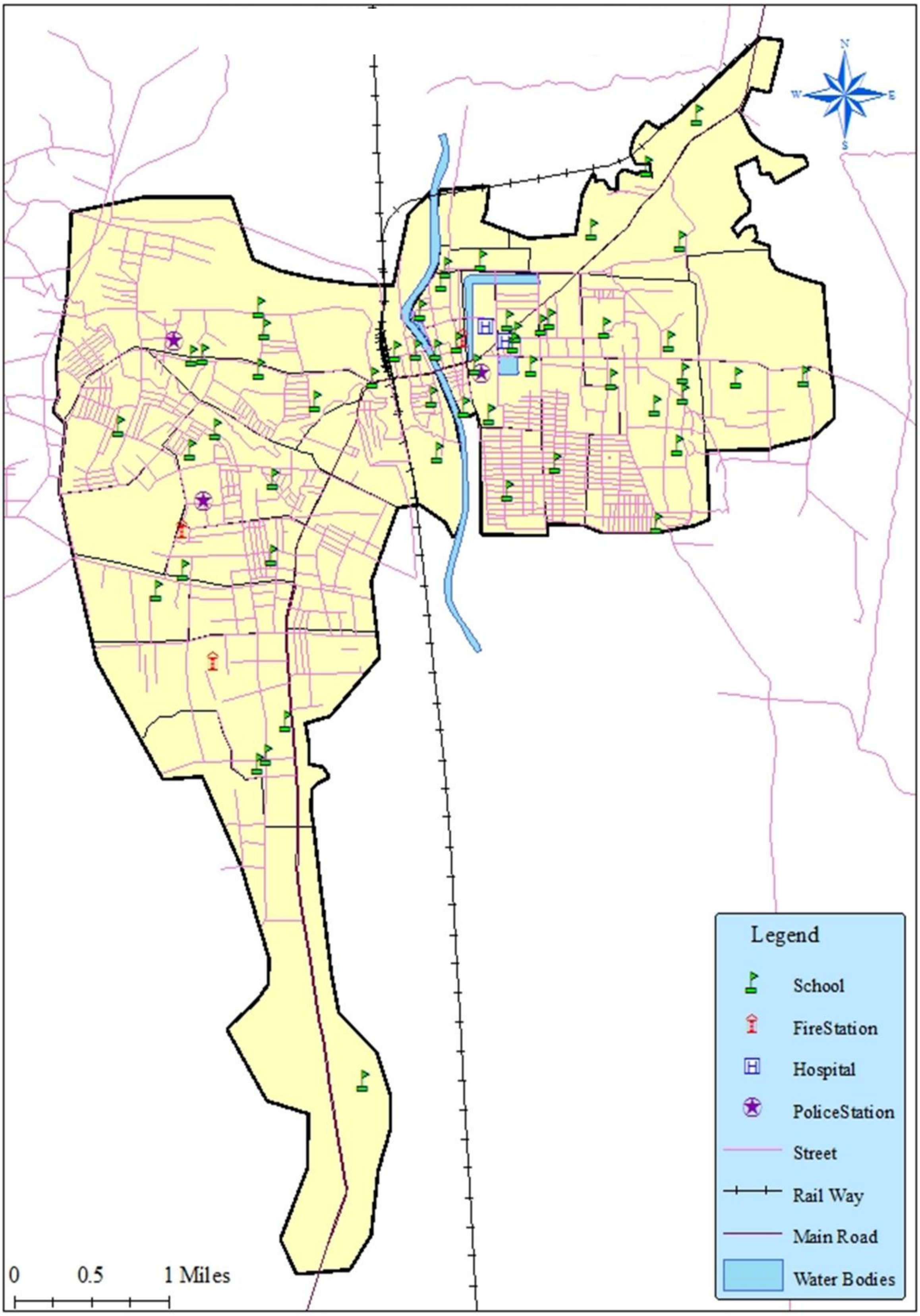


Figure (A-11) Essential Facilities in Bago City

APPENDIX- B

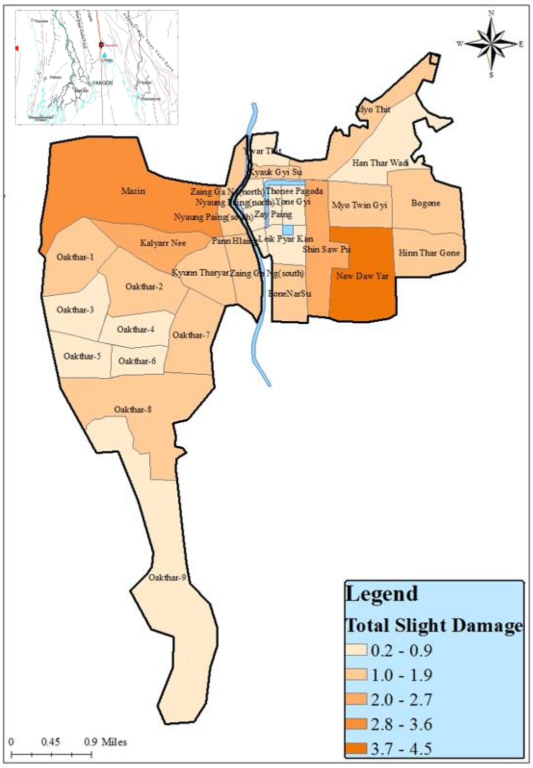


Figure (B-1) Total Slight Damage in Bago by Scenario I

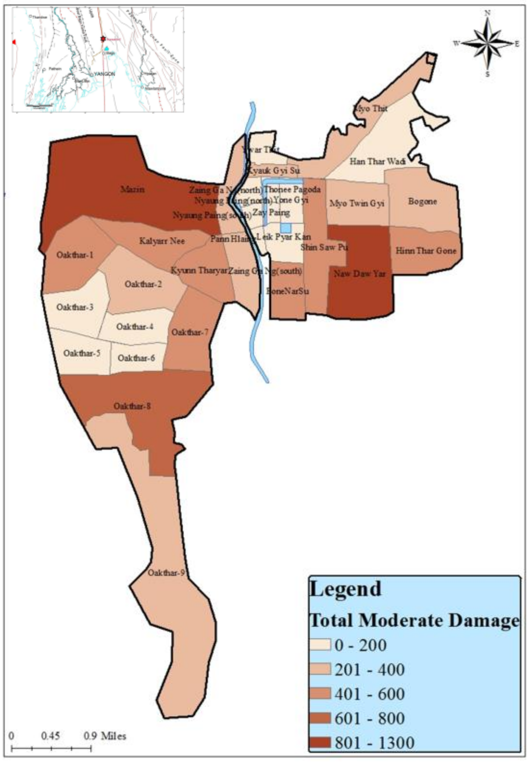


Figure (B-2) Total Moderate Damage in Bago by Scenario I

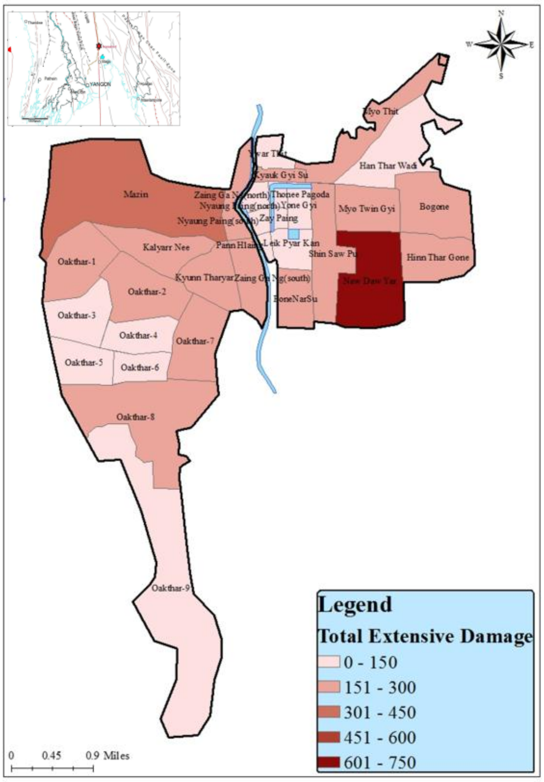


Figure (B-3) Total Extensive Damage in Bago by Scenario I

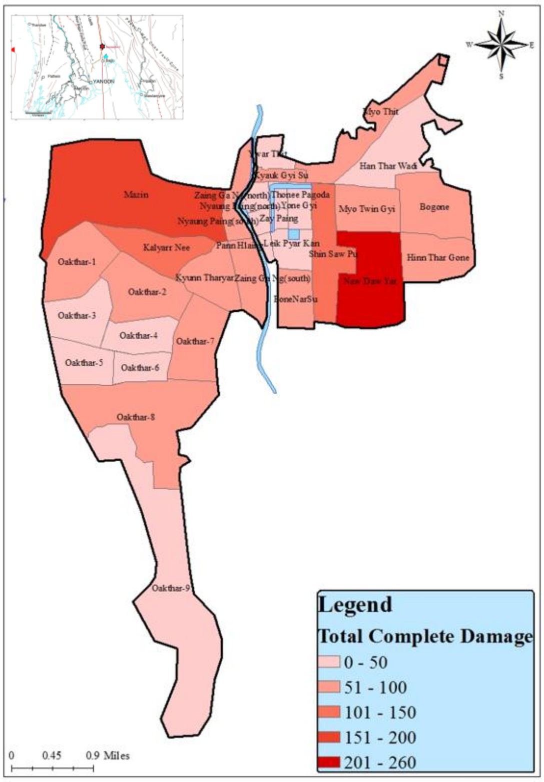


Figure (B-4) Total Complete Damage in Bago by Scenario I

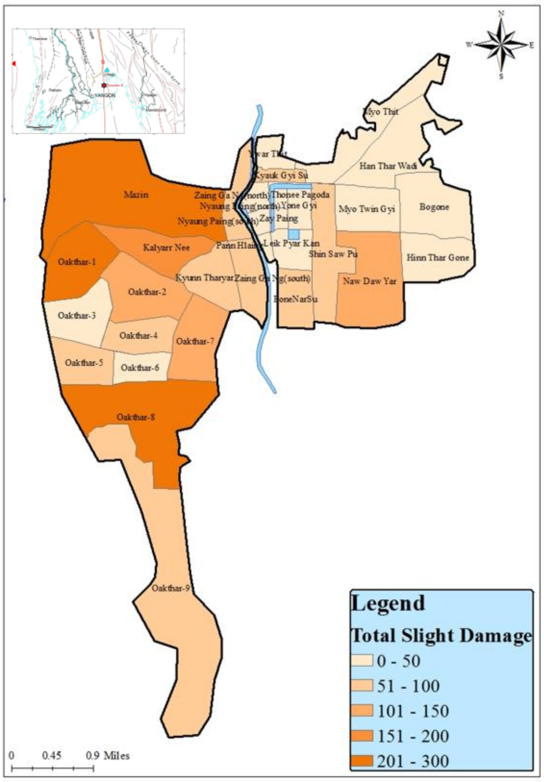


Figure (B-5) Total Slight Damage in Bago by Scenario II

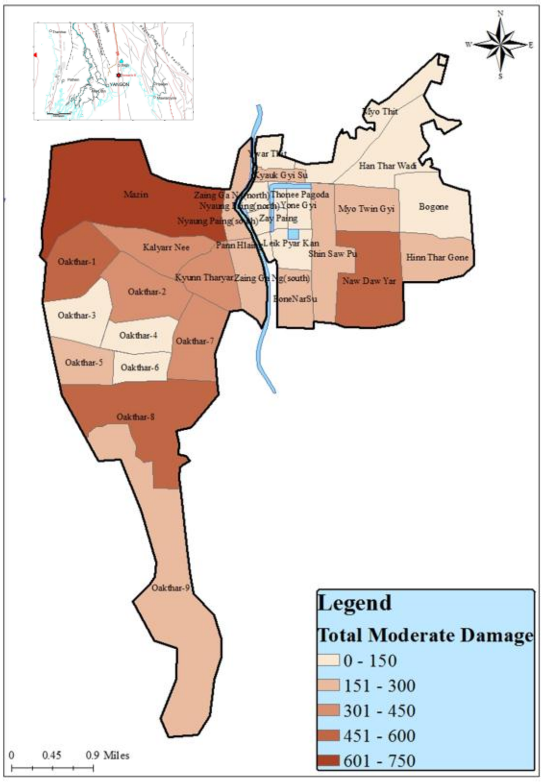


Figure (B-6) Total Moderate Damage in Bago by Scenario II

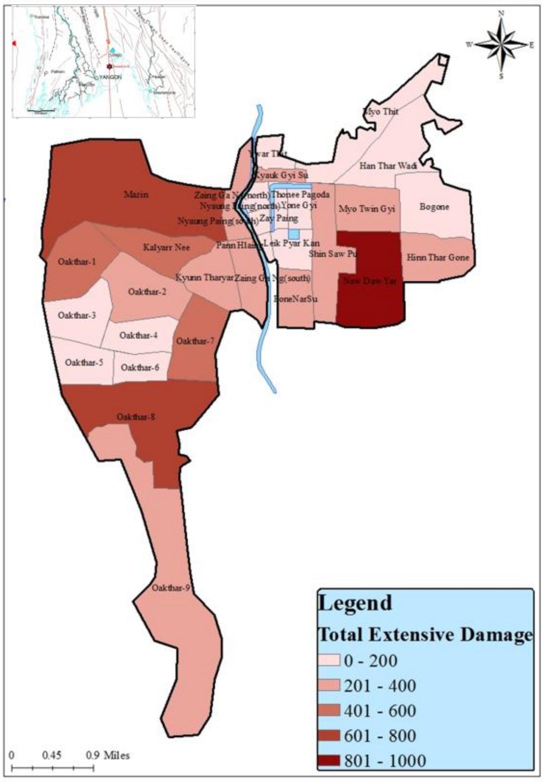


Figure (B-7) Total Extensive Damage in Bago by Scenario II

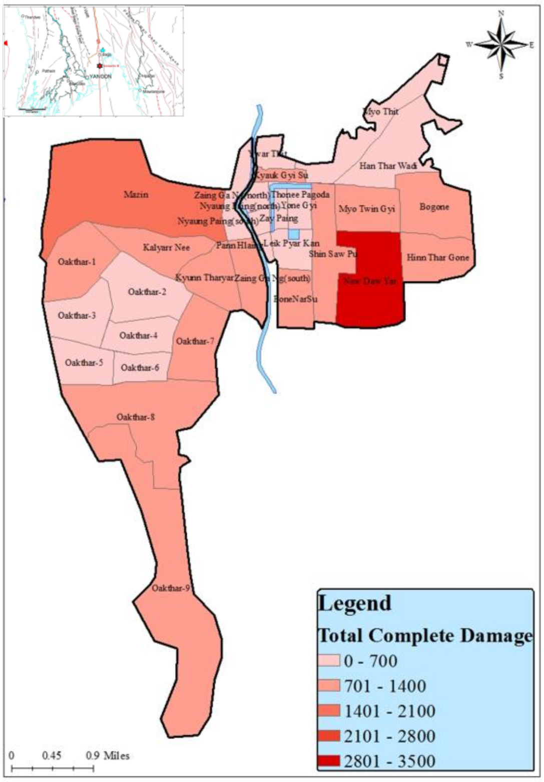


Figure (B-8) Total Complete Damage in Bago by Scenario II

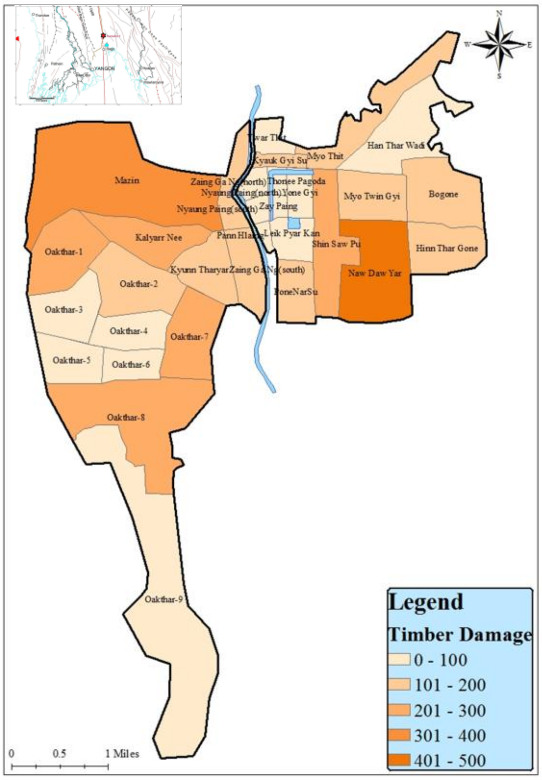


Figure (B-9) Slight Damage of Timber building in Bago by Scenario I

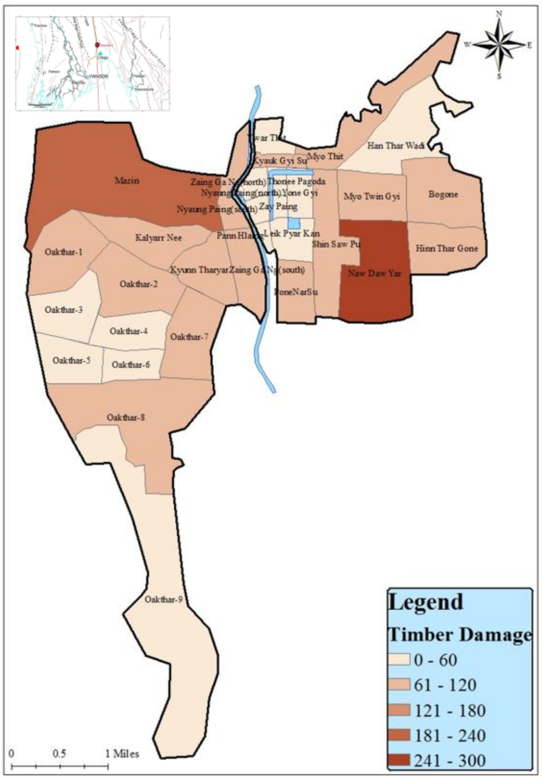


Figure (B-10) Moderate Damage of Timer Building in Bago by Scenario I

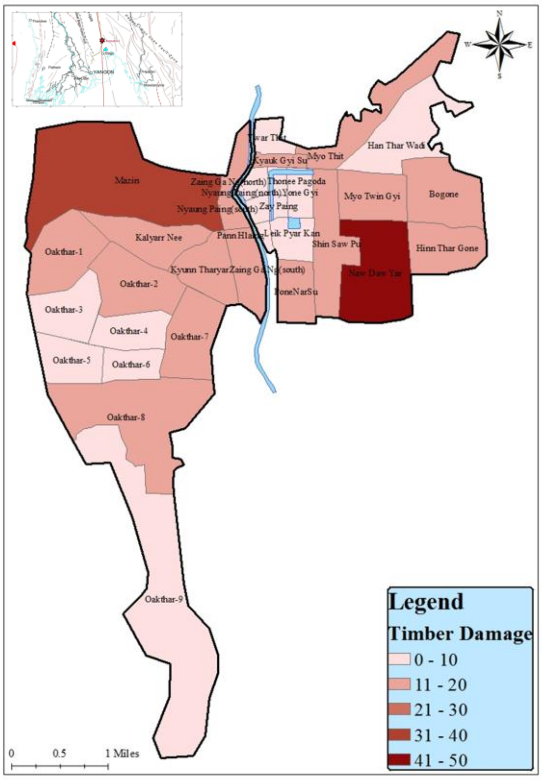


Figure (B-11) Extensive Damage of Timber Building in Bago by Scenario I

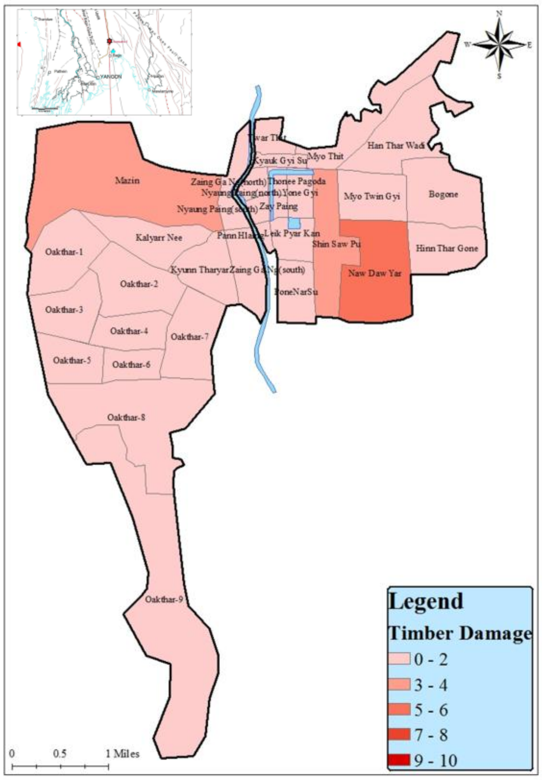


Figure (B-12) Complete Damage of Timer Building in Bago by Scenario I

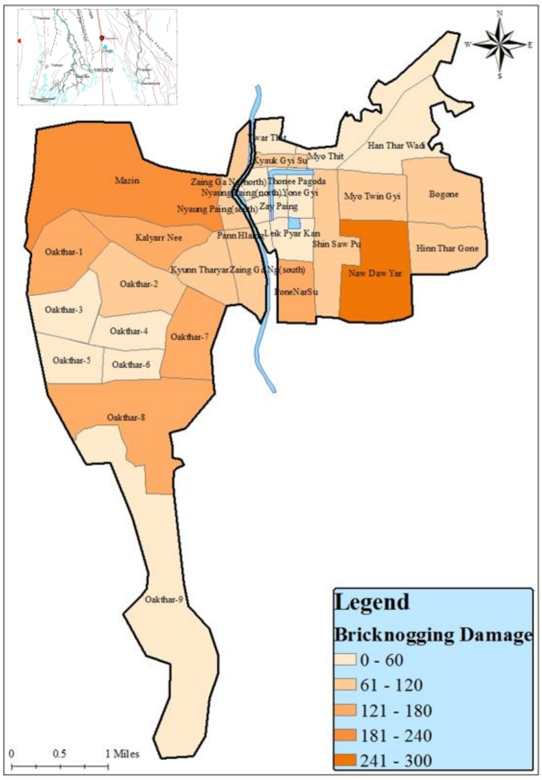


Figure (B-13) Slight Damage of Bricknogging Building in Bago by Scenario I

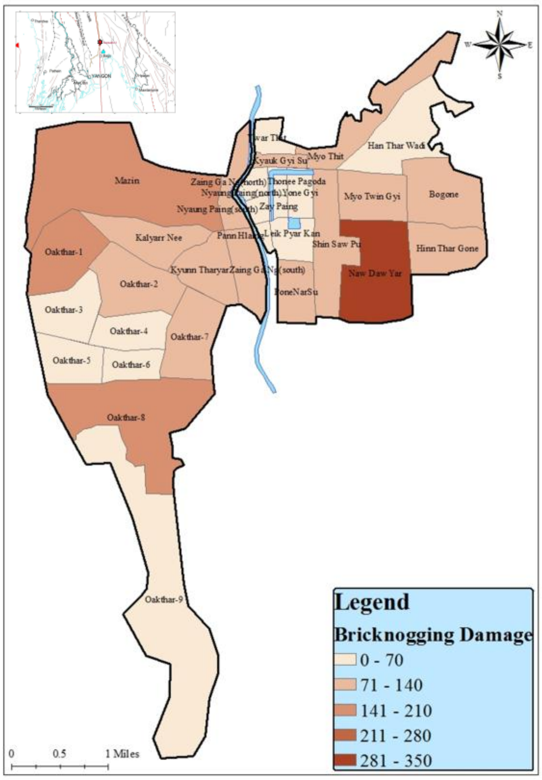


Figure (B-14) Moderate Damage of Bricknogging Building in Bago by Scenario I

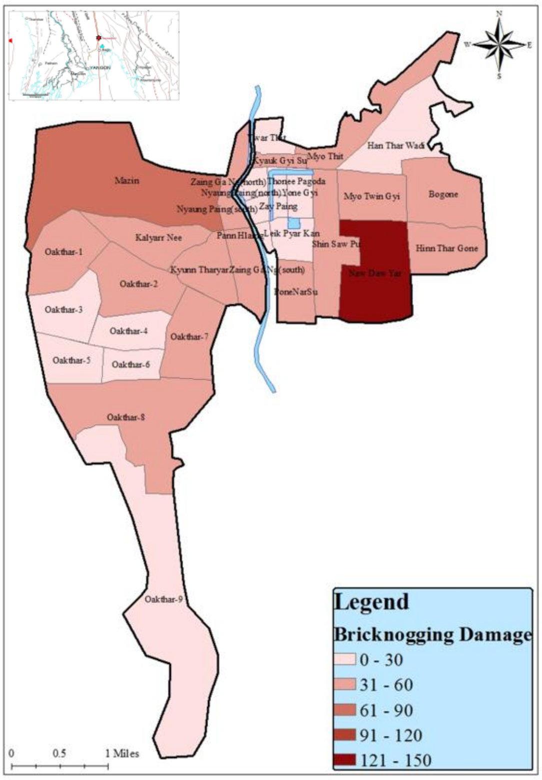


Figure (B-15) Extensive Damage of Bricknogging Building in Bago by Scenario I

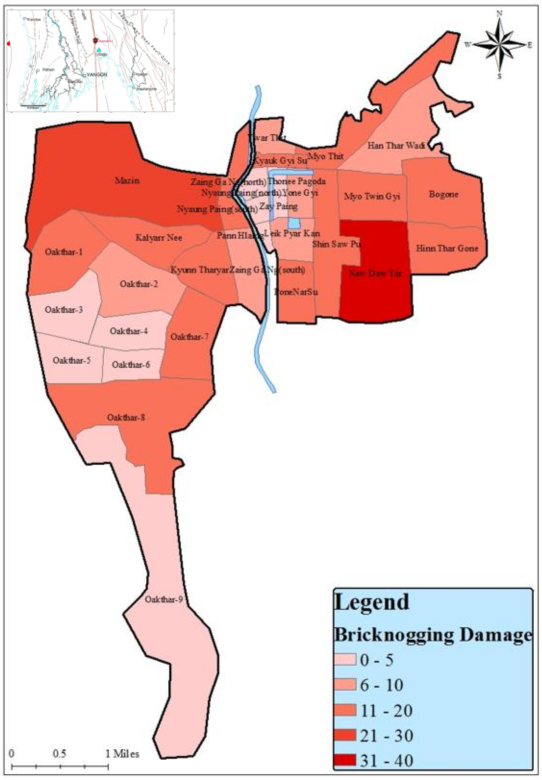


Figure (B-16) Complete Damage of Bricknogging Building in Bago by Scenario I

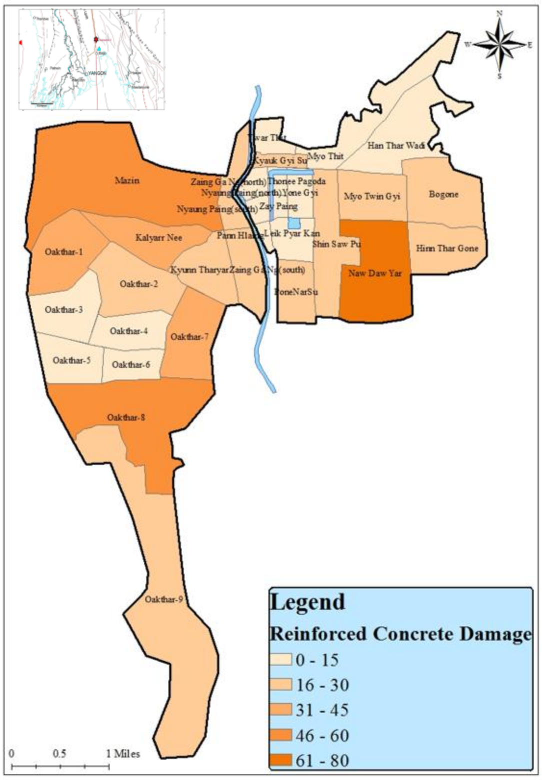


Figure (B-17) Slight Damage of Reinforced Concrete Building in Bago by Scenario I

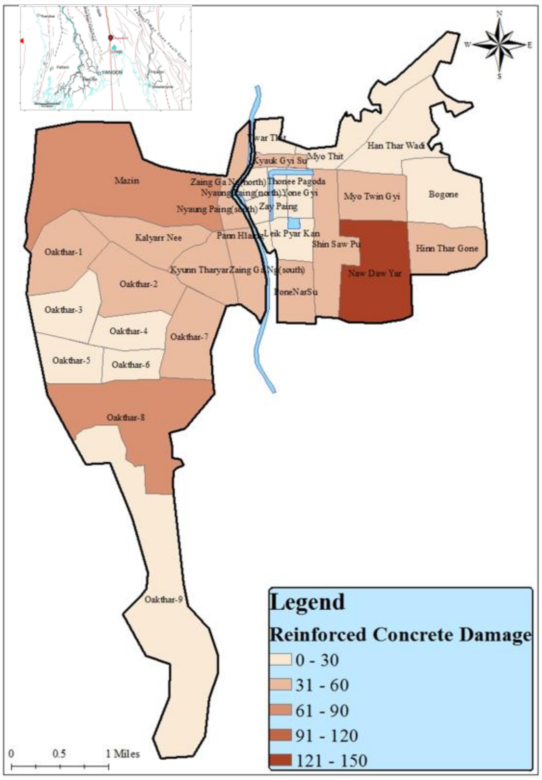


Figure (B-18) Moderate Damage of Reinforced Concrete Building in Bago by Scenario I

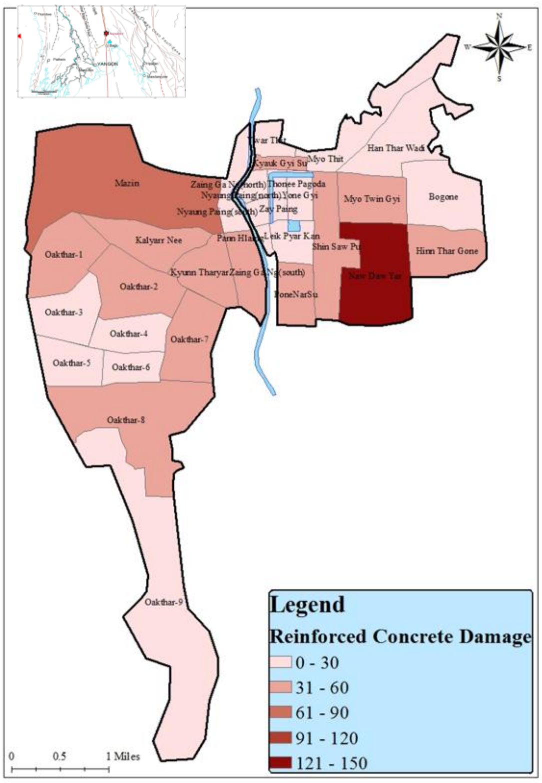


Figure (B-19) Extensive Damage of Concrete Building in Bago by Scenario I

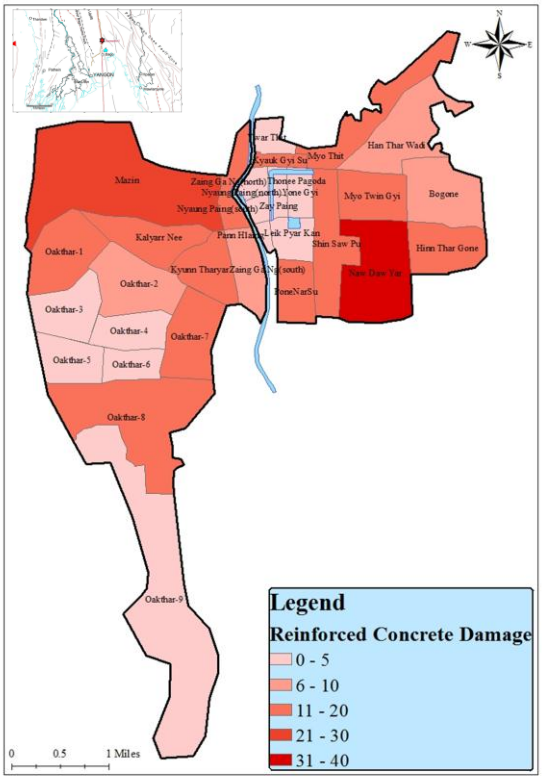


Figure (B-20) Complete Damage of Concrete Building in Bago by Scenario I

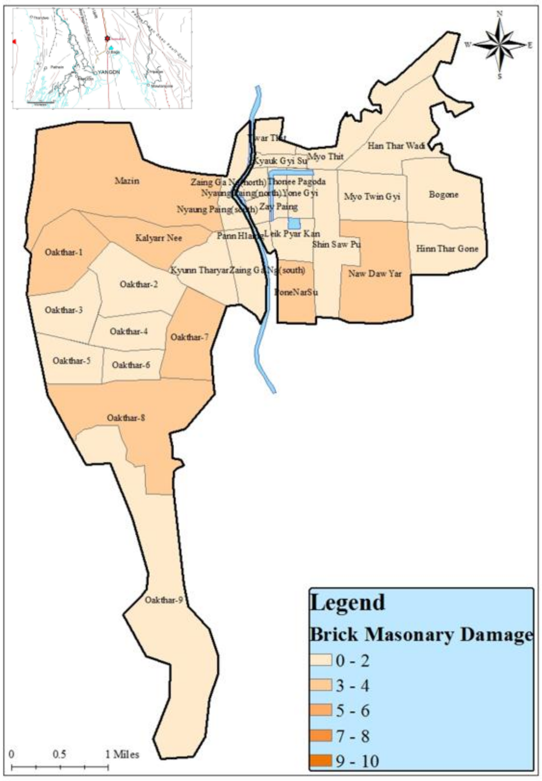


Figure (B-21) Slight Damage of Brick Masonry Building in Bago by Scenario I

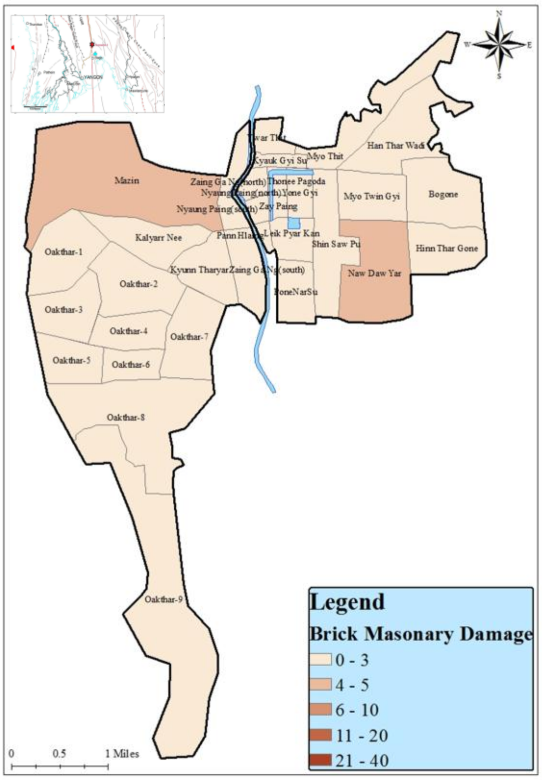


Figure (B-22) Moderate Damage of Brick Masonry Building in Bago by Scenario I

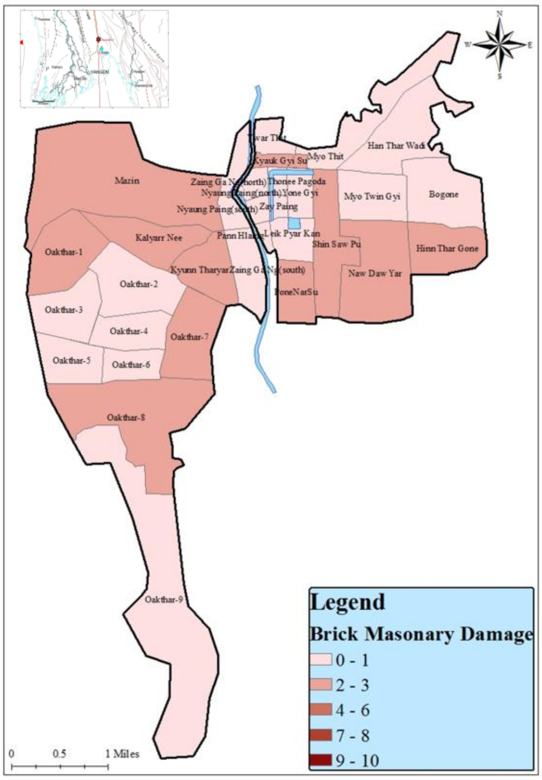


Figure (B-23) Extensive Damage of Brick Masonry Building in Bago by Scenario I

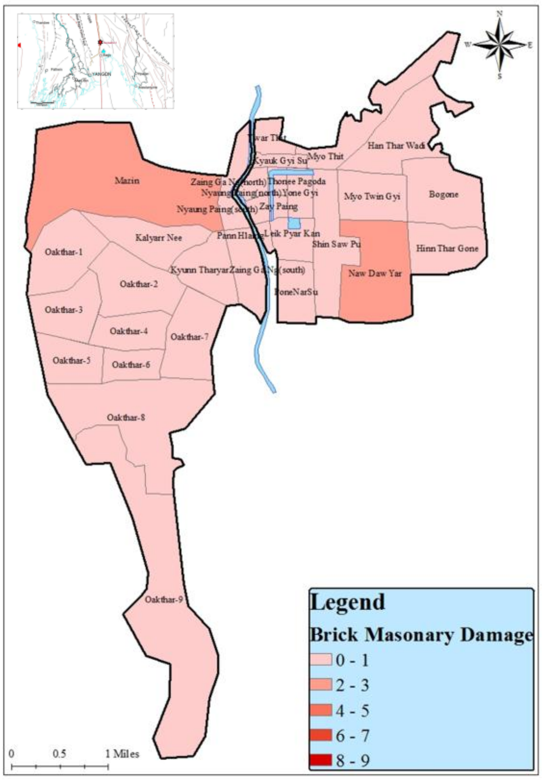


Figure (B-24) Complete Damage of Brick Masonry Building in Bago by Scenario I

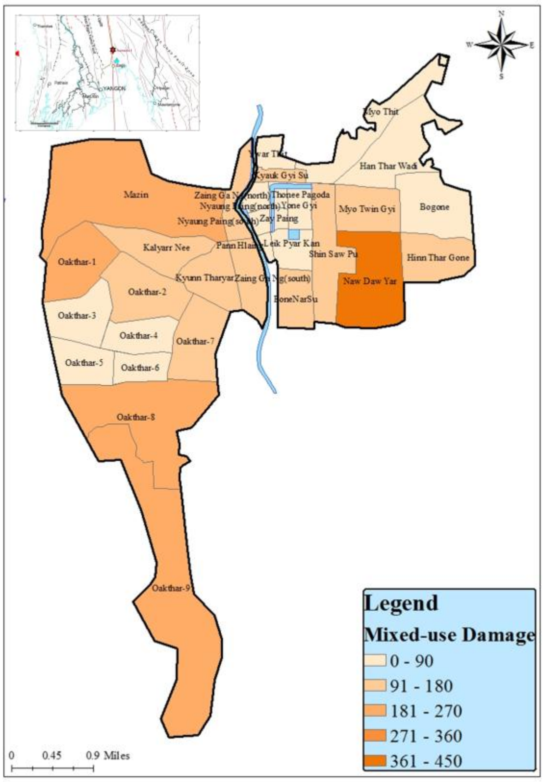


Figure (B-25) Slight Damage of Mixed-use Building in Bago by Scenario I

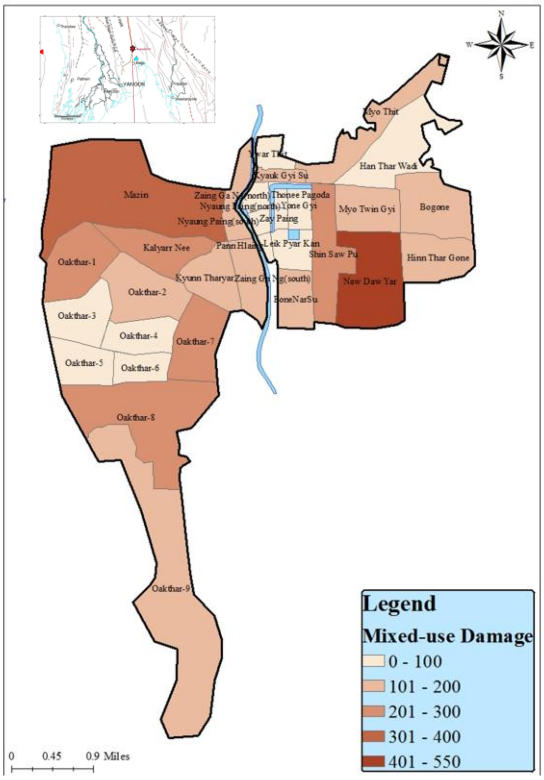


Figure (B-26) Moderate Damage of Mixed-use Building in Bago by Scenario I

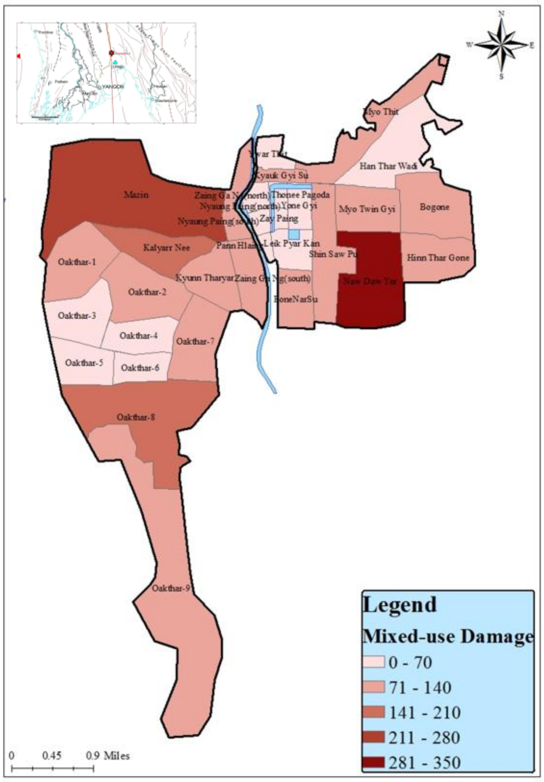


Figure (B-27) Extensive Damage of Mixed-use Building in Bago by Scenario I

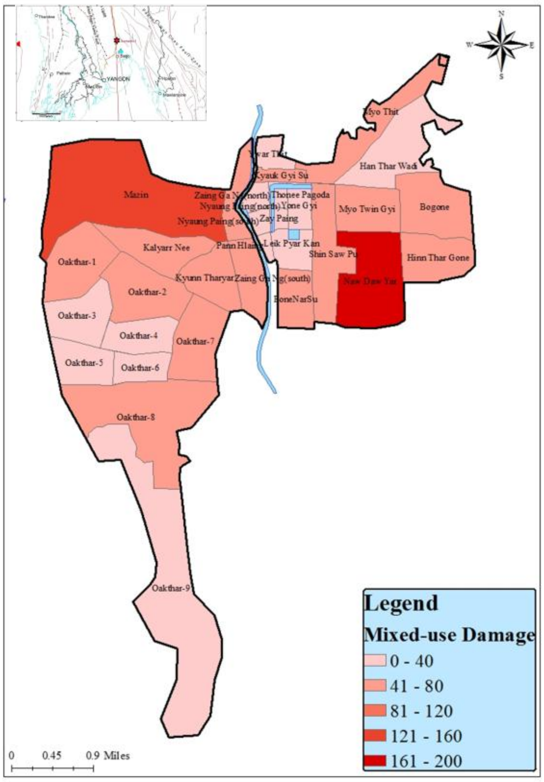


Figure (B-28) Complete Damage of Mixed-use Building in Bago by Scenario I

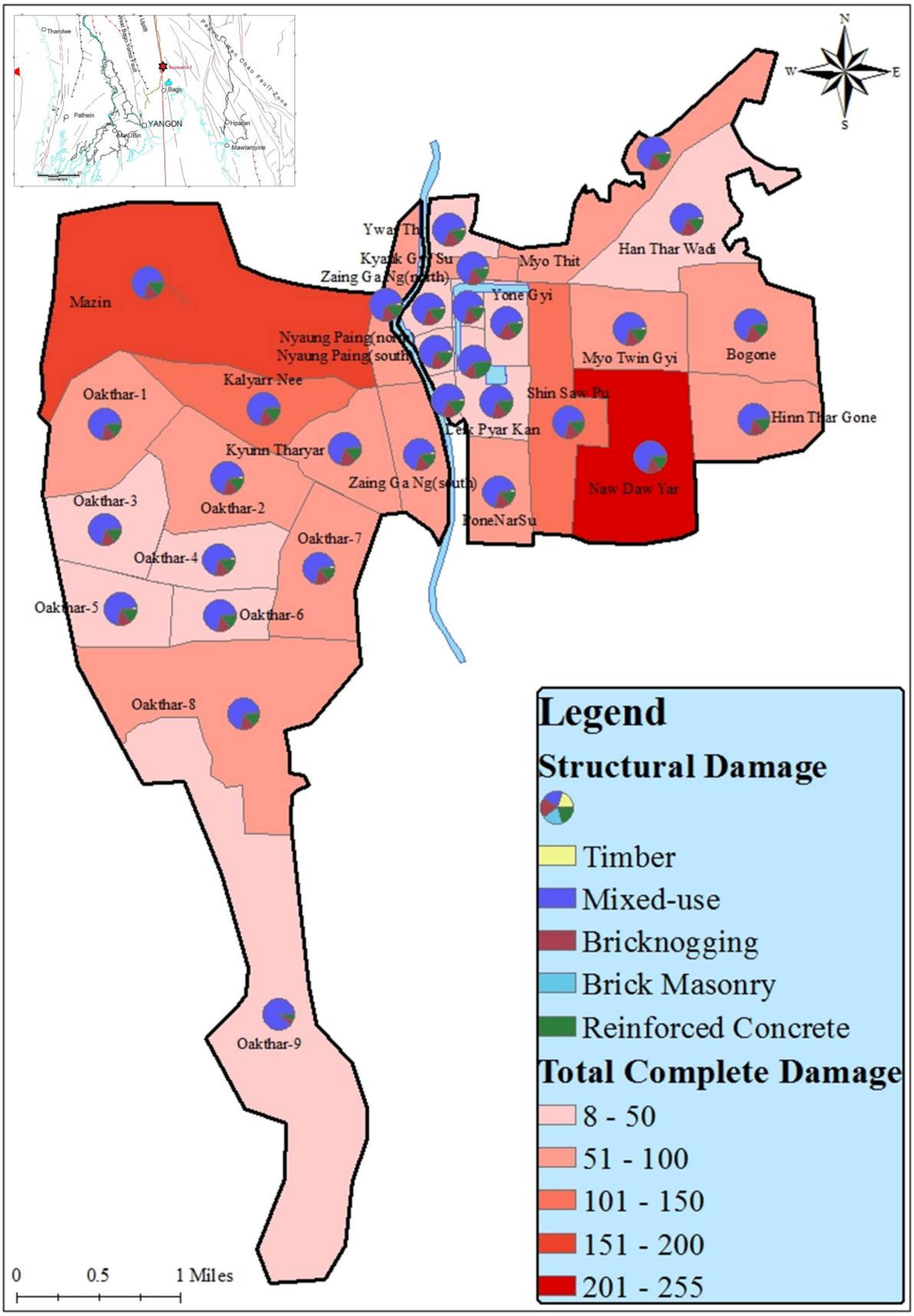


Figure (B-29) Complete Damage in term of Structural Type by Scenario I (M-7)

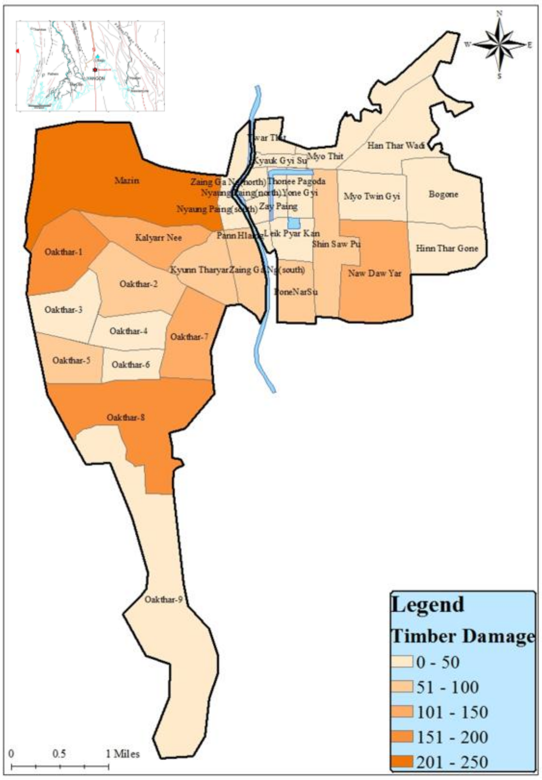


Figure (B-30) Slight Damage of Timber building in Bago by Scenario II

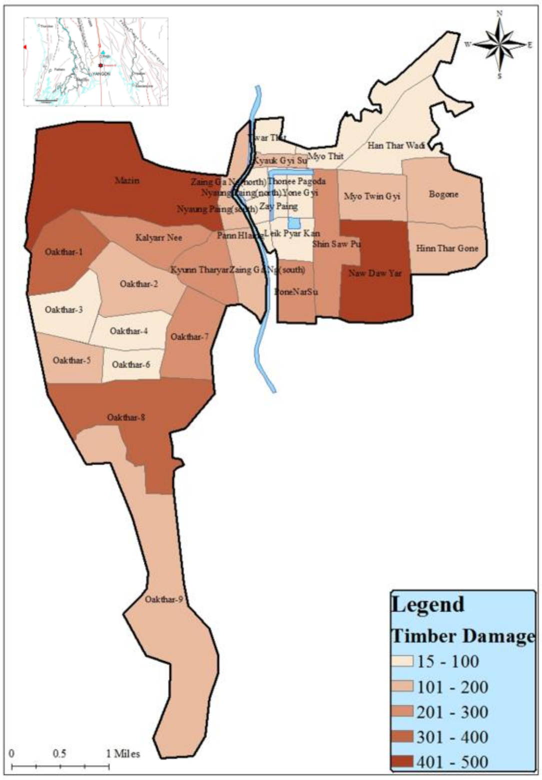


Figure (B-31) Moderate Damage of Timber Building in Bago by Scenario II

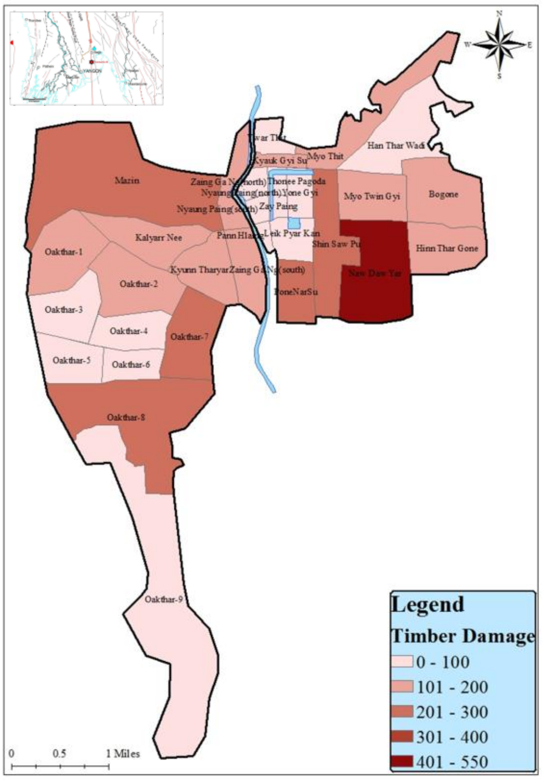


Figure (B-32) Extensive Damage of Timber Building in Bago by Scenario II

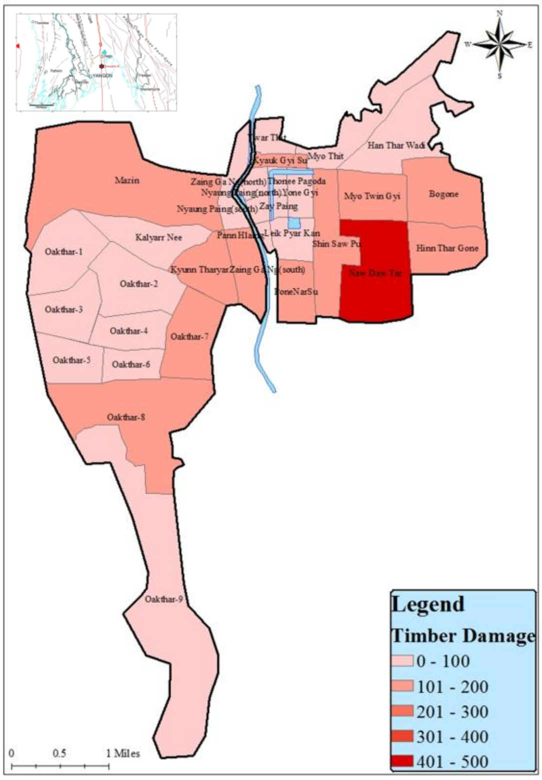


Figure (B-33) Complete Damage of Timber Building in Bago by Scenario II

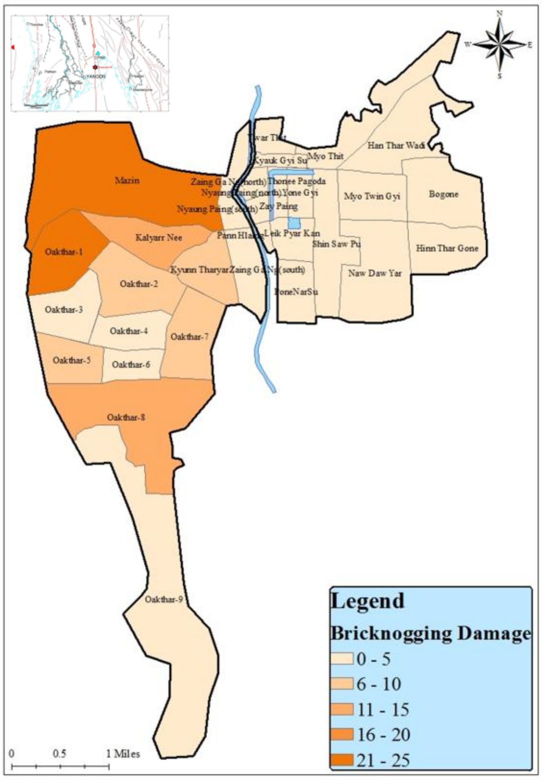


Figure (B-34) Slight Damage of Bricknogging Building in Bago by Scenario II

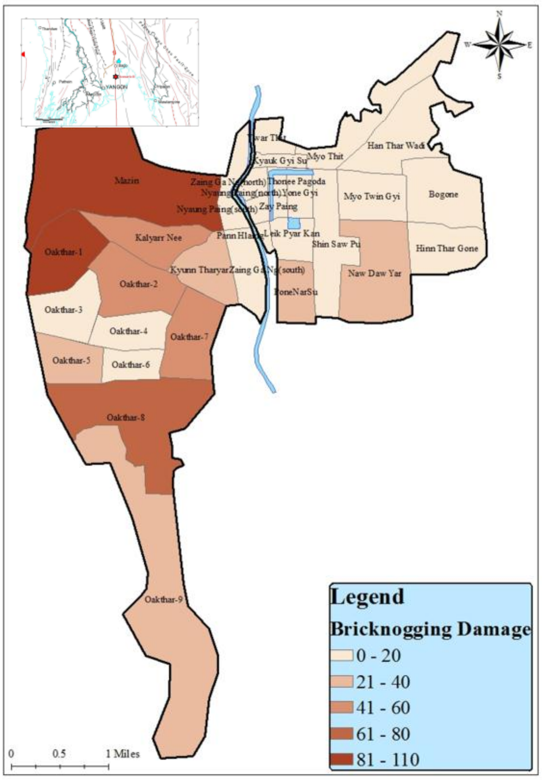


Figure (B-35) Moderate Damage of Bricknogging Building in Bago by Scenario II

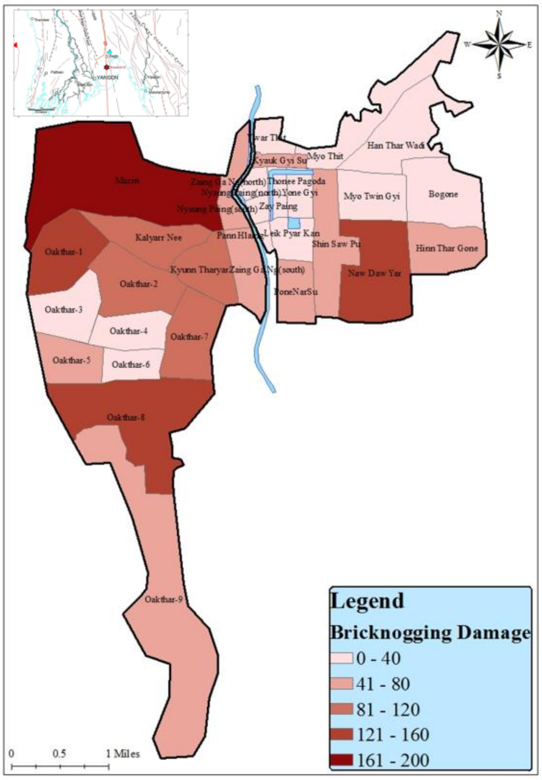


Figure (B-36) Extensive Damage of Bricknogging Building in Bago by Scenario II

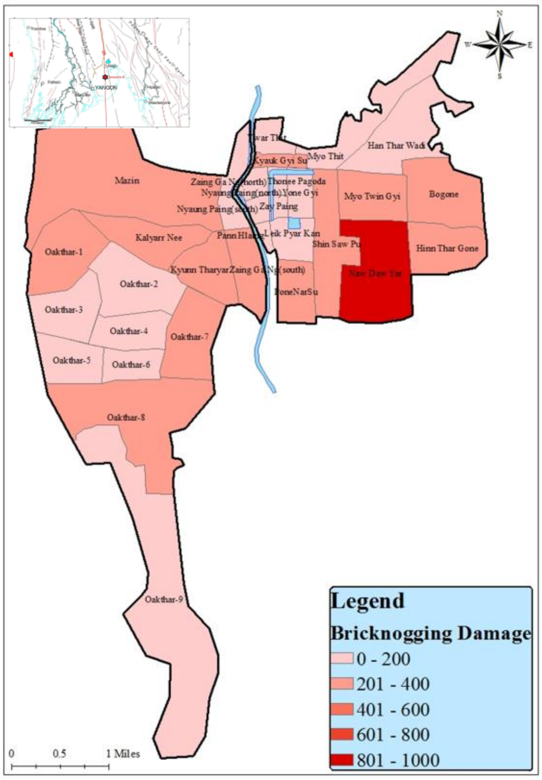


Figure (B-37) Complete Damage of Bricknogging Building in Bago by Scenario II

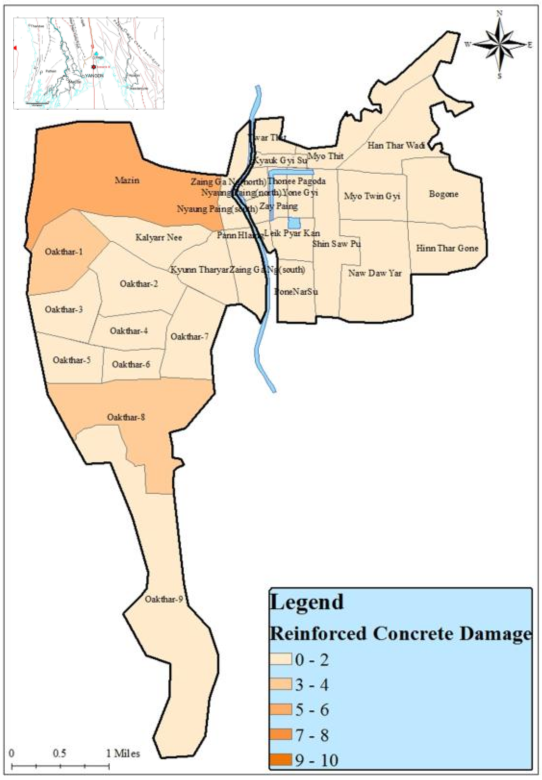


Figure (B-38) Slight Damage of Reinforced Concrete Building in Bago by Scenario II

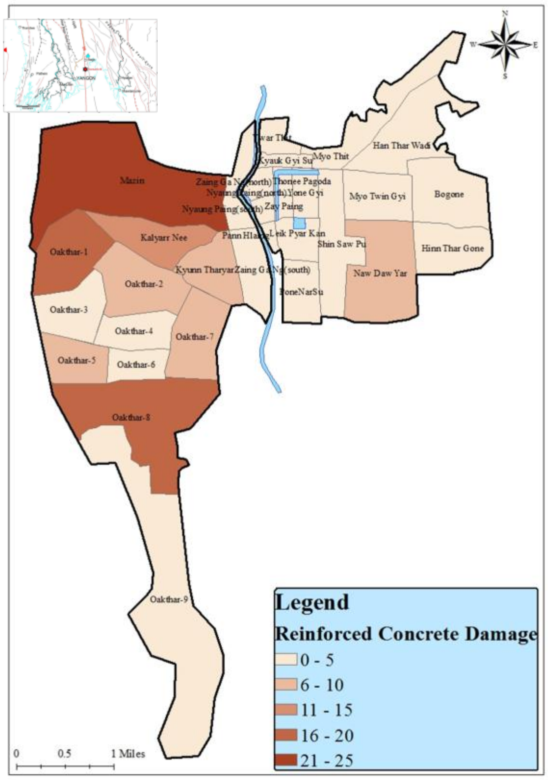


Figure (B-39) Moderate Damage of Reinforced Concrete Building in Bago by Scenario II

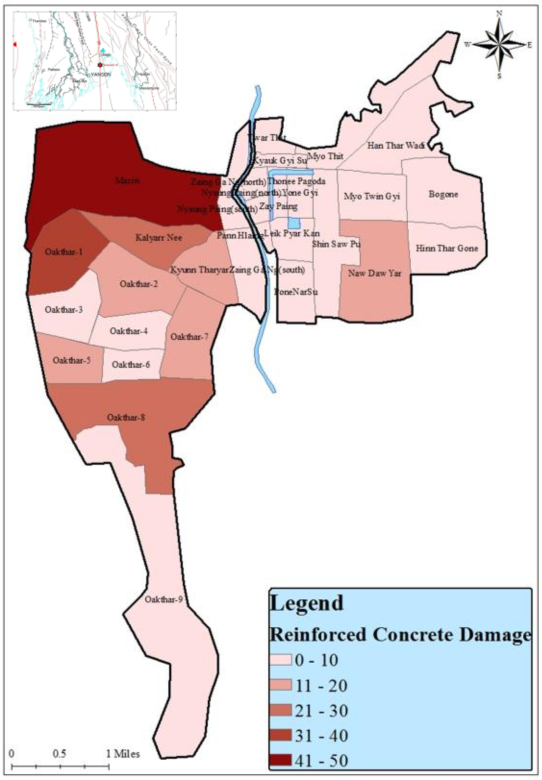


Figure (B-40) Extensive Damage of Reinforced Concrete Building in Bago by Scenario II

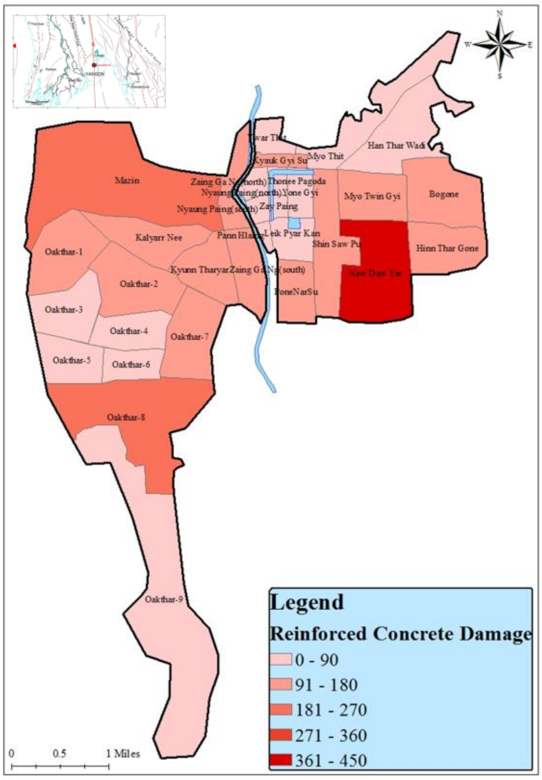


Figure (B-41) Complete Damage of Reinforced Concrete Building in Bago by Scenario II

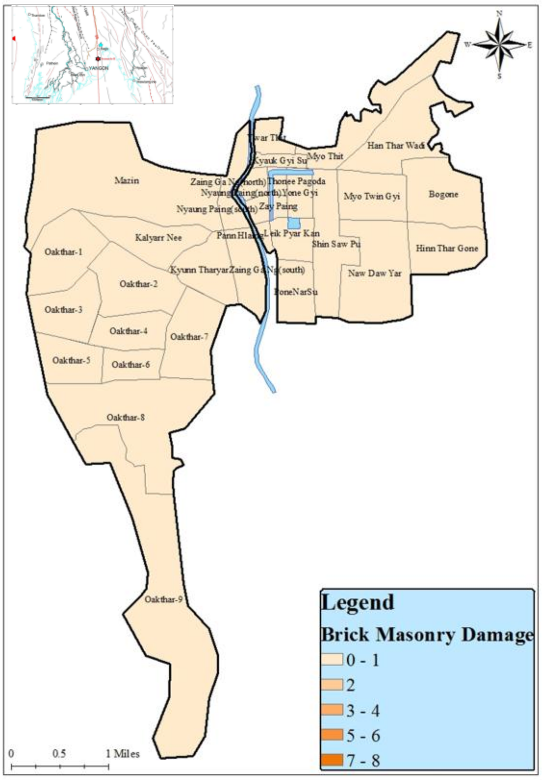


Figure (B-42) Slight Damage of Brick Masonry Building in Bago by Scenario II

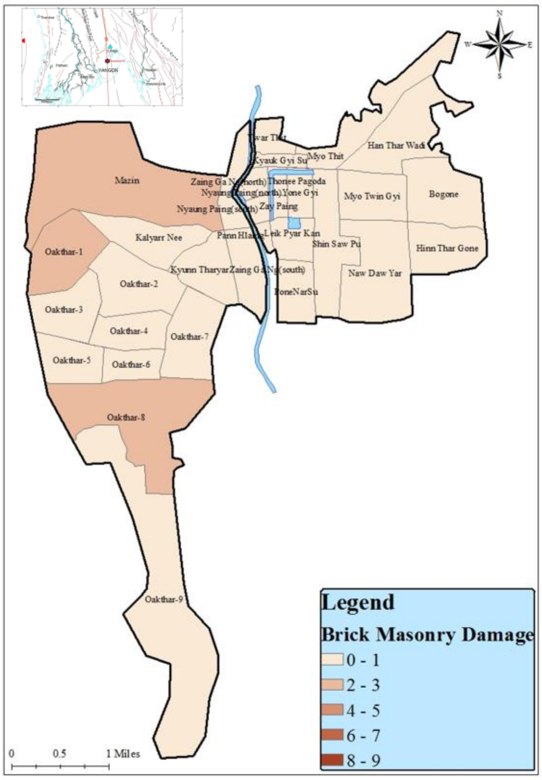


Figure (B-43) Moderate Damage of Brick Masonry Building in Bago by Scenario II

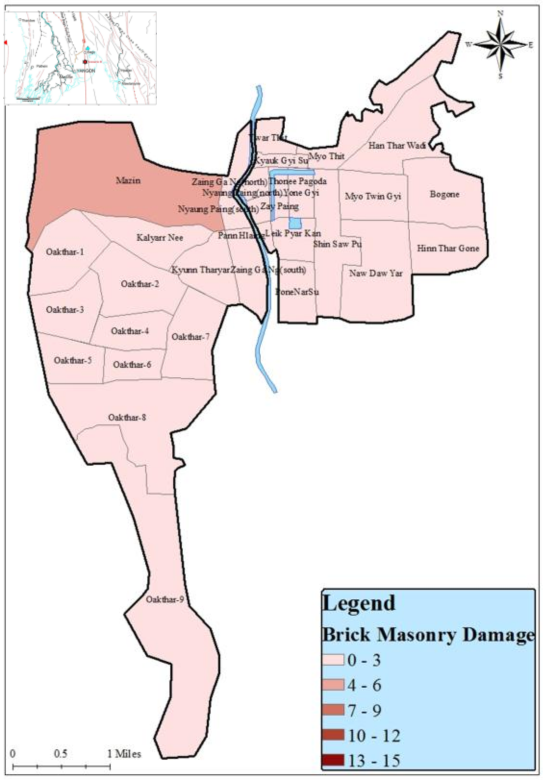


Figure (B-44) Extensive Damage of Brick Masonry Building in Bago by Scenario II

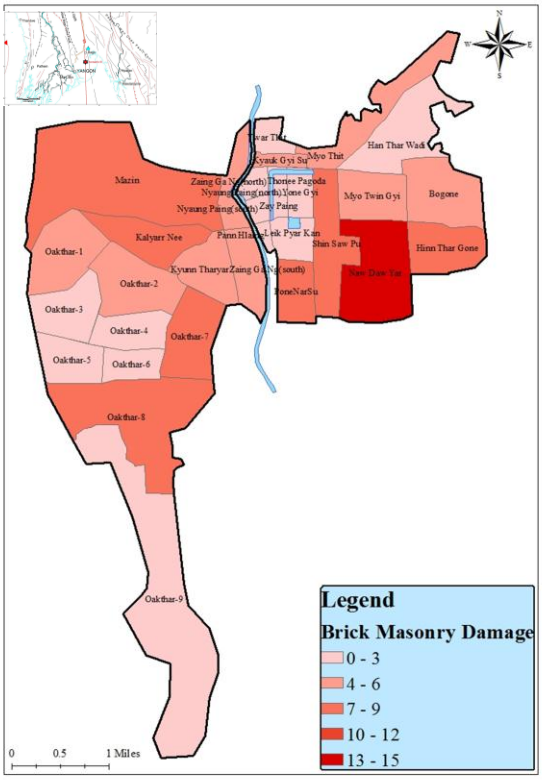


Figure (B-45) Complete Damage of Brick Masonry Building in Bago by Scenario II

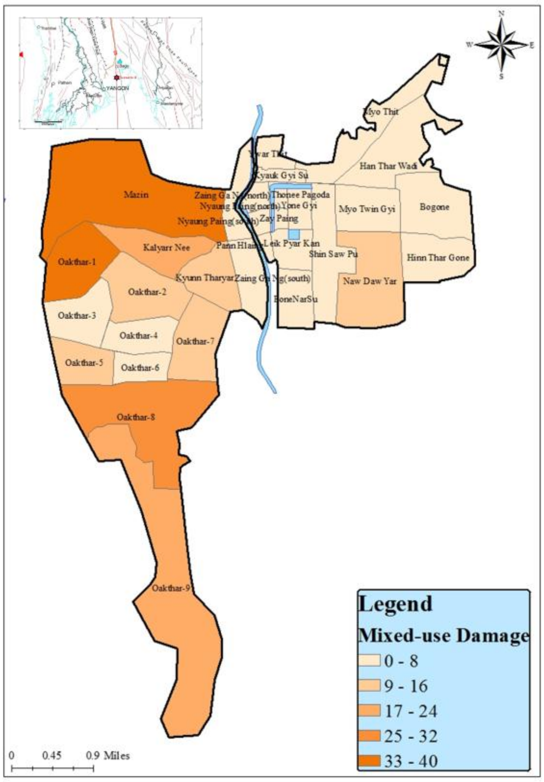


Figure (B-46) Slight Damage of Mixed-use Building in Bago by Scenario II

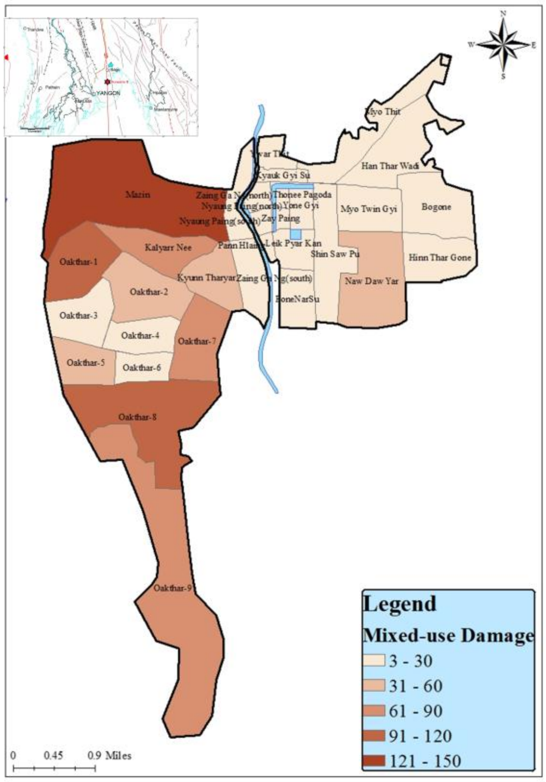


Figure (B-47) Moderate Damage of Mixed-use Building in Bago by Scenario II

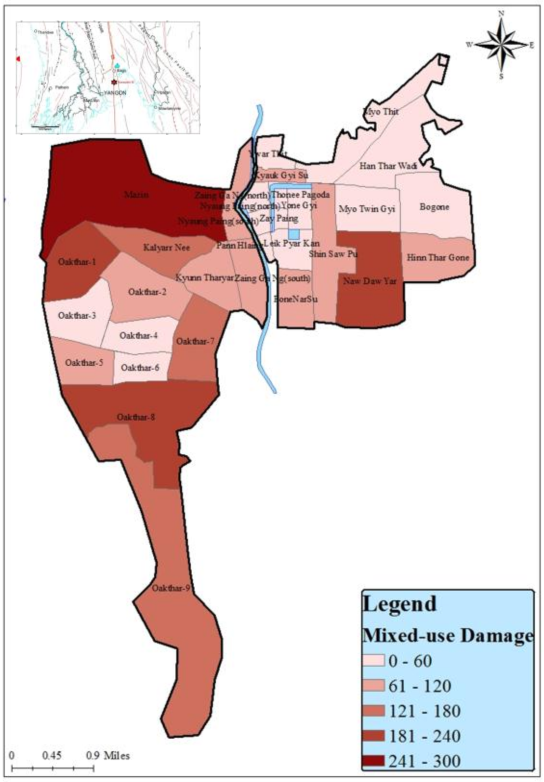


Figure (B-48) Extensive Damage of Mixed-use Building in Bago by Scenario II

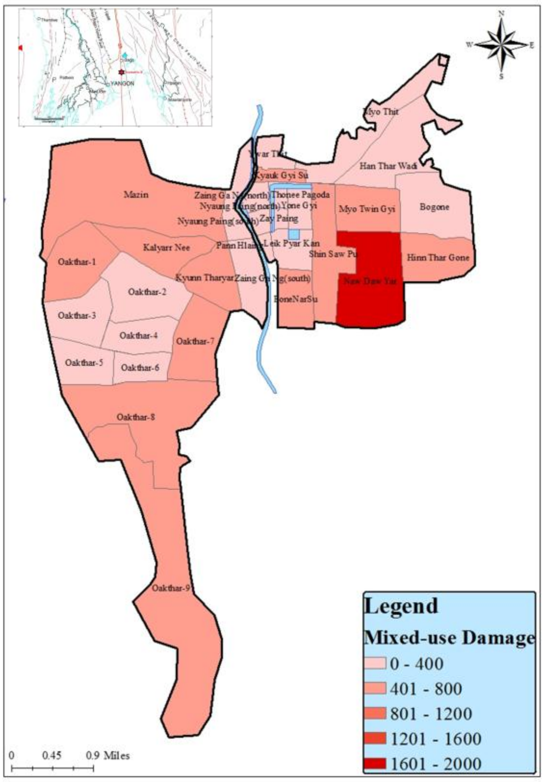


Figure (B-49) Complete Damage of Mixed-use Building in Bago by Scenario II

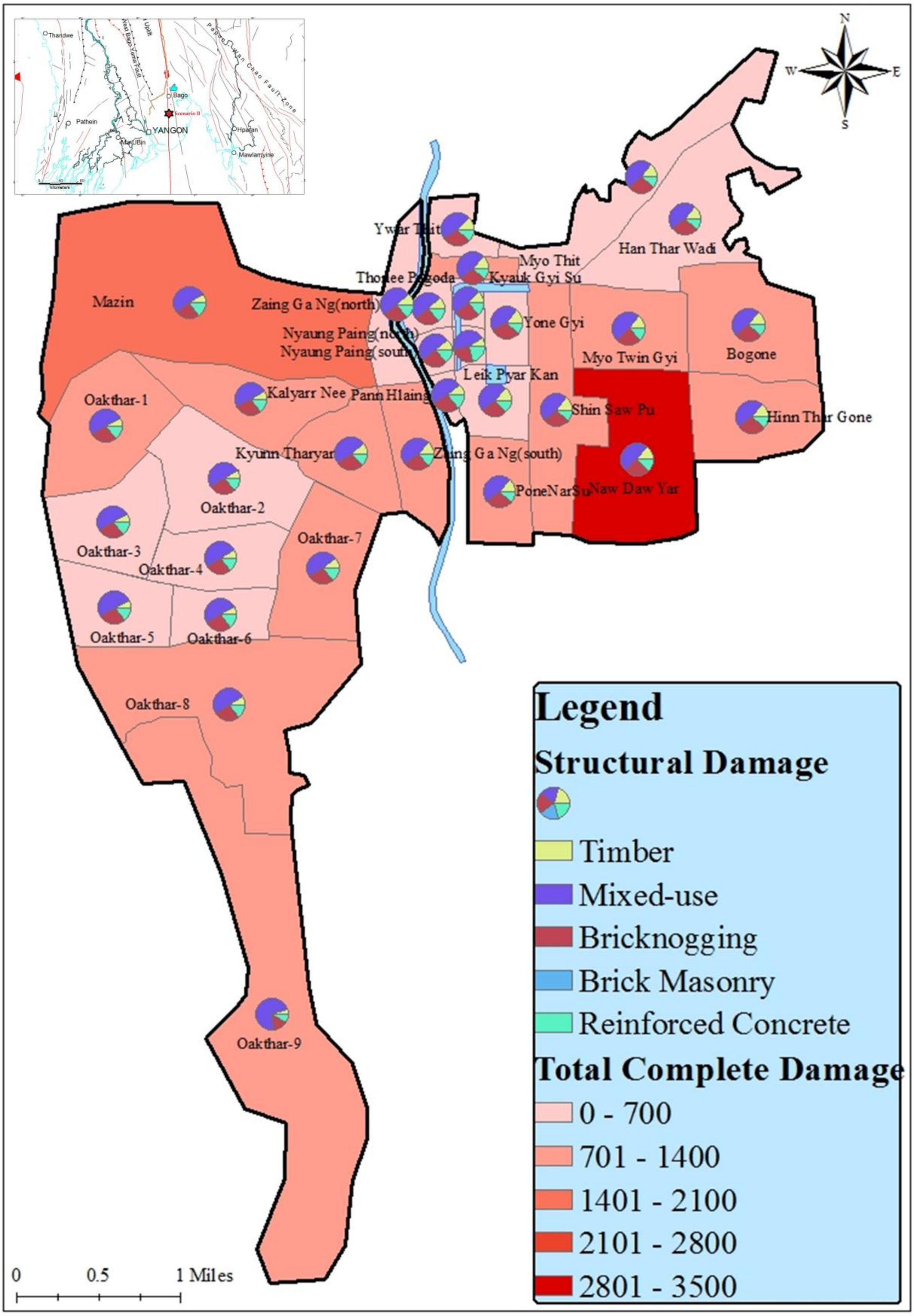


Figure (B-50) Complete Damage in term of Structural Type by Scenario II (M-7.4)