ENHANCING AND DEVELOPING SEISMIC RISK ASSESSMENT FOR TAUNGOO CITY OF MYANMAR

Taungoo City, Bago Region, Myanmar

Safer Costal and Urban Communities through Inclusive Disaster Risk Reduction in Myanmar Project Funded by DIPECHO

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Background

Developing countries typically suffer far greater than developed countries as a result of earthquakes. Poor socioeconomic conditions often lead to poorly constructed homes that are vulnerable to damage during earthquakes. Our country, Myanmar is a developing country and one of the multi-hazard prone areas around the world according to its geographical situation. Myanmar lies on one of the world's two main earthquake belts and many of the urban centers are along the Sagaing fault running North –South of the country. 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, 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 PhyoMaungMaung, 2011).

Rapid and unplanned urbanization in Myanmar is increasing the vulnerability of future disasters especially for earthquake. Besides, over the past three decades, urbanization in Myanmar has been rapidly increasing. In most cities throughout the country, this urbanization took place minimal consideration of building codes, sound construction, and urban planning practices. 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 Timber, Brick Nogging, Brick Masonry and reinforced Reinforced Concrete, there is an increasing concern on the potential damage to urban areas such as Yangon, Bago, Taungoo and Sagaing, Meikhtila, Taunggyi along the Sagaing fault. Therefore, this paper tends to estimate the damage and casualties, to develop seismic risk and related assessment of building structures (Public, Private, and Pagodas) for the maximum estimated seismic scenarios in Taungoo 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.

Methodology

HAZUS methodology for earthquake loss estimation model is used for risk assessment tool. 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 just developed as output result of HAZUS analysis because of limited resources. 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. The flow chart of HAZUS methodology is shown in Fig (1).

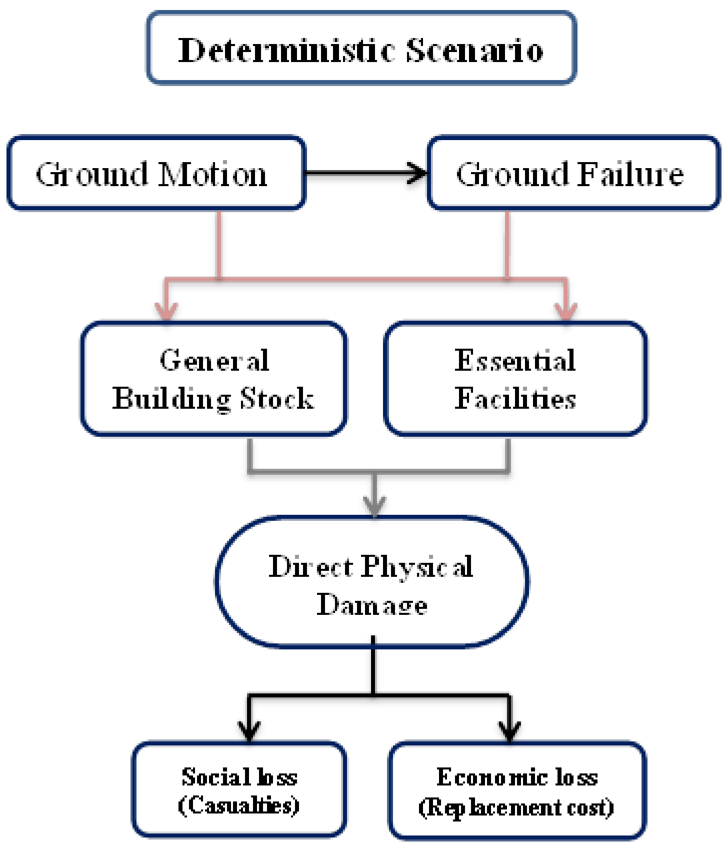


Figure (1) Flowchart of the Earthquake Loss Estimation Methodology adopted by HAZUS

Taungoo City

Taungoo is a city in the Bago Region of Myanmar, 220 km form Yangon, towards the north-eastern end of the division, with mountain ranges to the east and west. The main industry is in forestry products, with teak and other hardTimbers extracted from the mountains. The city is known for its areca palms, to the extent that a Burmese proverb for unexpected good fortunes is equated to a “betel lover winning a trip to Taungoo”. The location map of Taungoo City is shown in figure (2).

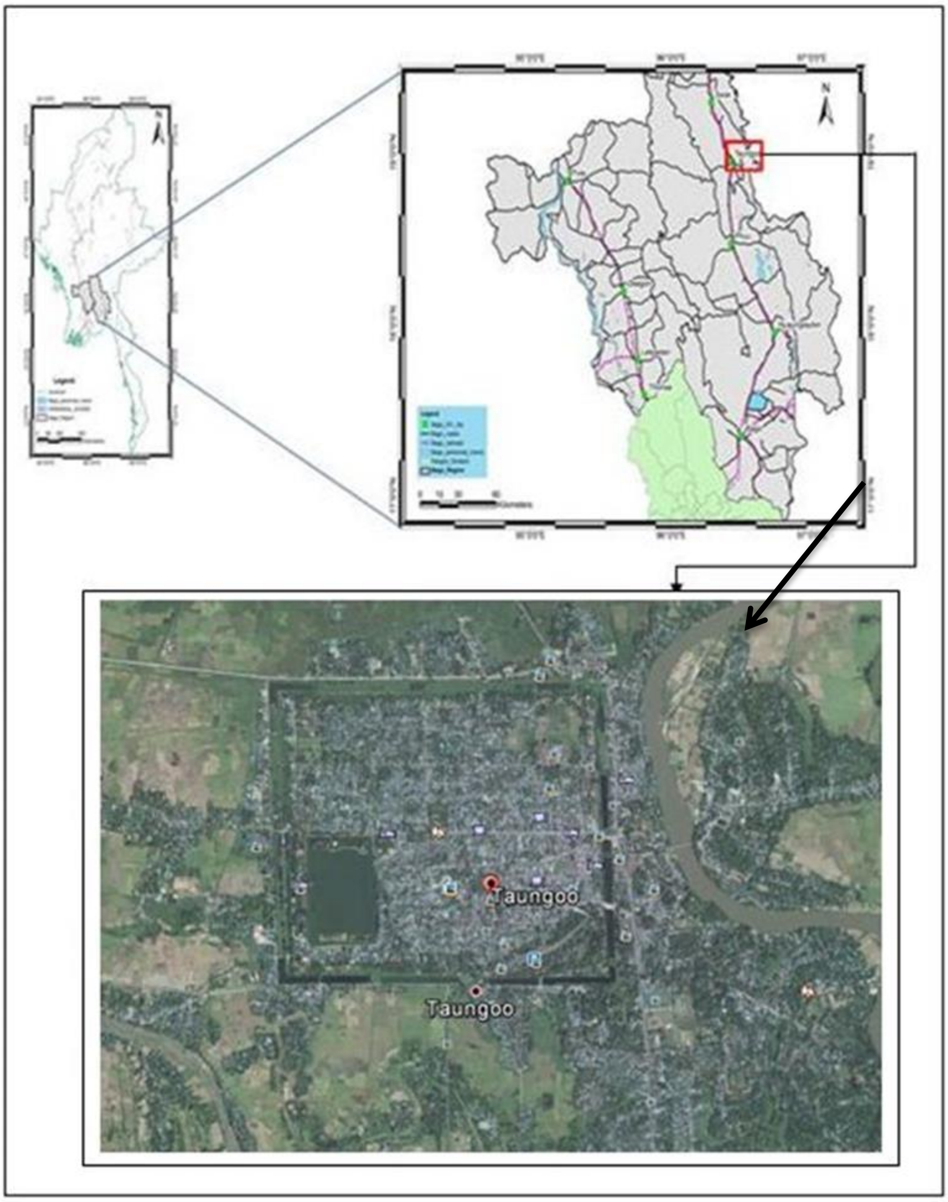


Figure (2) Location Map of the Study Area

The city is famous in Burmese history for the Taungoo Dynastry which ruled the country for over 200 years between the 16th and 18th centuries. Taungoo was the capital of Burma in 1510-1539 and 1551-1552. Taungoo city is mainly composed of 23 wards and there are over 17 thousand households in the region with a total estimated population of over 1 million. Significant and famous places of Taungoo city is shown in figure (3)

Figure (3) Significant and Famous Places in Taungoo City

Taungoo City lies among the Sagaing Fault, Kyaukkyan Fault and Papuan Fault. Sagaing Fault is situated in the west of the study area, Kyaukkyan Fault and Papun Fault are in the east. The earthquake risk of the Taungoo City is mainly caused by the movement along the Sagaing Fault which is a right-lateral strike-slip fault that runs north-south along the eastern flank of Bago Yoma. High magnitude events indicate that the Sagaing Fault is the principle source of seismic hazards in Myanmar. Taungoo City is the earthquake prone city in study area.

The most significant event is the magnitude 7.3, August 8, 1929 Swa earthquake. This earthquake caused severe damage in Taungoo Township, e.g. the railway was bent and the bridges and culverts caused damage and the loaded trucks were turned upside down. Another one is the Bago earthquake that struck on May 5, 1930 with the magnitude of 7.3. This event caused 500 deaths in Bago and several buildings damaged. Phyu earthquake occurred on December 3, 1930 with the magnitude of 7.3. It destroyed many houses and caused 30 casualities in Phyu. Figure (4) below shows previous past earthquakes around Taungoo City and distribution of past earthquakes in Myanmar.

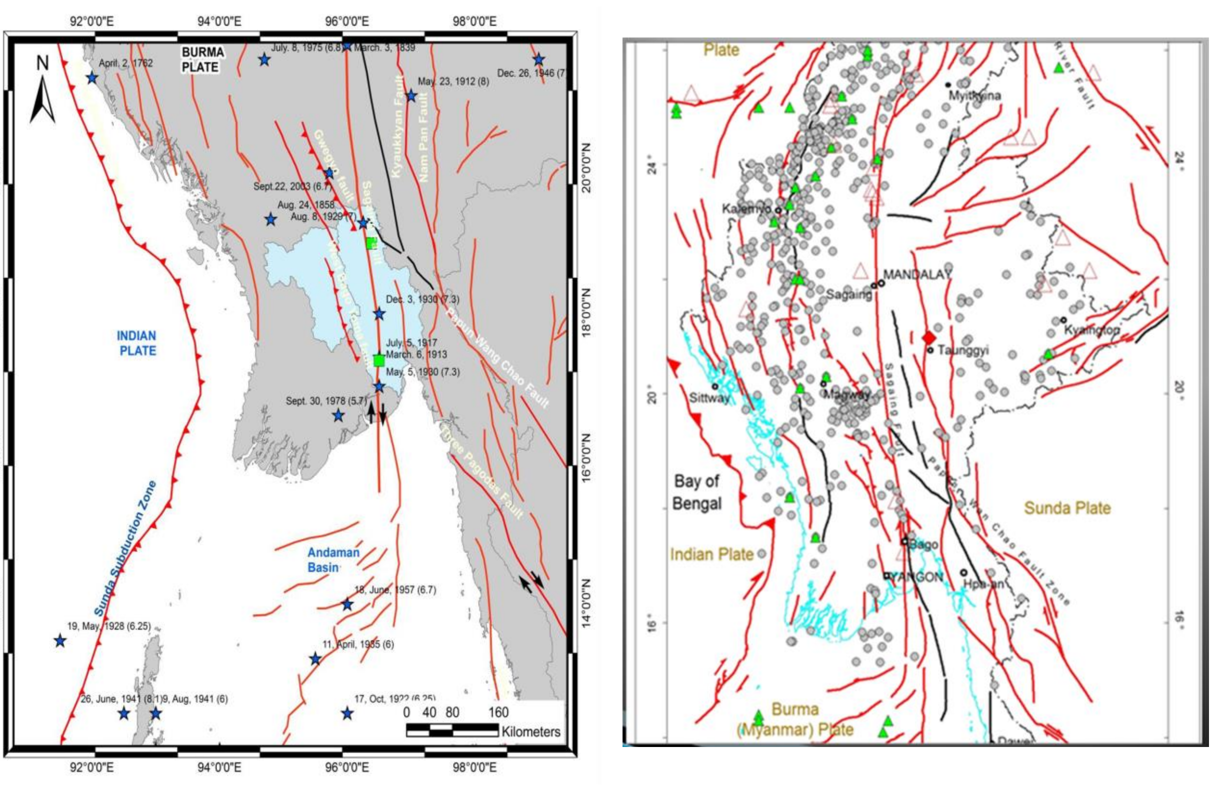


Figure (4) Epicentral distribution of the previous earthquakes with magnitude ≥ 6, happened around Taungoo Region and Distribution of Earthquakes 1900-2009

Livelihood in Taungoo

As per demographic data, Yakhinesu Naypukhone ward has the highest population whereas South Pan Pae Tan ward has the lowest one. Among all other data in the livelihood, the highest number of building, population, and households are in Yakhinesu Naypukhone ward. Tat Myae ward is the second populated area in Taungoo in which Min Kyee Nyo is in the third place. Yakhinesu Naypukone (10478), Tat Myae (8280), and Minn Kyee Nyo (7526) have got the highest population among any other wards in Taungoo whereas South Pan Pae Tan (953) have got the lowest population. Population is just above 9% of highest population in Shan Tan and Lann Ma Kyae wards (Figure A-1). The highest population density (population per area-km2) among any other wards is in Zaung Chan Taung. And Kwae Zay is the second highest in population density. (Figure A-2).

As Yakhinesu Naypukone 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 South Pan Pae Tan (773), Lann Ma Kyae(799) and Shan Tan (802) are the lowest (Figure A-3). Ngwe Hlan Oae Kone (2001), Myo Gyi (2023), Tat Myae (2486), and Minn Kyee Nyo (2881) are the second highest number of aged above 18.(Figure A-4). In female to male ratio, Kan Taw, Zaung Chan Taung, Lann Ma Kyae, Kyat Tae, South Pan Pae Tan and North Pan Pae Tan are the highest in Taungoo.(Figure A-5). The number of households in Yakhinesu Naypukone (2250) and Tat Myae (1748) are the largest as population distribution. The wider the ward is, the higher the household is (Figure A-6). Among all wards, South Pan Pae Tan and Shan Tan wards have the lowest building counts of under 200 (Figure A-7). Also Zay Taung, Kwae Zay and Kyat Tae wards have got the highest building density in any other wards in Taungoo (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 is related to economic loss. Three groups of wards in Taungoo 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 five structure types which can be found in Taungoo. These are Timber, Brick Nogging, Reinforced Concrete, Brick Masonry, and Mixed-use. Timber building types are the most common type in Taungoo.

Reinforced Concrete Building (C3L)

Brick Nogging Building (RM1L)

Mixed- Use Building (MH)

Brick Masonry Building (URML)

Timber Building (W1L)

Figure (5) Different types of Structural Types in Taungoo City

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 Table (3.10). 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 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. Table (1) shows definition of each structural type and table (2) and (3) show structural and occupancy types distribution of each ward in Taungoo.

Table (1) Definition of Structural Type

Timber (W1)	Timber, Light Frame (< 5,000 sq. ft.)
Brick-nogging (RM1L)	Unreinforced Brick Masonry Bearing Walls with Timber Diaphragms
Brick Masonry (URML)	Unreinforced Brick Masonry Bearing Walls
Reinforced Concrete (C3L)	Reinforced Concrete Frame with Unreinforced Brick Masonry Infill Walls
Mixed-use (MH)	Other Type of Building or Mixed use buildings

Table (2) Distribution of Structural Types in Taungoo

Name	C3L	C3M	TFM	URML	W1	MH
Minn Kyee Nyo	5	0	1012	7	372	0
Chin Thae Oo	10	0	446	2	400	8
Myo Gyi	12	0	805	16	400	0
Yakhinesu Naypukhone	23	0	1289	6	587	84
North Oak Kyut Tan	11	0	479	5	130	140
North Pan Pae Tan	0	0	214	4	75	22
Kan Taw	35	0	668	45	272	72
Zay Tan	20	0	175	3	191	0
East Oak Kyut Tan	0	0	143	6	55	193
Ngwe Hlan Oae Kone	52	0	306	15	617	135
Zayar Khin Oo	0	0	445	13	160	0
South Oak Kyut Tan	4	1	163	11	130	2
Tat Myae	0	0	900	18	700	0
Htee Hlaing	25	0	83	7	255	218
Shan Tan Kwae Zay	51	0	68	7	42	2
South Pan Pae Tan	4	0	105	0	85	3
Taung Kwae Zay	34	0	226	0	59	0
Zay	29	0	310	5	11	0
Lann Ma Kyae	5	0	149	0	50	0
Kyat Tae	23	0	166	0	106	0
Yoedar Tan	0	0	294	4	111	55
Zaung Chan Taung	0	0	100	5	78	217
Mann	2	0	281	0	75	52

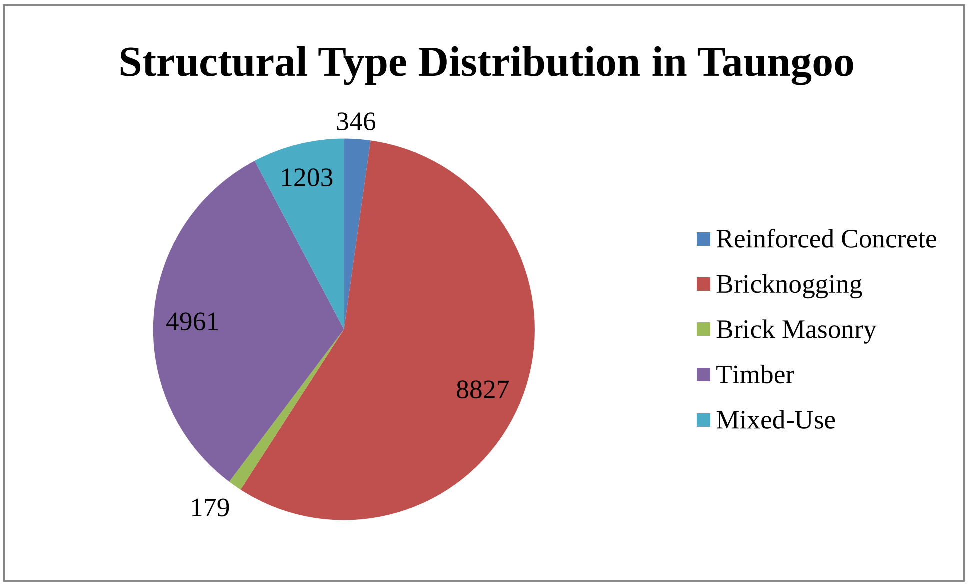


Figure (6) Structural Type Distribution in Taungoo City

- **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., Timber).
- **Demographics.** This table provides housing and population statistics for the study region.

Table (3) Distribution of Occupancy Types in Taungoo

Name	Residential	Commercial	Industrial	Medical	Government	Education	Religious
Minn Kyee Nyo	1333	49	1	2	1	2	8
Chin Thae Oo	685	171	4	3	1	1	1
Myo Gyi	1202	1	4	1	3	3	19
Yakhinesu Naypukhone	1932	39	5	0	1	3	9
North Oak Kyut Tan	686	62	0	3	7	0	7
North Pan Pae Tan	275	27	7	3	1	1	1
Kan Taw	1025	46	9	3	0	2	7
Zay Tan	358	16	1	1	0	3	10
East Oak Kyut Tan	394	0	0	0	0	2	1
Ngwe Hlan Oae Kone	1061	40	1	5	2	3	13
Zayar Khin Oo	613	0	0	0	2	1	2
South Oak Kyut Tan	291	10	2	1	1	1	5
Tat Myae	1584	11	1	4	12	3	3
Htee Hlaing	577	3	0	0	0	1	7
Shan Tan Kwae Zay	150	6	0	0	2	2	10
South Pan Pae Tan	189	6	0	1	0	0	1
Taung Kwae Zay	147	162	0	3	4	1	2
Zay	259	86	0	0	2	0	8
Lann Ma Kyae	167	29	0	4	2	1	1

Kyat Tae	289	4	0	0	1	1	0
Yoedar Tan	445	13	1	0	1	0	4
Zaung Chan Taung	392	5	1	1	0	1	0
Mann	391	18	0	0	1	0	0

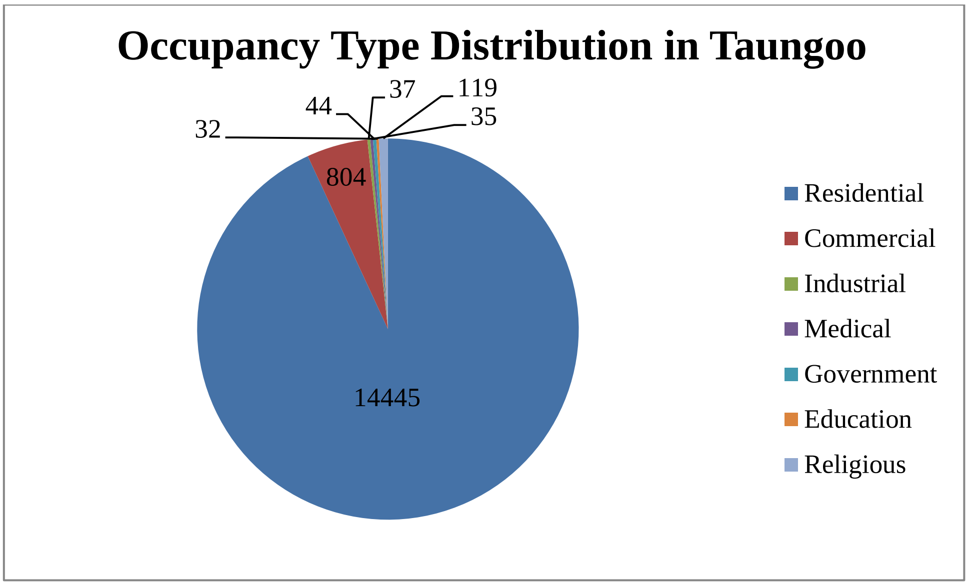


Figure (7) Occupancy Type Distribution in Taungoo City

Essential Facilities Inventory

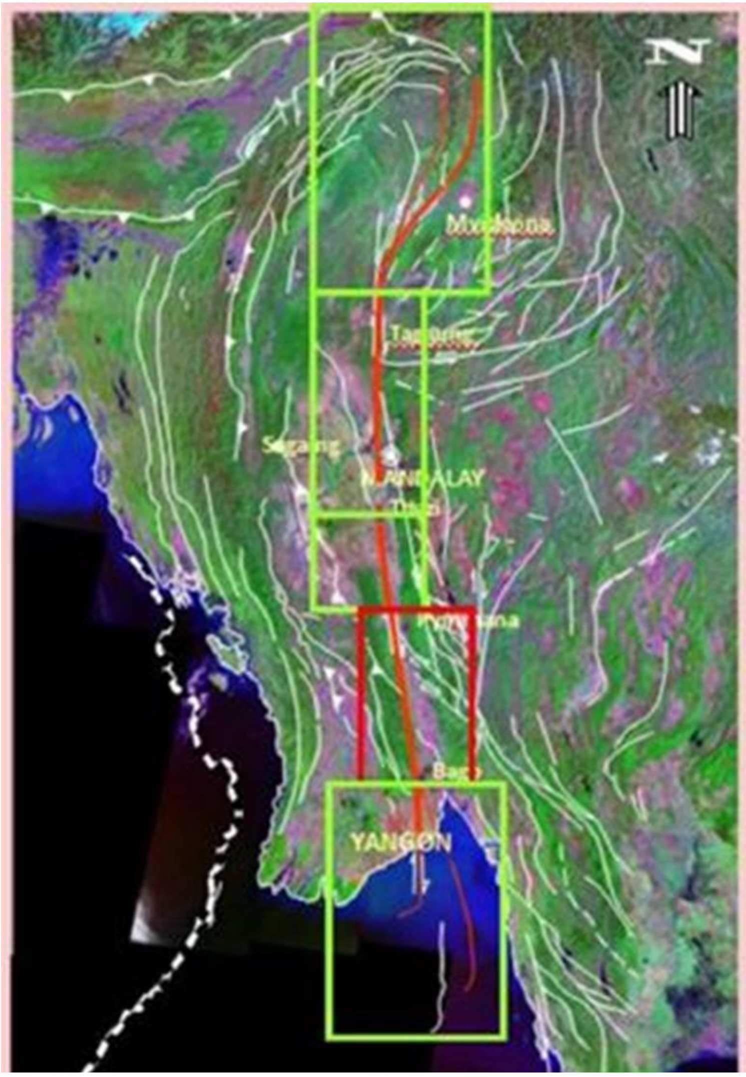
Essential facilities in Taungoo contain 16 hospitals, 4 police stations, 2 fire stations and 53 schools with a specific location of each building. The number of beds in hospital and the number of fire trucks at fire station are collected and applied. The ground motion parameters will be used on a site-specific 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.

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 run the analysis for 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 Sceanrios

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 (7). Two scenario earthquakes with the maximum probable magnitude in Phyu segment (143km long) and Swa segment (80km long) are assumed to be occurred. Epicenter location of two earthquake scenarios is shown in Figure 8, and scenario information is listed in Table (4) and (5).



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(8) Five Segments on Sagaing Fault

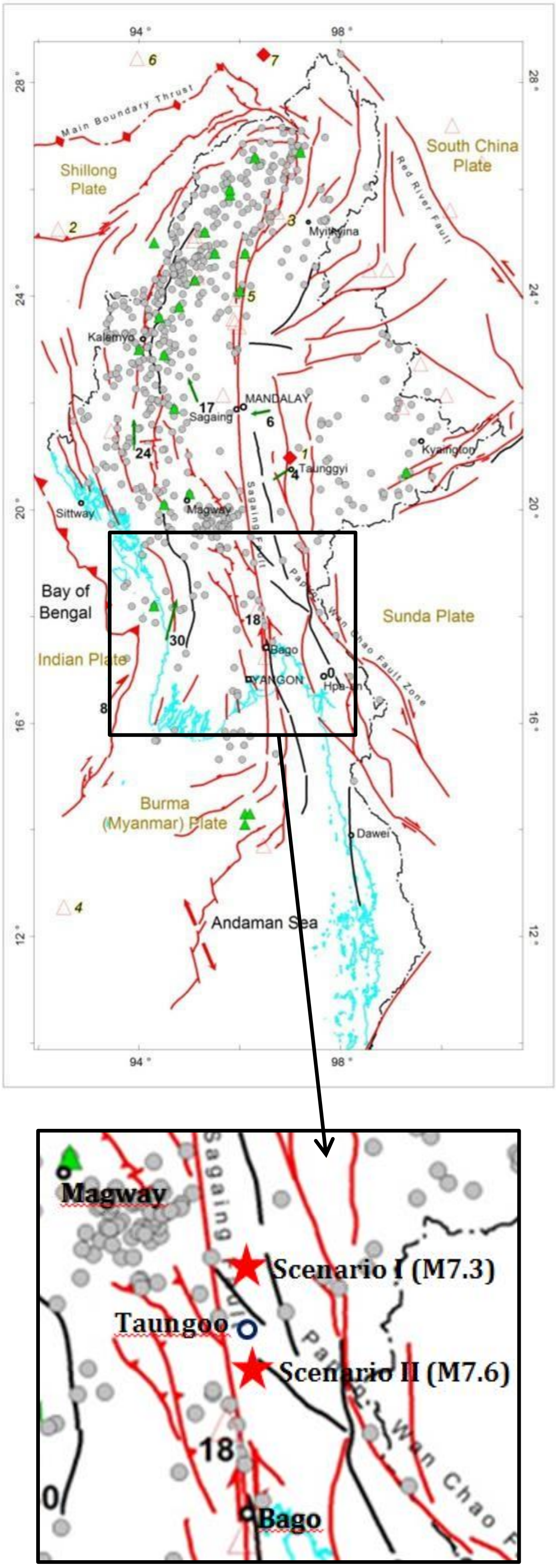


Figure (9) Tectonic Map of Myanmar and Two scenarios on Sagaing Fault

Scenario Name	Scenario I
Type of Earthquake	Strike Slip Fault
Epicentral Distance	68.54 km
Earthquake Magnitude	7.3
Depth(km)	10
Rupture Width	16.2
Rupture Orientation (Degrees)	170
Dip (Deg)	90
Attenuation Function	Boore. Joyner and Fumal (1997)

Table (5) Scenarios II (Phyu Segment)

Scenario Name	Scenario II
Type of Earthquake	Strike Slip Fault
Epicentral Distance	48.77 km
Earthquake Magnitude	7.6
Depth(km)	10
Rupture Width	19.4
Rupture Orientation (Degrees)	170
Dip (Deg)	85
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 Meterology and Hydrology (Nay Pyi Daw) that based on geological condition of Myanmar.

Direct Earthquake 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

In Scenario I, HAZUS estimates that about 4139 buildings will be at least moderately damaged. This is over 27.00 % of the total number of buildings in the region. There are an estimated 205 buildings that will be damaged beyond repair. Figure (B-9 to B-28) is the damage distribution of building in each ward for M 7.3 earthquake in Swa segement.

In Scenario II, HAZUS estimates that about 12117 buildings will be at least moderately damaged. This is over 78.00 % of the total number of buildings in the region.

There are an estimated 5212 buildings that will be damaged beyond repair. Figure (B-29 to B-48) is the damage distribution of building in each ward for M 7.6 earthquake in Phyu segement.

Table (6) and table (7) present building damages by structural types in two scenarios.

Table (6) Expected Building Damage by Structural Type (Maximum Est. Magnitude M7.3)

	Total No. of Buildings	None	Slight	Moderate	Extensive	Complete
Timber	4794	2927	1260	536	66	5
Reinforced Concrete	498	119	104	149	106	20
Brick Nogging	8774	4146	2136	1887	576	29
Brick Masonry	230	14	26	81	81	28
Mixed-use	1221	78	143	435	423	142
Total	15517	7285	3669	3087	1252	224

Table (7) Expected Building Damage by Structural Type (Maximum Est. Magnitude M7.6)

	Total No. of Buildings	None	Slight	Moderate	Extensive	Complete
Timber	4794	1197	1618	1488	414	77
Reinforced Concrete	498	4	10	53	91	340
Brick Nogging	8774	156	429	2176	2465	3548
Brick Masonry	230	0	3	8	54	165
Mixed-use	1221	2	8	51	312	848
Total	15517	1360	2066	3776	3337	4978

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. Police station and fire station should also be functional to prevent fire following earthquake and to serve in search and rescue after earthquake.

For Scenario I, no hospital beds are available to use by patients already in the hospital and those injured on the day of the earthquake. After one week, 54.00% of the beds will be back in service. By 30 days, 81.00% will be operational. (Table 8)

For Scenario II, no hospital beds are available to use by patients already in the hospital and those injured on the day of the earthquake. After one week, 4.00% of the beds will be back in service. By 30 days, 17.00% will be operational. (Table 8)

Table (8) Essential Facilities Damages in Two Earthquake Scenarios

	Classification	Total	At Least Moderate damage >50%	Complete damage >50%	With Functionality > 50% on day1
Scenario I (M7.3)	Hospitals	16	16	0	0
	Schools	53	0	0	2
	EOCs	0	0	0	0
	Police Stations	4	0	0	0
	Fire Stations	2	2	0	0
Scenario II (M 7.6)	Hospitals	16	16	16	0
	Schools	53	53	0	0
	EOCs	0	0	0	0
	Police Stations	4	4	0	0
	Fire Stations	2	2	2	0

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

For Scenario I, a total of 0.130 million tons of debris is generated (Table 9). Of the total amount, Brick/Timber comprises 36.00% of the total, with the remainder being Reinforced Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 5000 truckloads (@ 25 tons/truck) to remove the debris generated by the earthquake M7.3 in Swa segment.

For Scenario II, a total of 0.740 million tons of debris is generated (Table 9). Of the total amount, Brick/Timber comprises 32.00% of the total, with the remainder being Reinforced Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 29440 truckloads (@ 25 tons/truck) to remove the debris generated by the earthquake M7.6 in Phyu segment.

Table (9) Debris and Total Truckloads for Earthquake Scenarios

Scenario Name	Brick/ Timber/ Others		RC/ Steel		Total Debris (Million Tons)	Number of Truckload
	Debris (Million Tons)	Truckload	Debris (Million Tons)	Truckload		
Scenario I, M 7.3	46 (36%)	1800	81	3200	128	5000
Scenario II, M 7.6	234 (32%)	9421	502	20019	736	29440

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.

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 (10) Causalities Estimates

Scenario Name	Level 1			Level 2			Level 3			Level 4		
	2 AM	2 PM	5PM	2 AM	2 PM	5 PM	2 AM	2 PM	5 PM	2 AM	2 PM	5 PM
Scenario I, M 7.3	180	208	118	34	47	24	3	6	3	6	12	5
Scenario II, M 7.6	2257	2143	1407	737	719	462	127	130	82	250	252	158

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 (11) and (12) presents building related economic losses for two scenarios.

Table (11) Building-Related Economic Losses in Millions of Kyats
(Maximum Estimated Magnitude M7.3)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	520	3500	10	660	4690
	Capital- Related	0	230	3030	10	900	3950
	Rental	4590	4830	1520	10	250	11200
	Relocation	16960	3280	2630	60	1650	24570
	Subtotal	21550	8850	10680	90	2650	43820
Capital Stock Losses	Structural	2500650	103340	25360	70	730	2630160
	Nonstructural	5063560	381960	33890	150	170	5481270
	Content	1222820	83530	19880	110	750	1327100
	Inventory	0	0	210	40	0	240
	Subtotal	8787030	568830	79340	360	3190	9438770
	Total	88080580	577680	90020	460	5840	9482580

Table (12) Building-Related Economic Losses in Millions of Kyats
(Maximum Estimated Magnitude M7.6)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0	201000	15210	70	241000	19700
	Capital- Related	0	870	12920	40	390	14230
	Rental	24410	24800	6500	40	1000	56760
	Relocation	82390	14990	10430	190	6660	114670
	Subtotal	106800	42680	45070	340	10470	205360
Capital Stock Losses	Structural	14677230	576070	158210	340	3850	15415700
	Nonstructural	41513370	2935620	301050	1380	13170	44764590
	Content	8926940	587760	152100	940	5760	9673500
	Inventory	0	0	1650	320	10	1980
	Subtotal	65117540	4099450	613010	2990	22970	69855780
	Total	65224340	4142130	658080	3340	33250	70061140

Conclusion

The damage results of this paper will be useful to decision makers and government officials who are responsible for disaster prevention and disaster preparedness in Taungoo 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.

These results will be 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 (W1)	Brick Nogging (RML)	Reinforced Concrete(C3)	Brick Masonry(URML)	Mixed-use(MH)
Slight	Small timber-board cracks at corners of door and window openings and wall-ceiling intersections	Diagonal hairline cracks on Brick 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 Brick 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 Brick 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 Reinforced Concrete beams or columns.	Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; Brick Masonry walls may have visible separation from diaphragms; significant cracking of parapets; some Brick Masonry may fall from walls or parapets. some Brick Masonry may fall from walls or	Large timber-board cracks at corners of door and window openings. Most wall surfaces exhibit diagonal cracks.
Extensive	Large cracks at plyTimber joints; splitting of Timber 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 Timber diaphragms may exhibit cracking and separation along Timber 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 Reinforced 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; Brick Masonry walls may have visible separation from diaphragms; significant cracking of parapets; some Brick Masonry may fall from walls or parapets.	Large cracks at plyTimber joints; splitting of Timber sill plates and/or slippage of structure over foundations; small foundations cracks. The Timber diaphragms may exhibit cracking and separation along Timber 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 Reinforced 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.

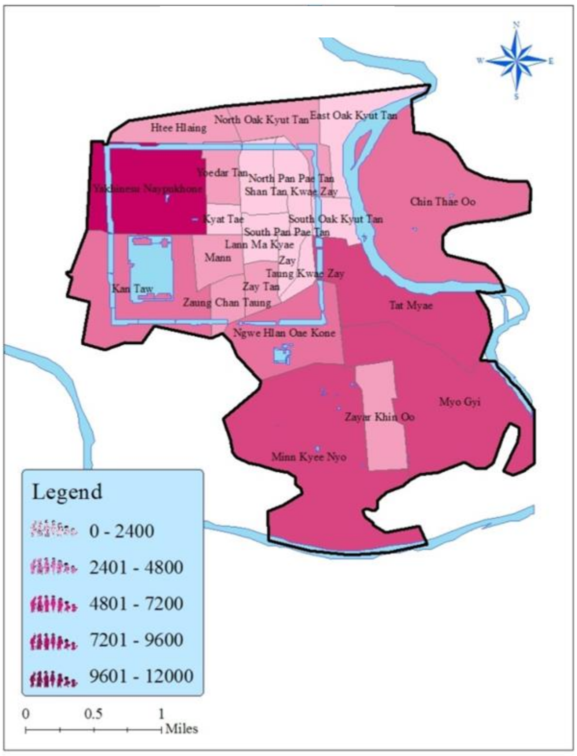


Figure (A-1) Population in Taungoo

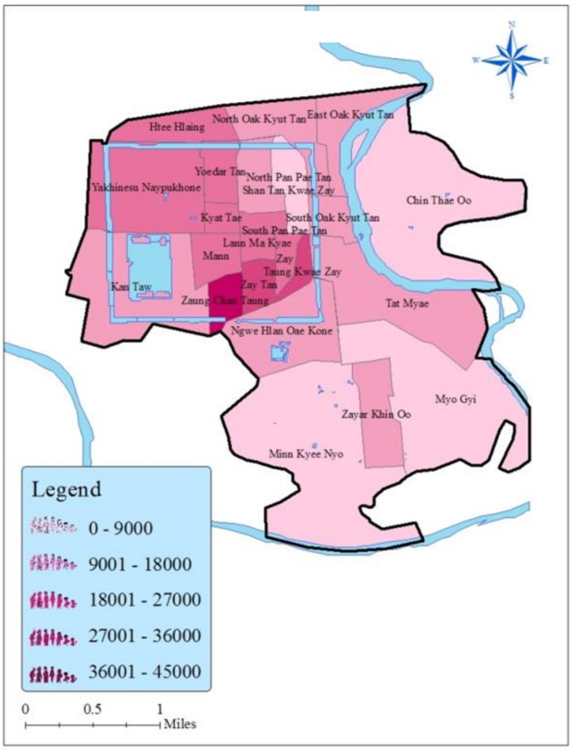


Figure (A-2) Population Density in Taungoo

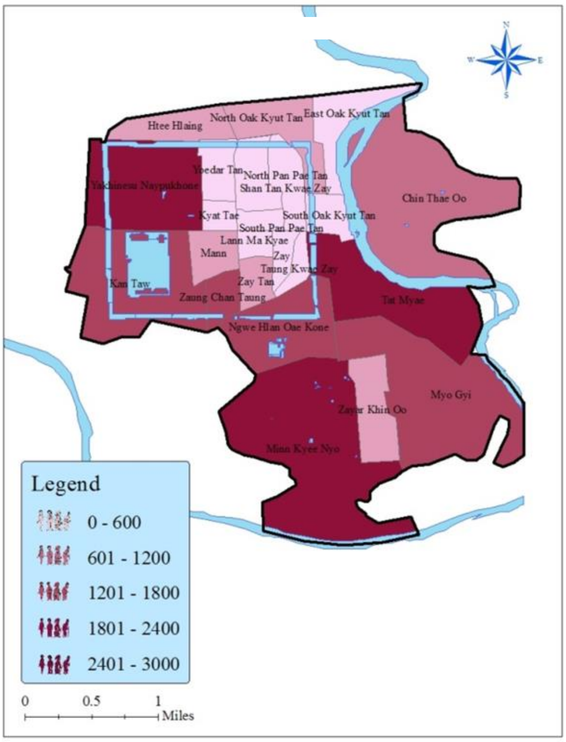


Figure (A-3) Age Over 18 in Taungoo

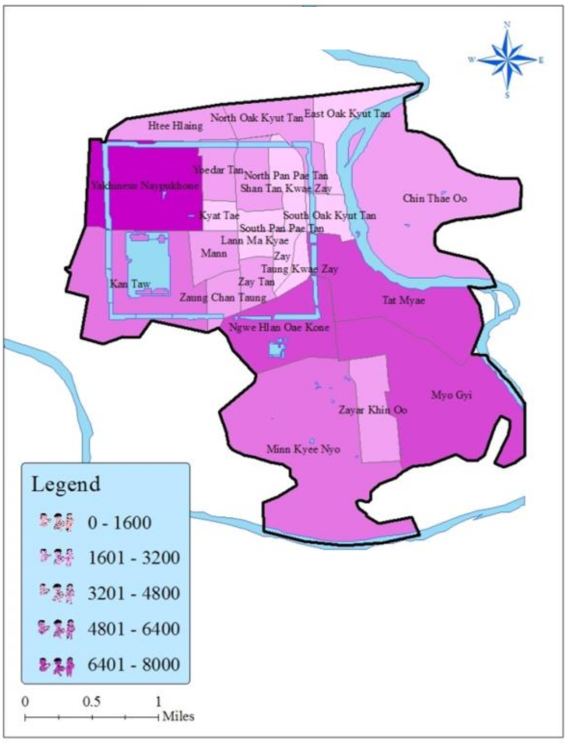


Figure (A-4) Age Under 18 in Taungoo

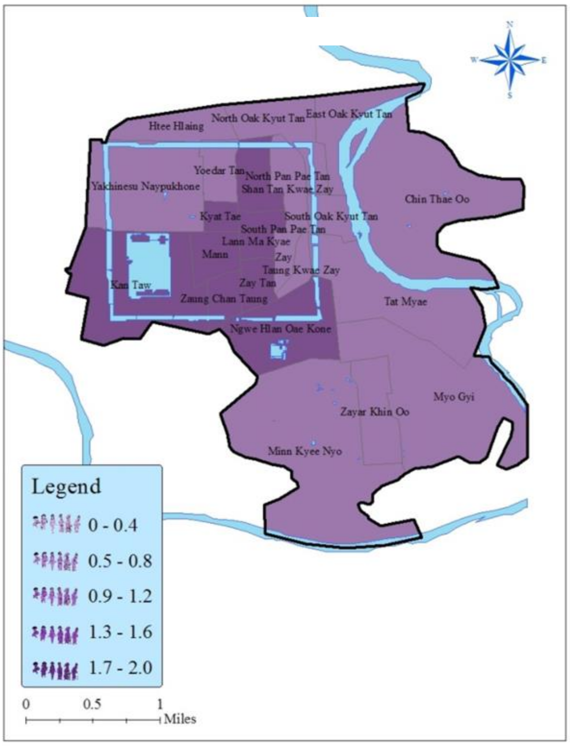


Figure (A-5) Female to Male Ratio in Taungoo

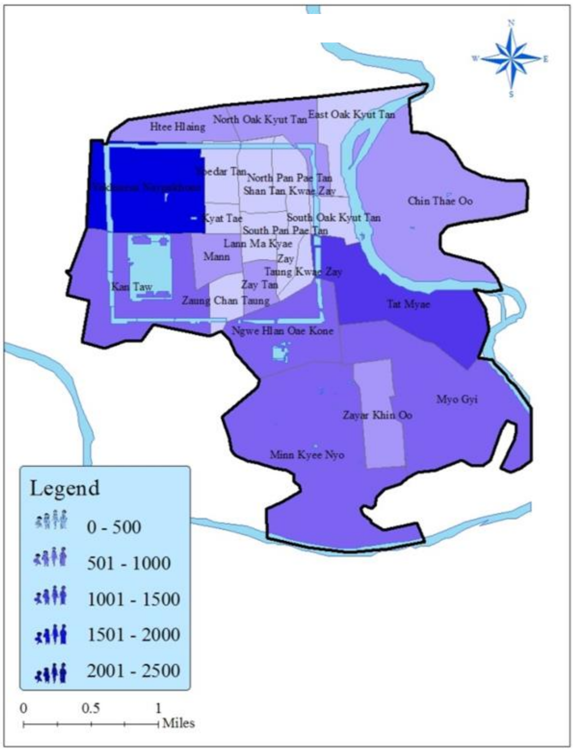


Figure (A-6) Households in Taungoo

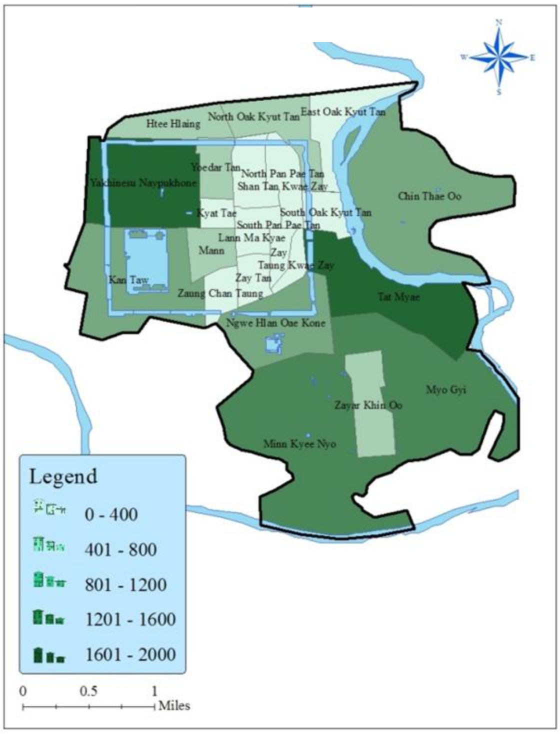


Figure (A-7) Building Count in Taungoo

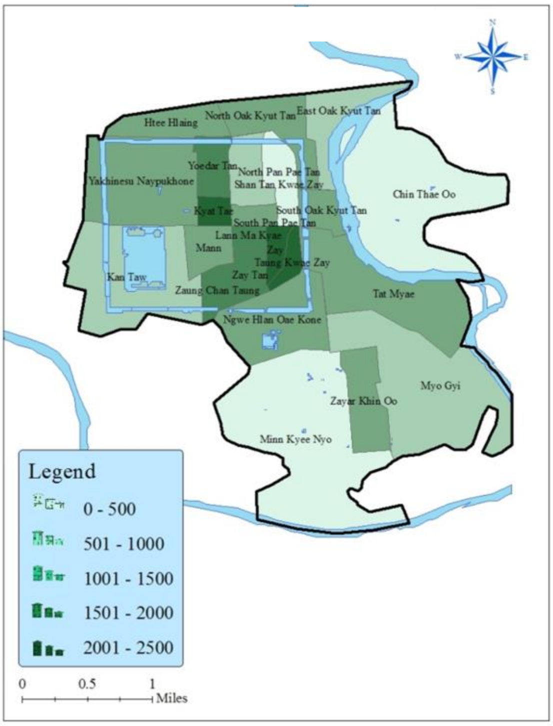


Figure (A-8) Building Density in Taungoo

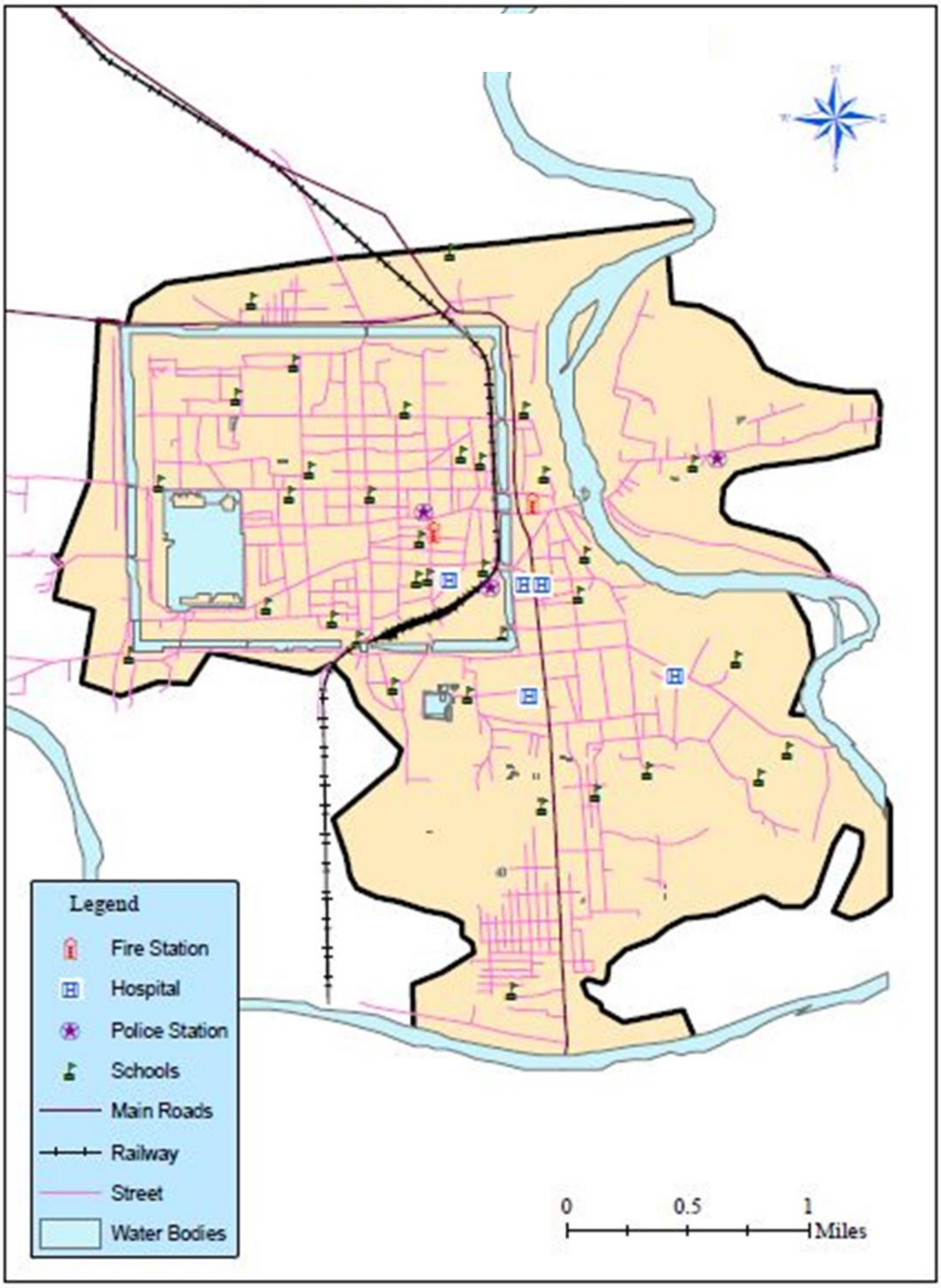


Figure (A-9) Location of Essential Facilities Map of Taungoo

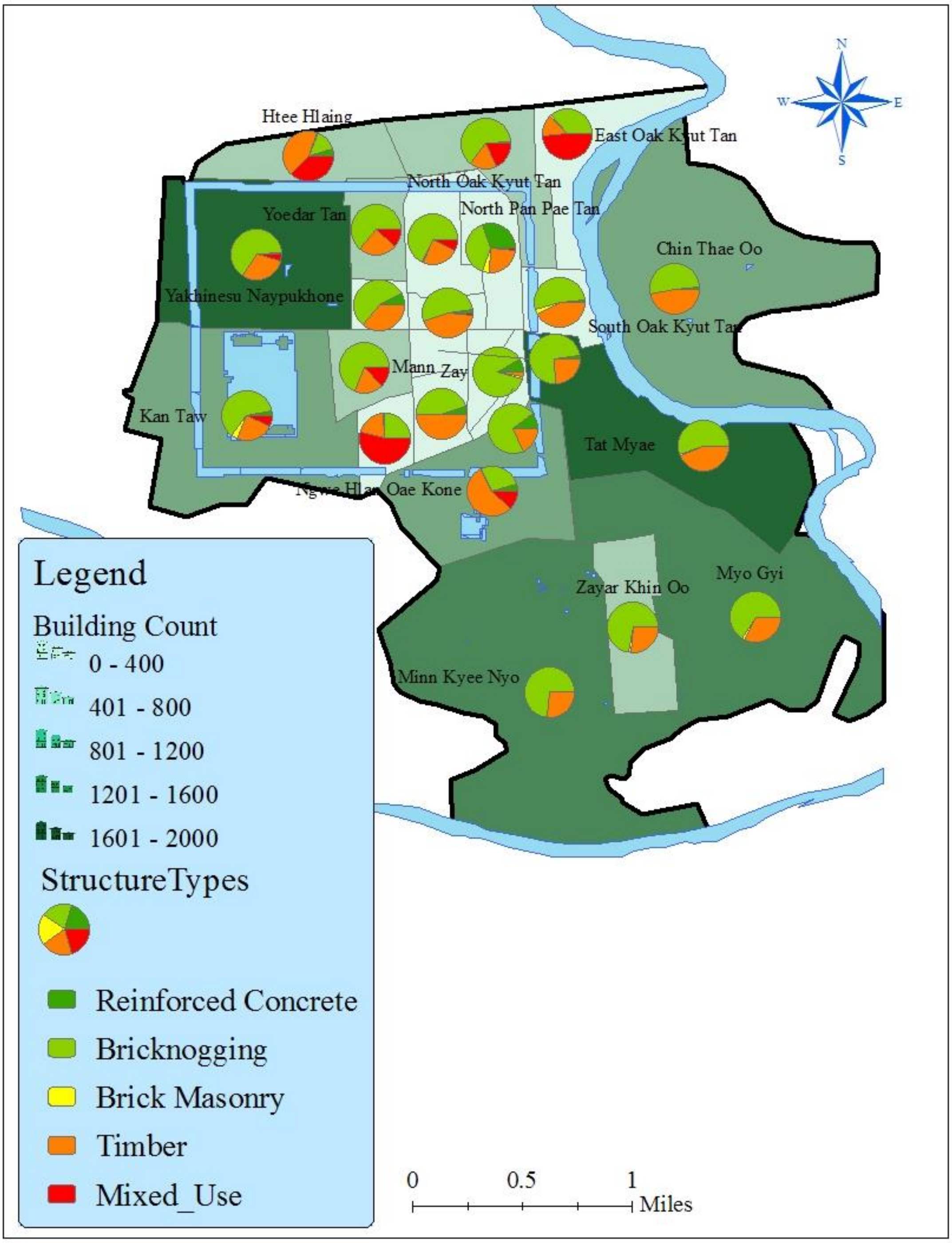


Figure (A-10) Structural Types Distribution of each ward in Taungoo City

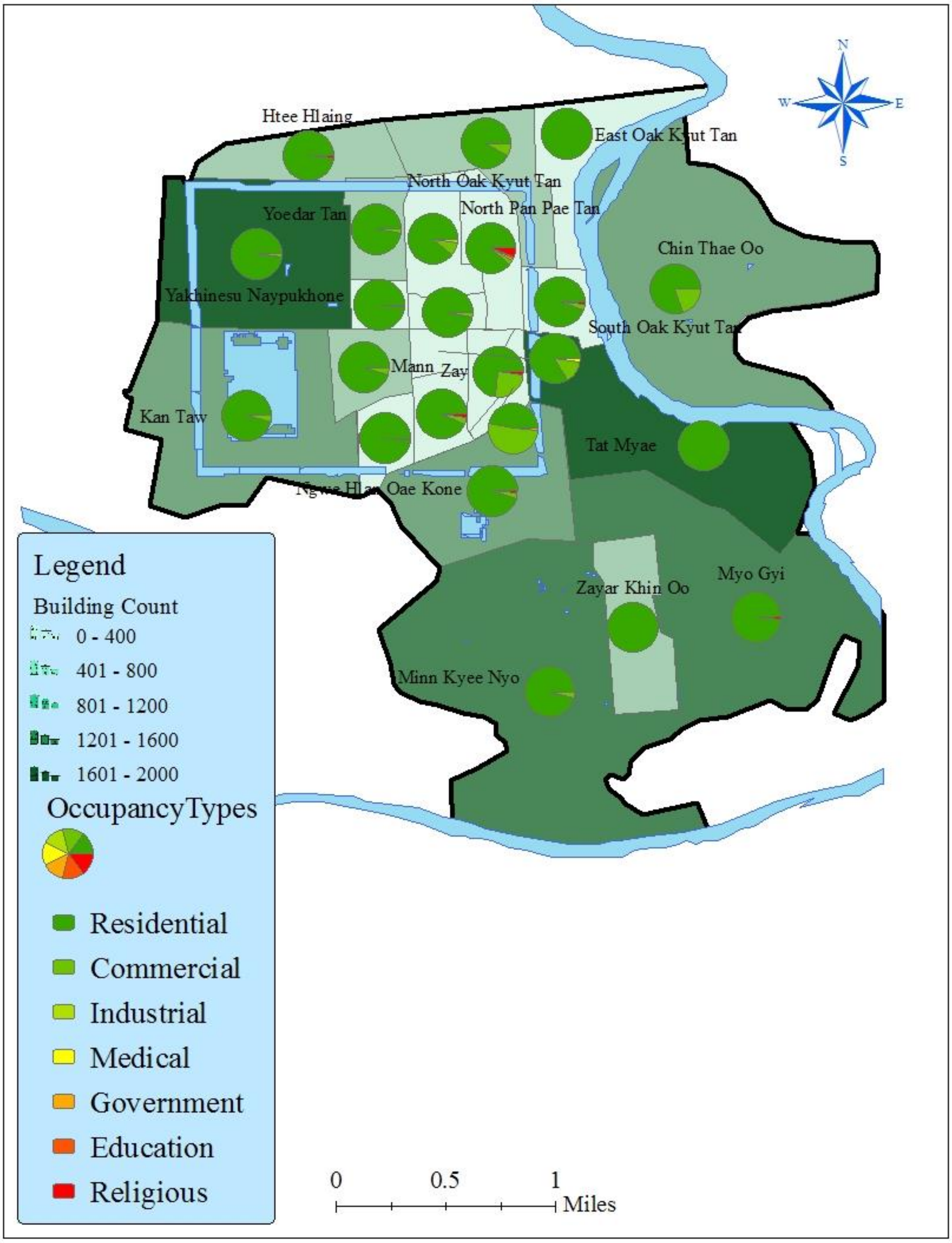


Figure (A-11) Occupancy Types Distribution of each ward in Taungoo City

APPENDIX-B

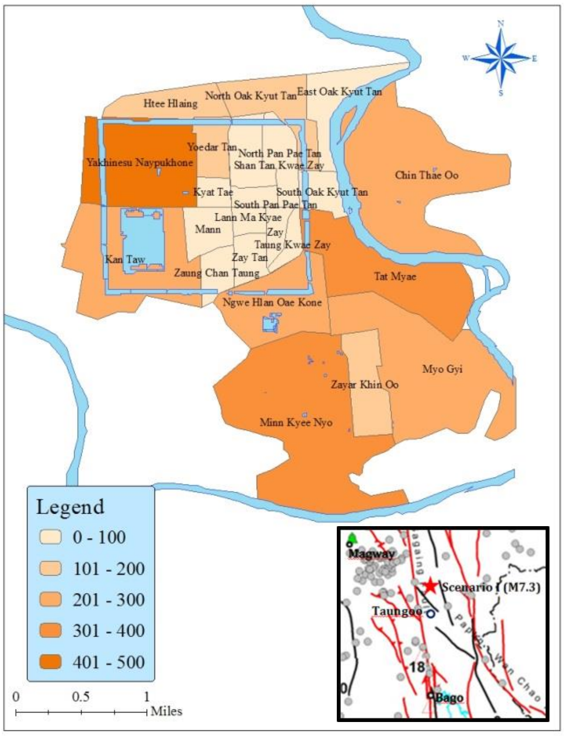


Figure (B-1) Total Slight Damaged Buildings in Taungoo (M 7.3)

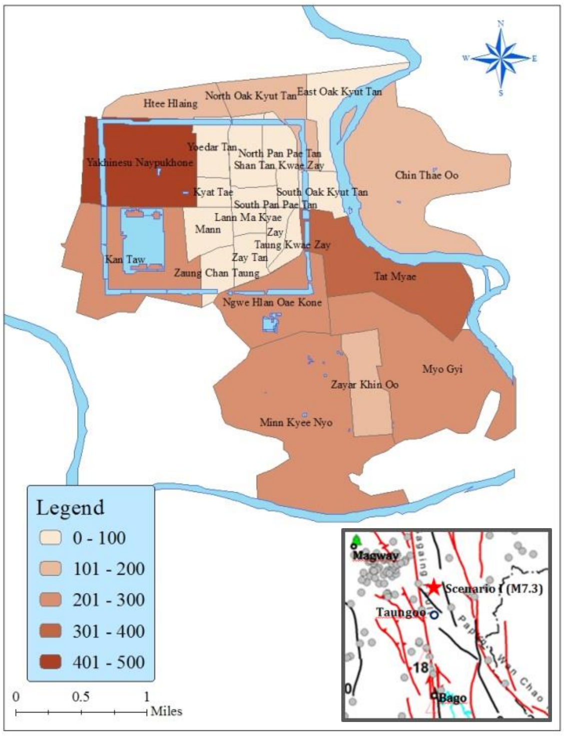


Figure (B-2) Total Moderate Damaged Buildings in Taungoo (M 7.3)

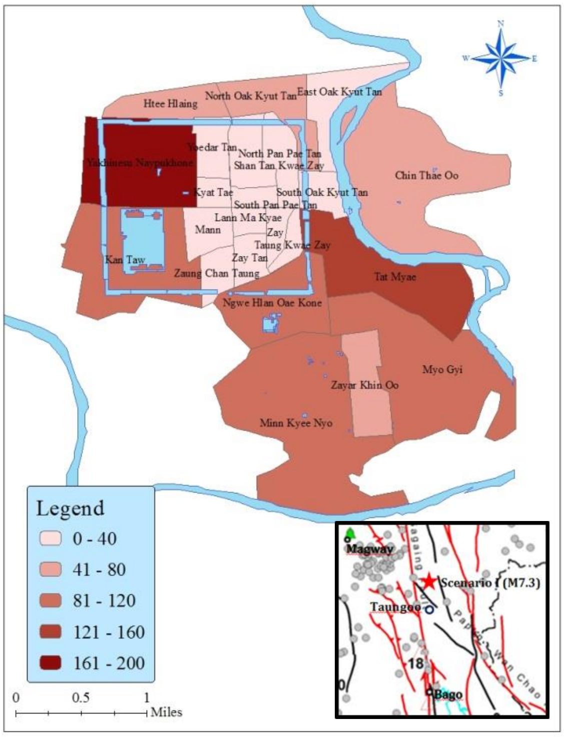


Figure (B-3) Total Extensive Damaged Buildings in Taungoo (M 7.3)

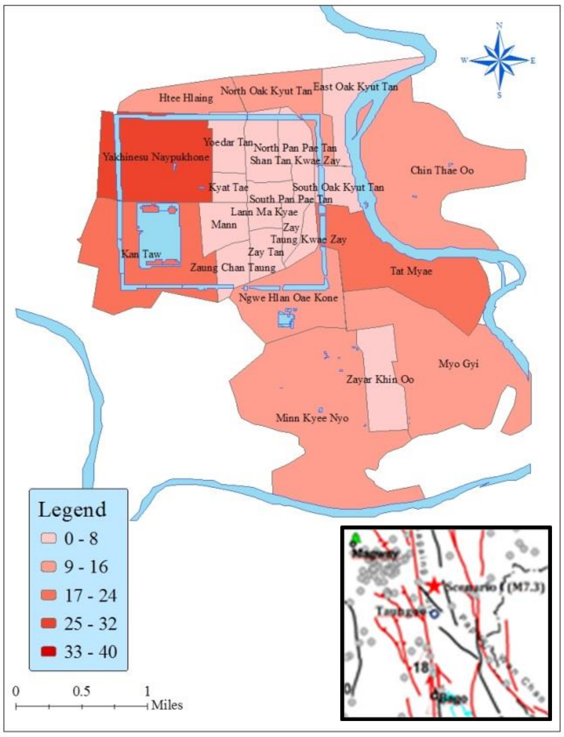


Figure (B-4) Total Complete Damaged Buildings in Taungoo (M 7.3)

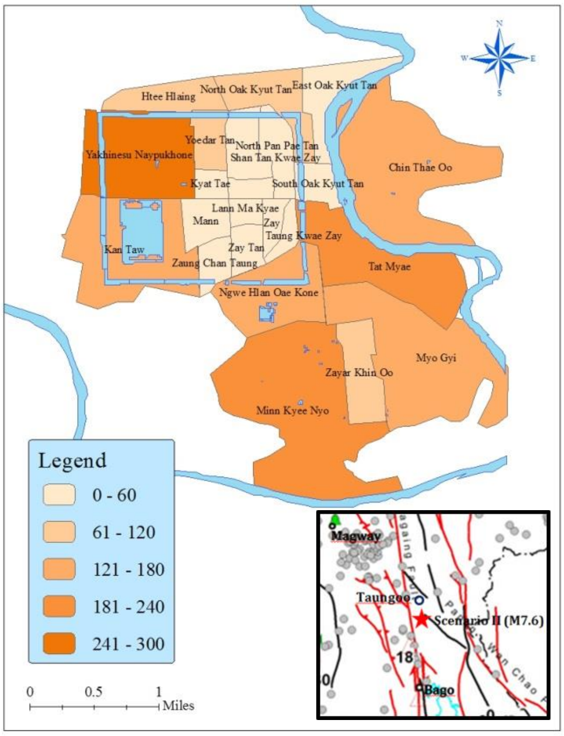


Figure (B-7) Total Slight Damaged Buildings in Taungoo (M 7.6)

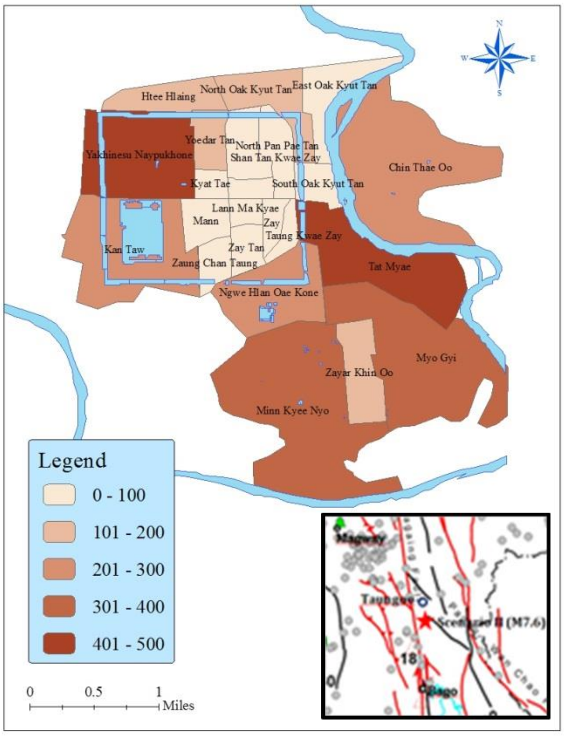


Figure (B-8) Total Moderate Damaged Buildings in Taungoo (M 7.6)

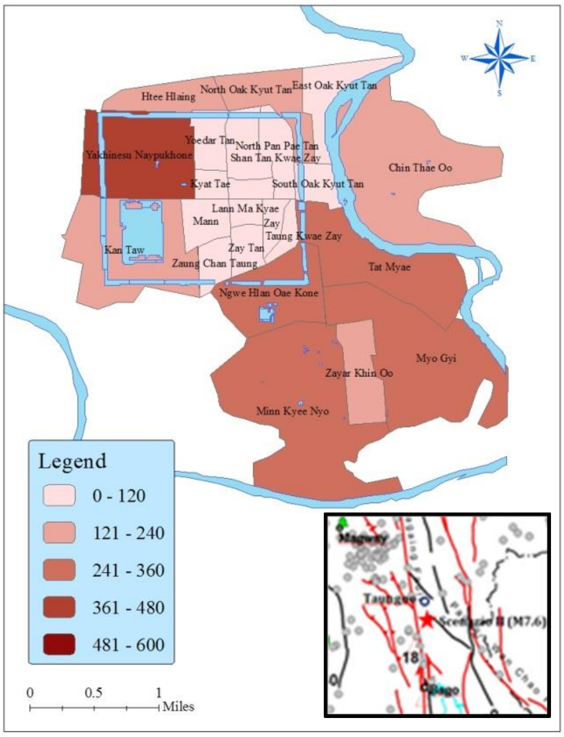


Figure (B-9) Total Extensive Damaged Buildings in Taungoo (M 7.6)

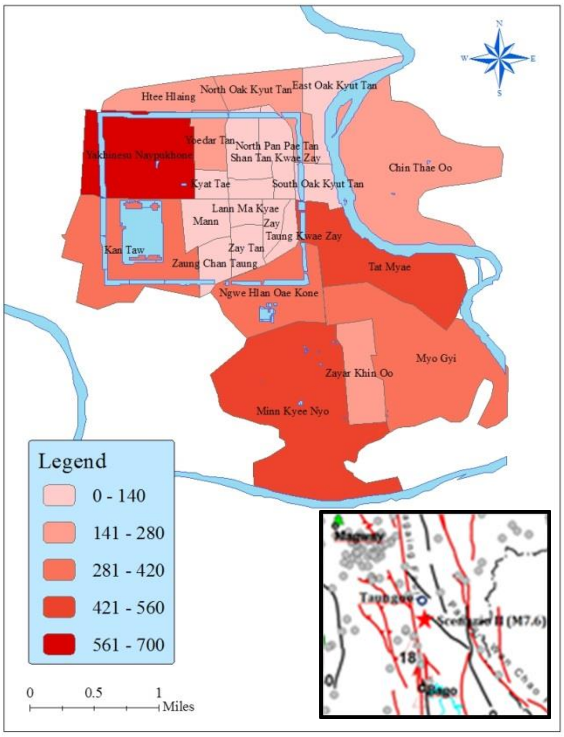


Figure (B-10) Total Complete Damaged Buildings in Taungoo (M 7.6)

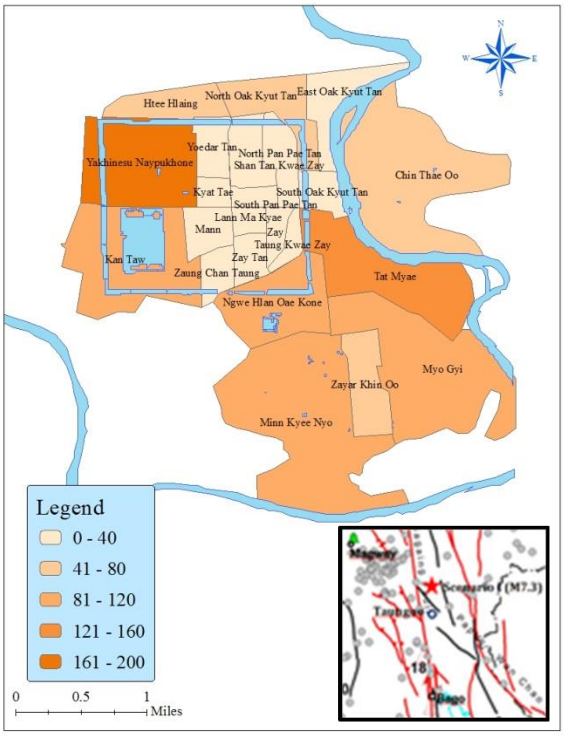


Figure (B-11) Slight Damage of Timber Buildings in Taungoo (M 7.3)

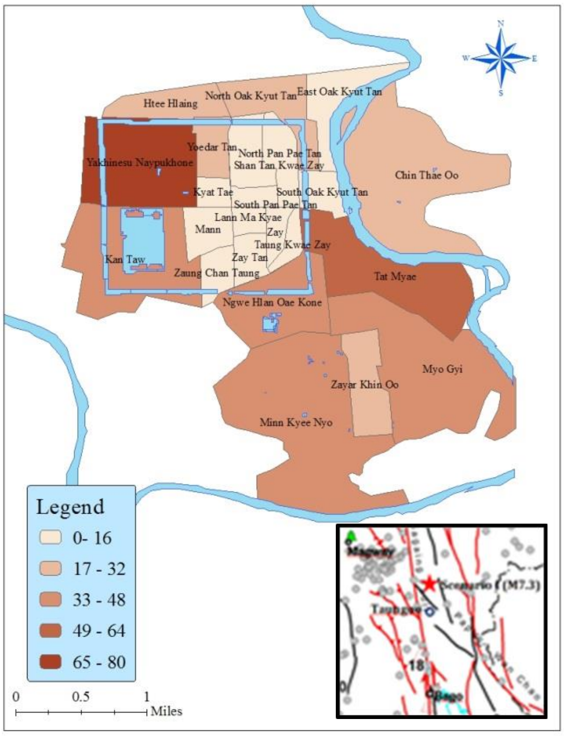


Figure (B-12) Moderate Damage of Timber Buildings in Taungoo (M 7.3)

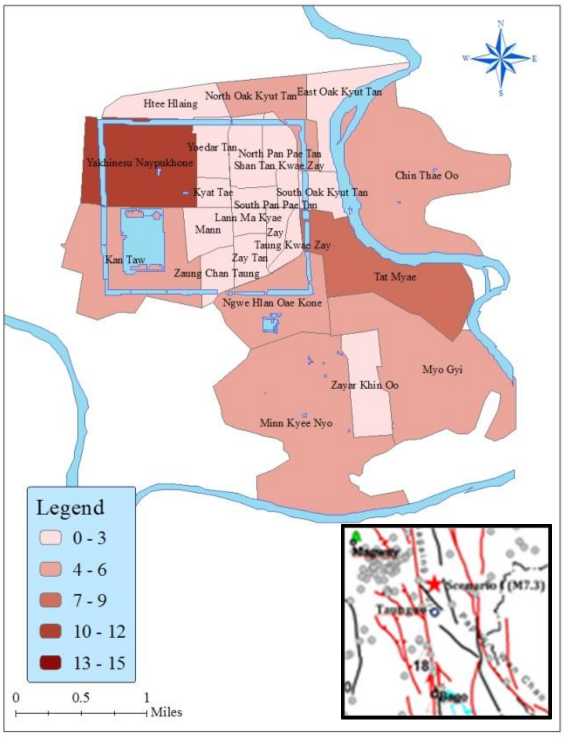


Figure (B-13) Extensive Damage of Timber Buildings in Taungoo (M 7.3)

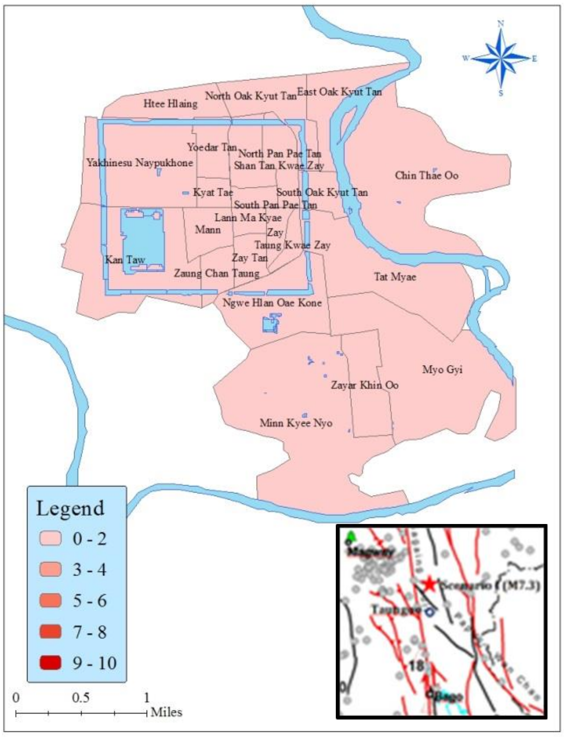


Figure (B-14) Complete Damage of Timber Buildings in Taungoo (M 7.3)

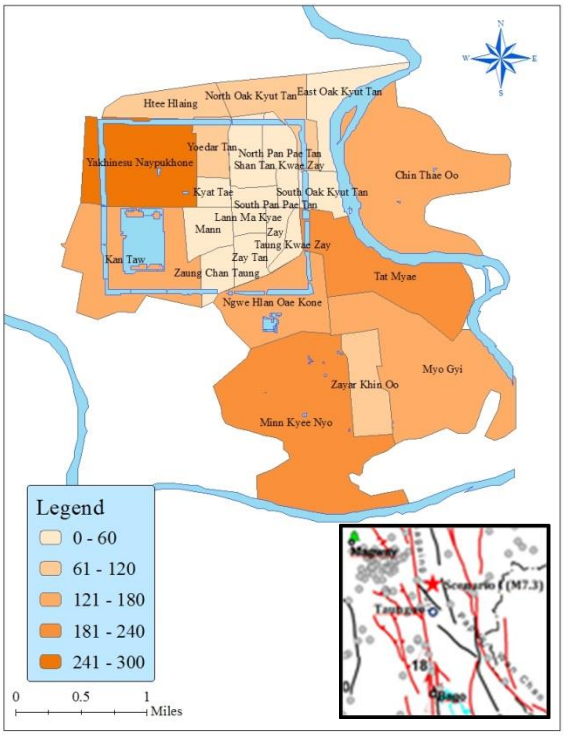


Figure (B-15) Slight Damage of Brick Nogging Buildings in Taungoo (M 7.3)

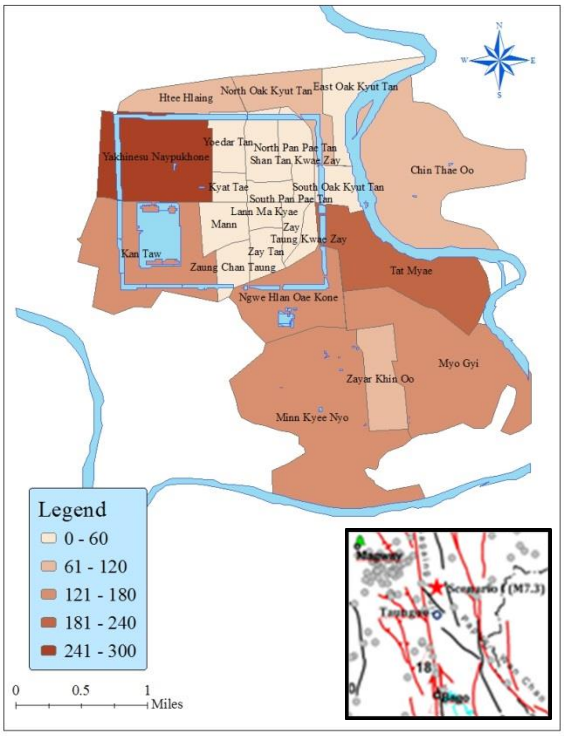


Figure (B-16) Moderate Damage of Brick Nogging Buildings in Taungoo (M 7.3)

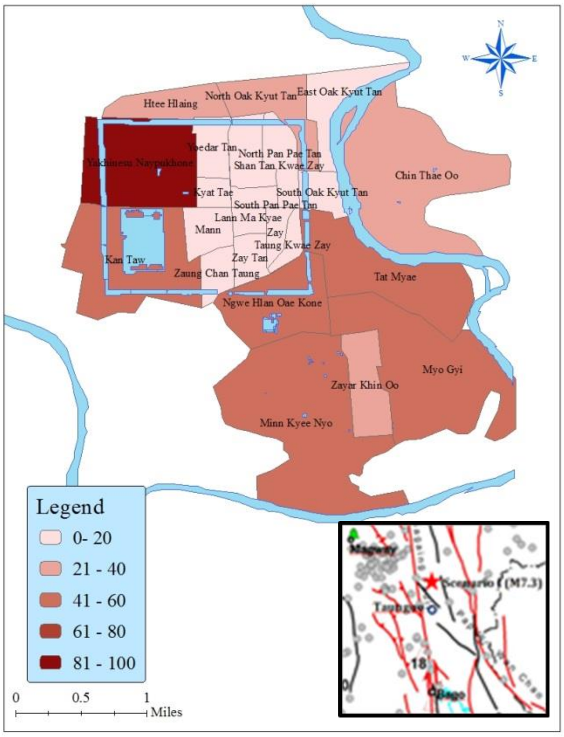


Figure (B-17) Extensive Damage of Brick Nogging Buildings in Taungoo (M 7.3)

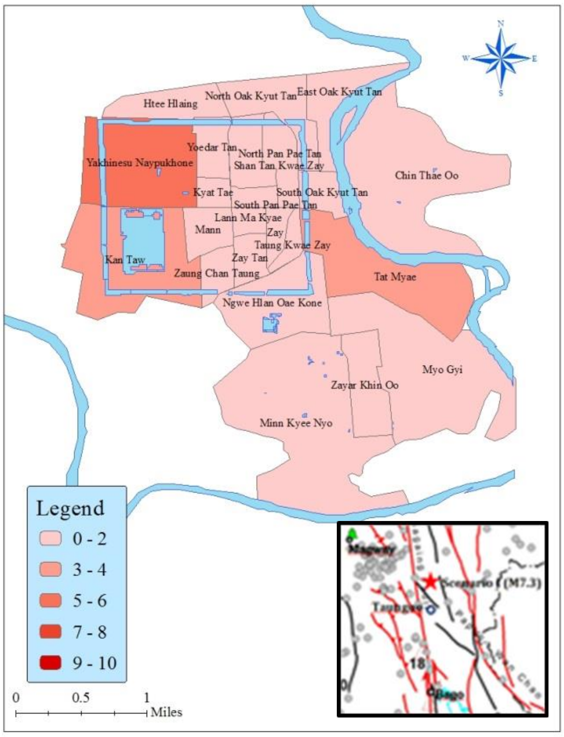


Figure (B-18) Complete Damage of Brick Nogging Buildings in Taungoo (M 7.3)

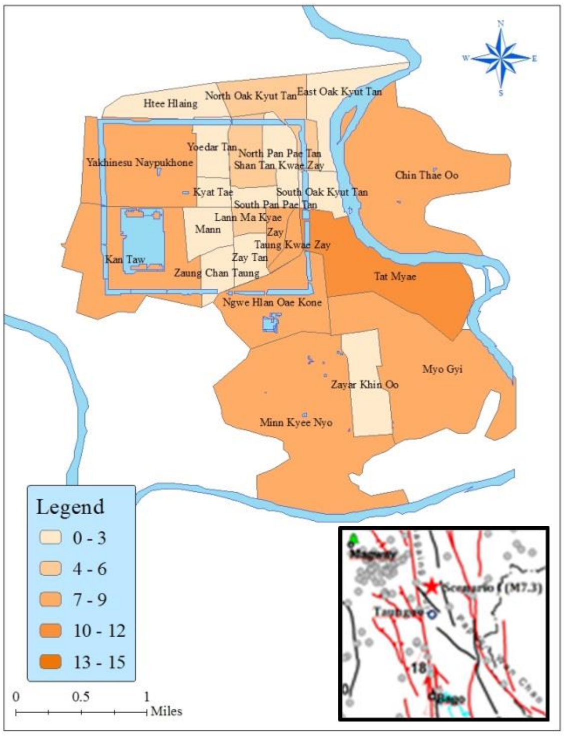


Figure (B-19) Slight Damage of Reinforced Concrete Buildings in Taungoo (M 7.3)

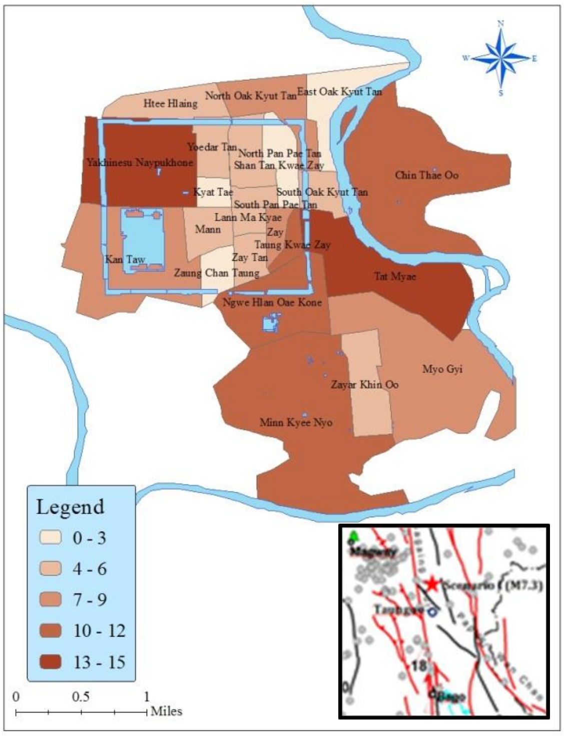


Figure (B-20) Moderate Damage of Reinforced Concrete Buildings in Taungoo (M 7.3)

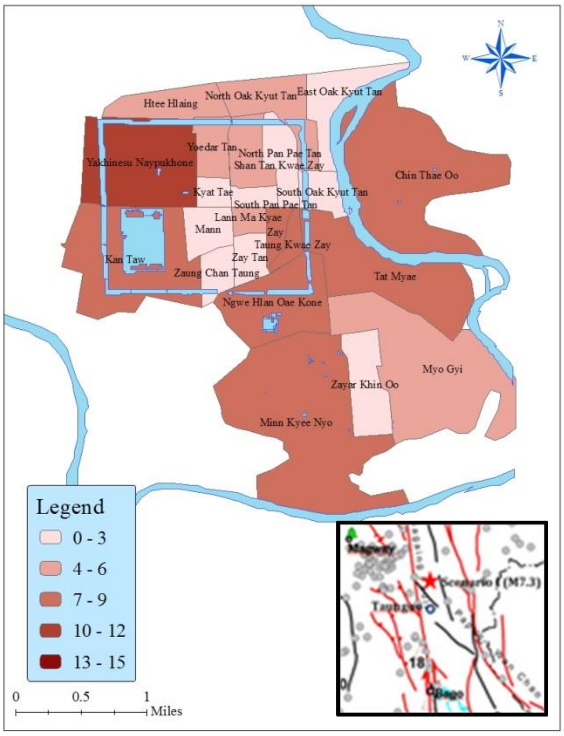


Figure (B-21) Extensive Damage of Reinforced Concrete Buildings in Taungoo (M 7.3)

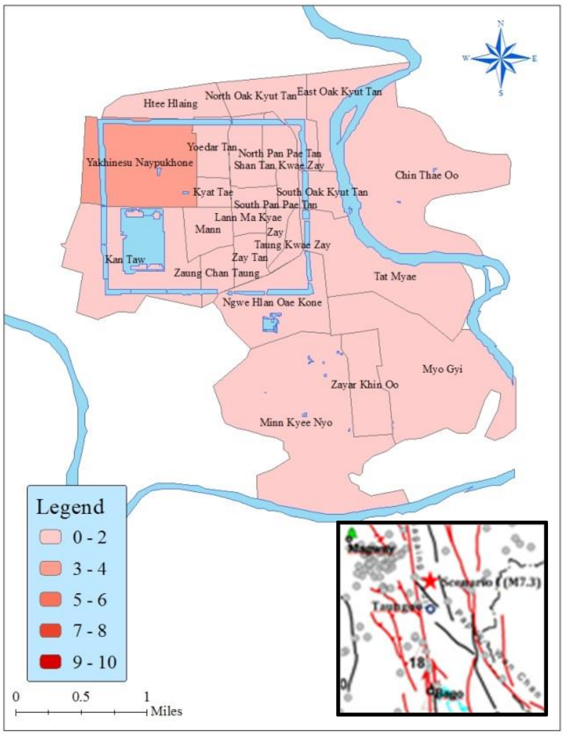


Figure (B-22) Complete Damage of Reinforced Concrete Buildings in Taungoo (M 7.3)

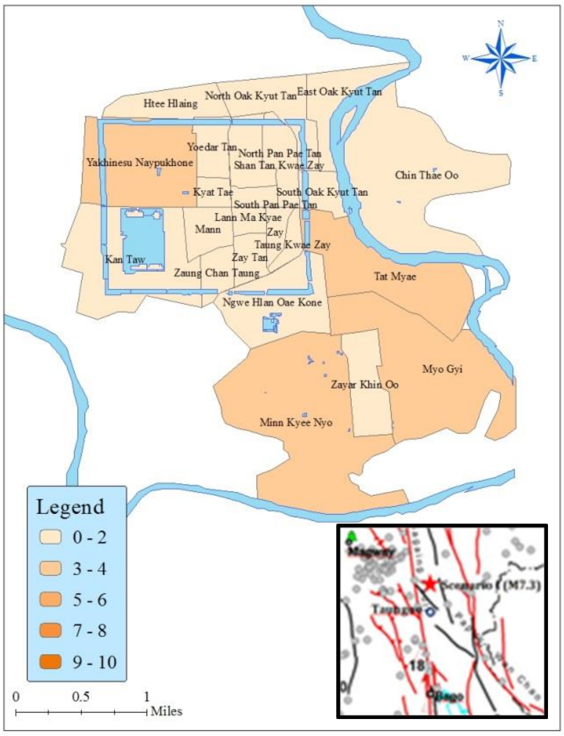


Figure (B-23) Slight Damage of Brick Masonry Buildings in Taungoo (M 7.3)

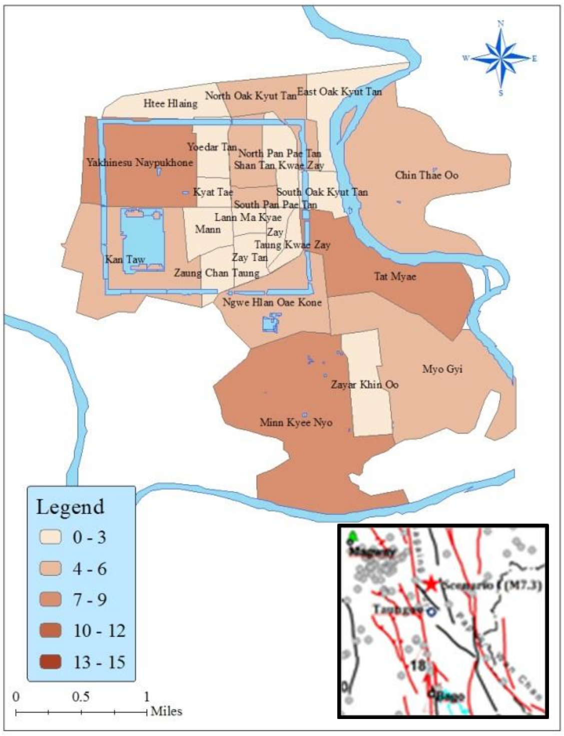


Figure (B-24) Moderate Damage of Brick Masonry Buildings in Taungoo (M 7.3)

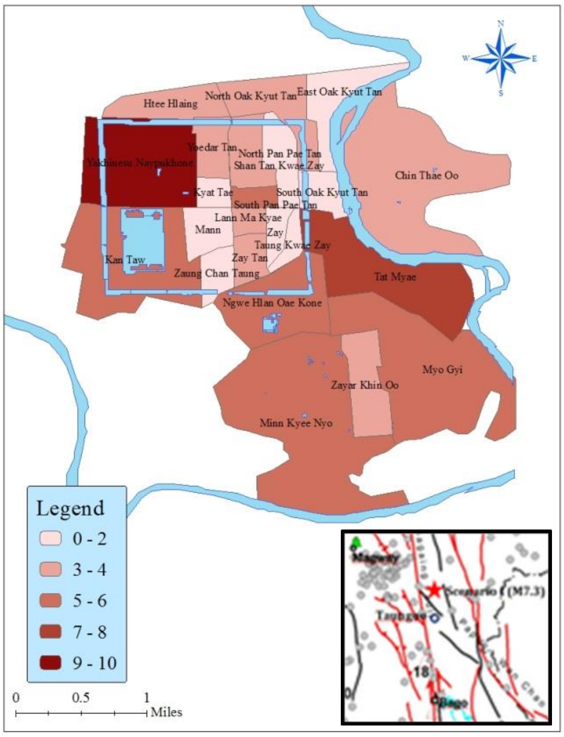


Figure (B-25) Extensive Damage of Brick Masonry Buildings in Taungoo (M 7.3)

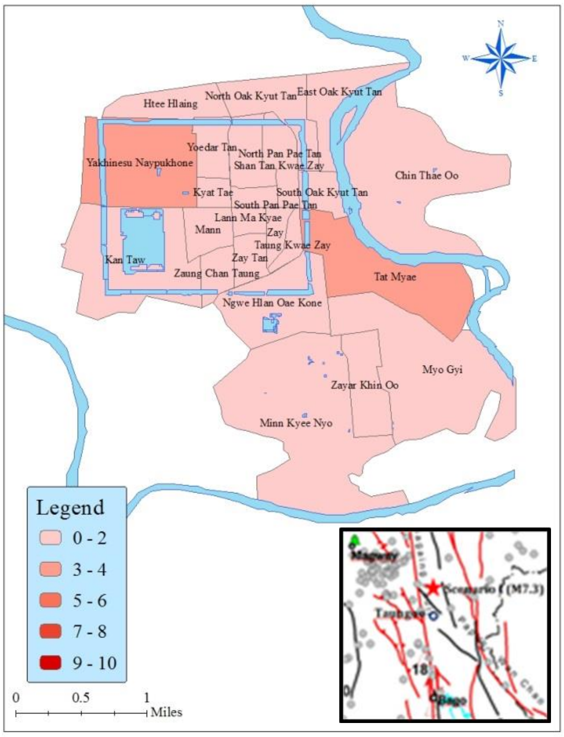


Figure (B-26) Complete Damage of Brick Masonry Buildings in Taungoo (M 7.3)

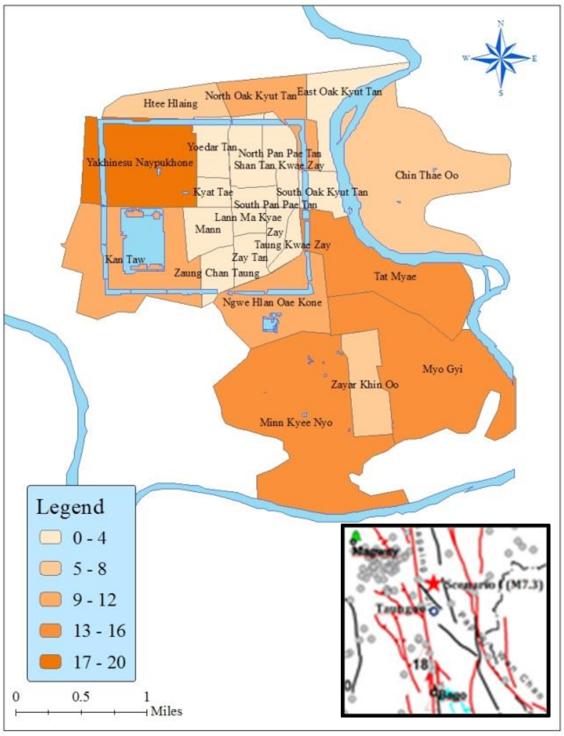


Figure (B-27) Slight Damage of Mix-used Buildings in Taungoo (M 7.3)

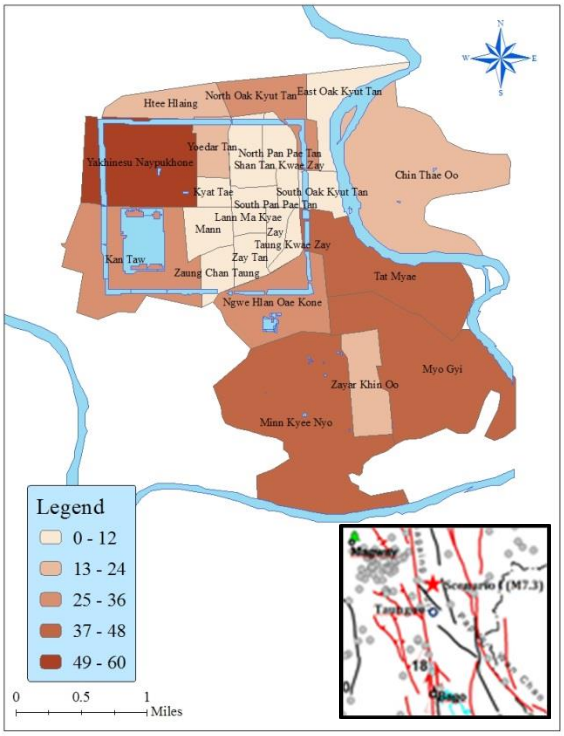


Figure (B-28) Moderate Damage of Mix-used Buildings in Taungoo (M 7.3)

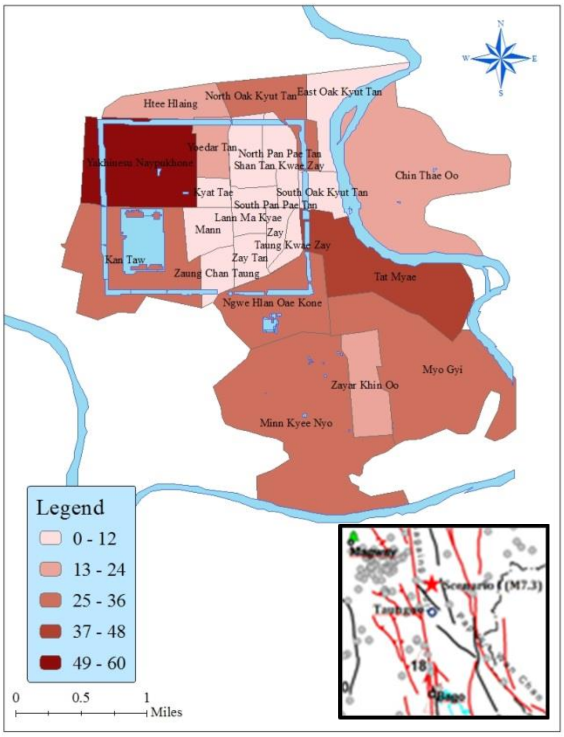


Figure (B-27) Extensive Damage of Mix-used Buildings in Taungoo (M 7.3)

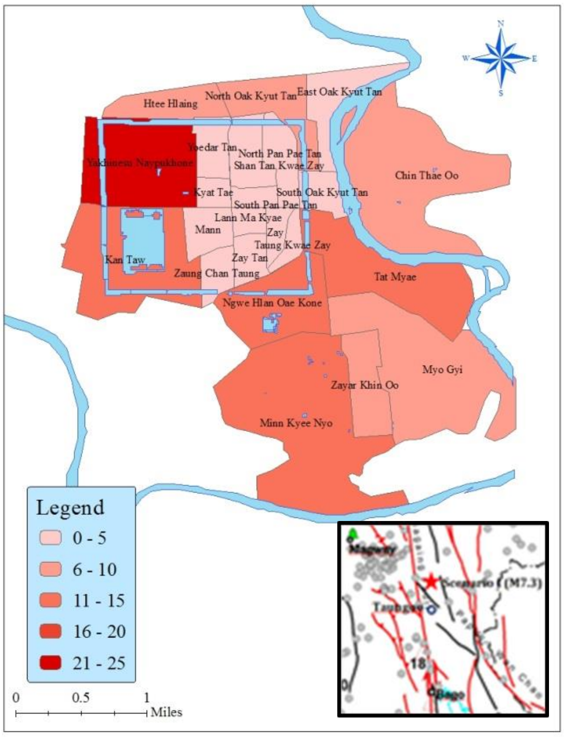


Figure (B-27) Complete Damage of Mix-used Buildings in Taungoo (M 7.3)

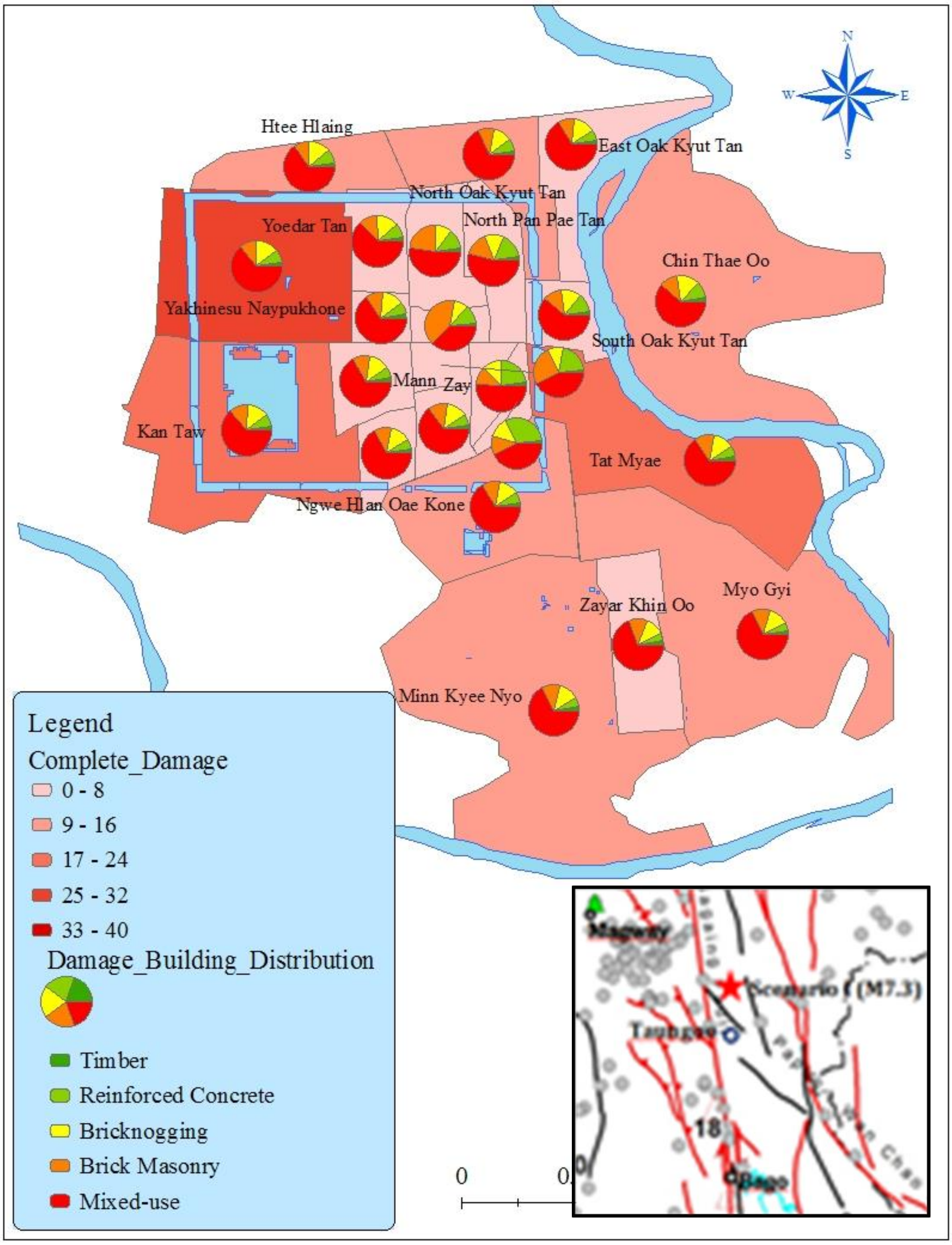


Figure (B-29) Complete Damage Building Distribution by Structural Types (M7.3)

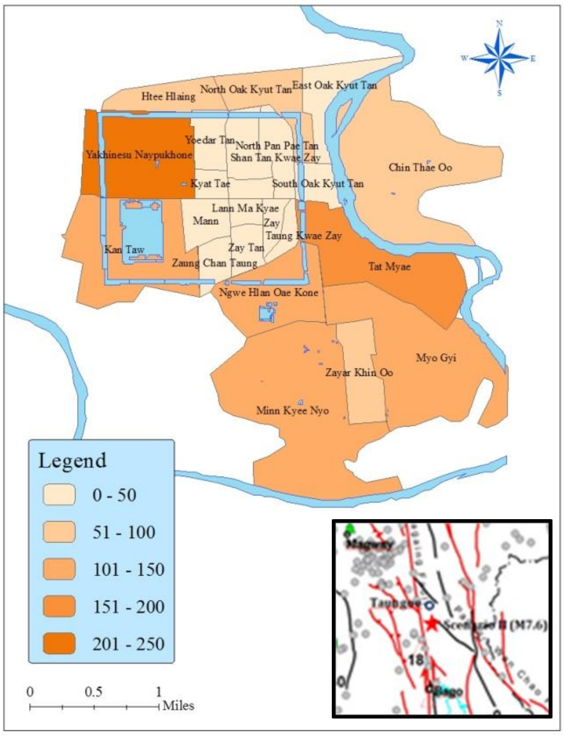


Figure (B-30) Slight Damage of Timber Buildings in Taungoo (M 7.6)

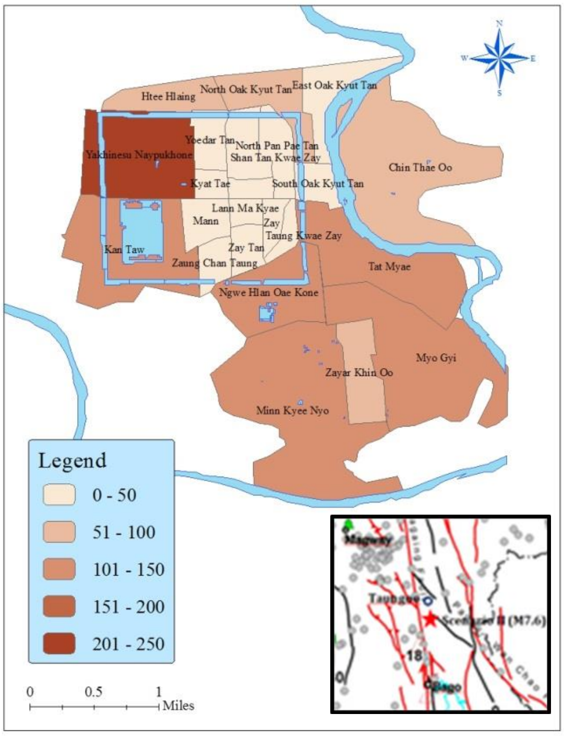


Figure (B-31) Moderate Damage of Timber Buildings in Taungoo (M 7.6)

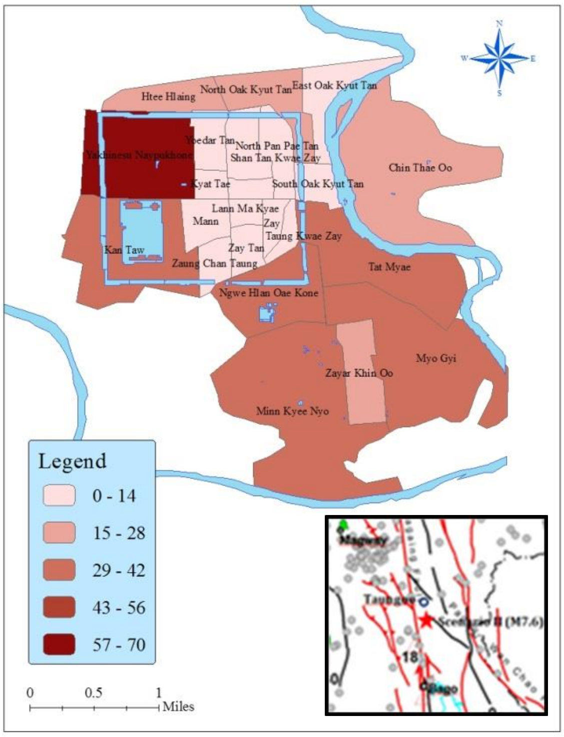


Figure (B-32) Extensive Damage of Timber Buildings in Taungoo (M 7.6)

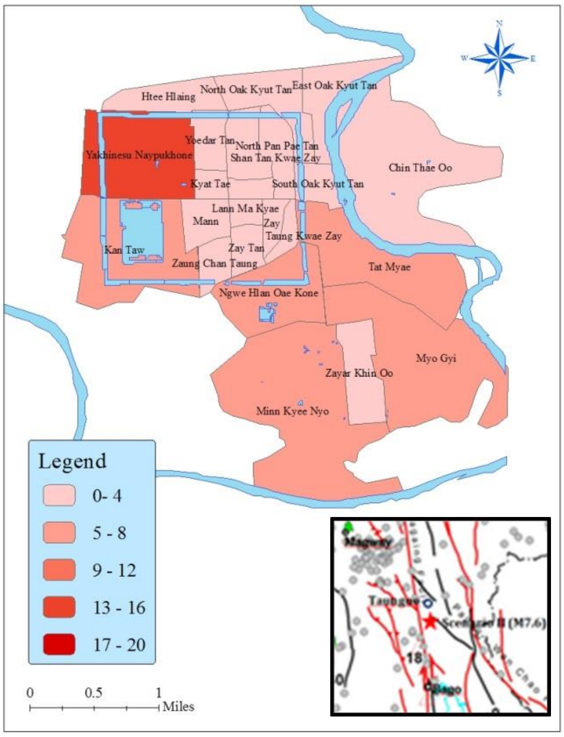


Figure (B-33) Complete Damage of Timber Buildings in Taungoo (M 7.6)

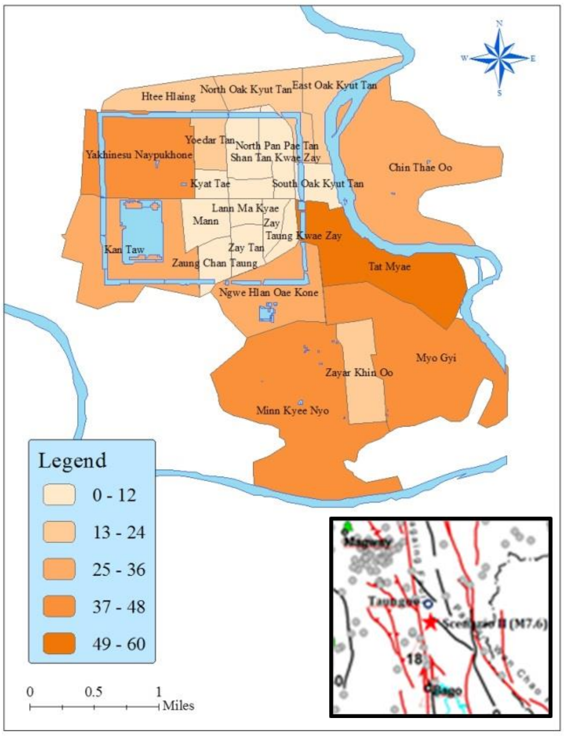


Figure (B-34) Slight Damage of Brick Nogging Buildings in Taungoo (M 7.6)

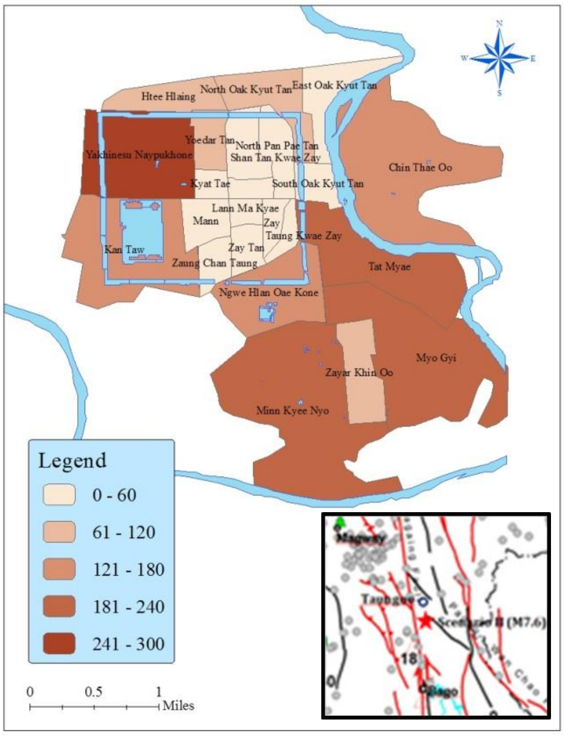


Figure (B-35) Moderaate Damage of Brick Nogging Buildings in Taungoo (M 7.6)

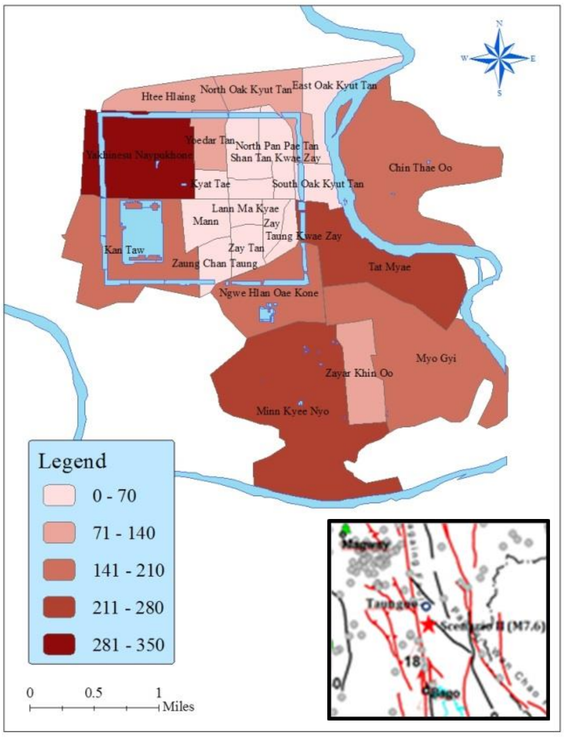


Figure (B-36) Extensive Damage of Brick Nogging Buildings in Taungoo (M 7.6)

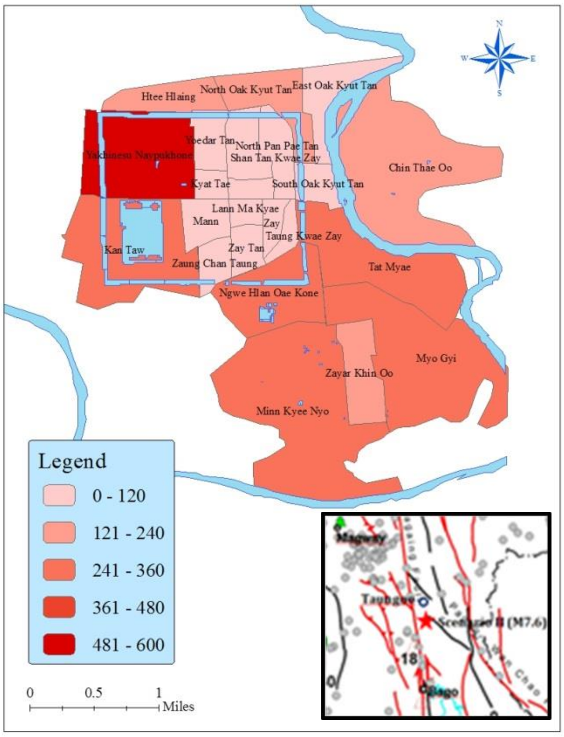


Figure (B-37) Complete Damage of Brick Nogging Buildings in Taungoo (M 7.6)

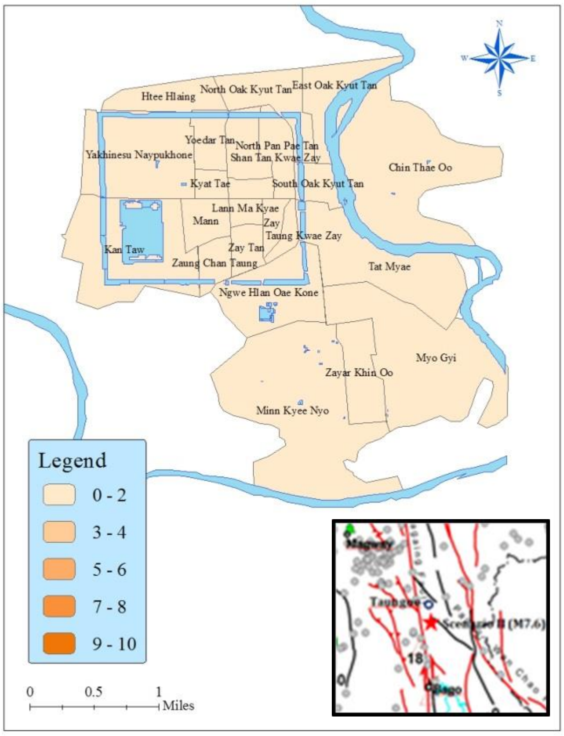


Figure (B-38) Slight Damage of Reinforced Concrete Buildings in Taungoo (M7.6)

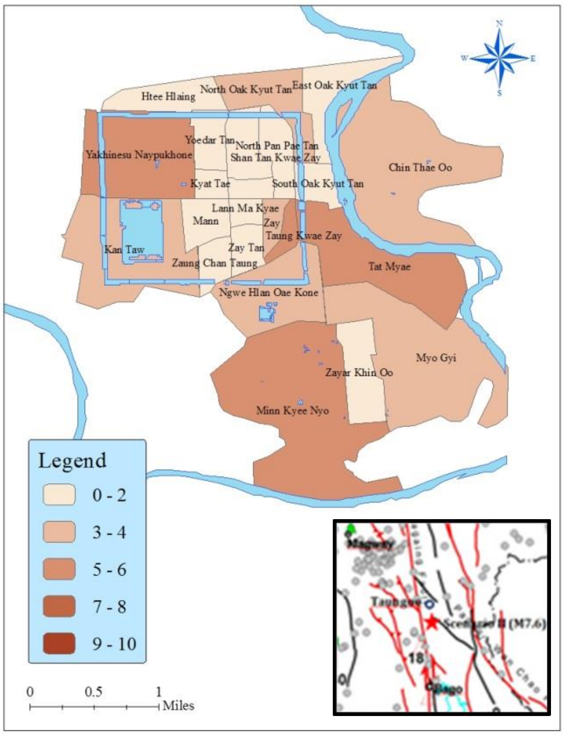


Figure (B-39) Moderate Damage of Reinforced Concrete Buildings in Taungoo (M7.6)

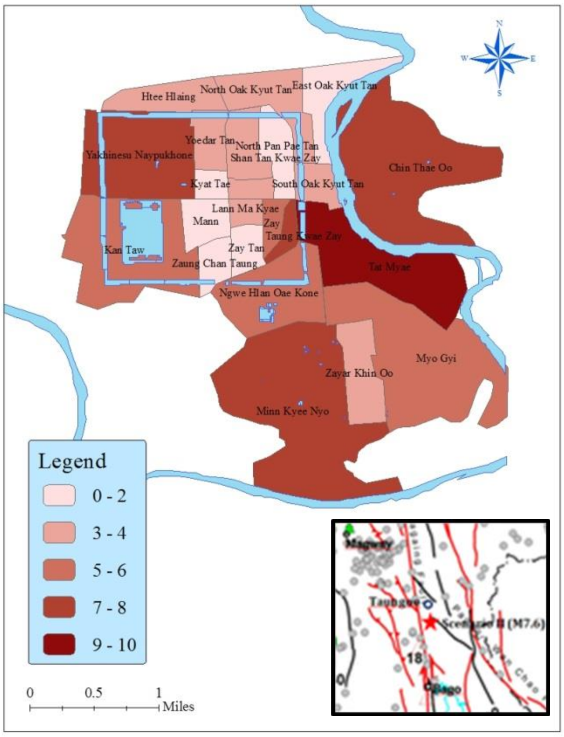


Figure (B-40) Extensive Damage of Reinforced Concrete Buildings in Taungoo (M7.6)

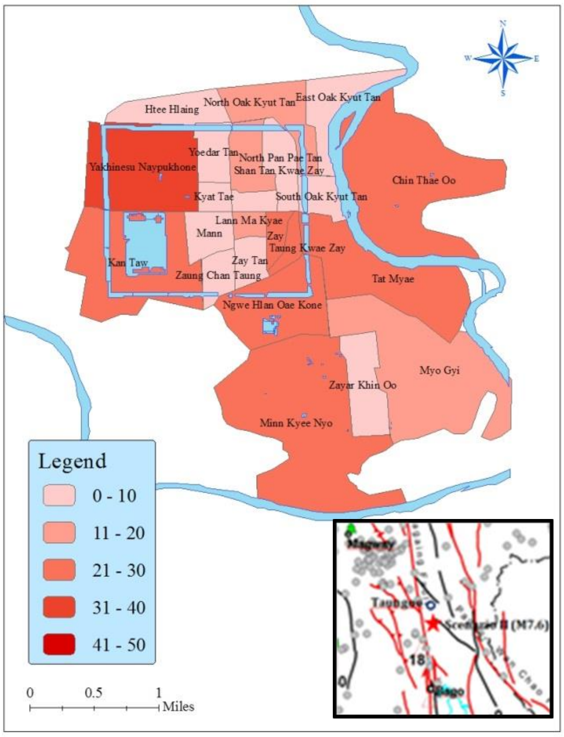


Figure (B-41) Complete Damage of Reinforced Concrete Buildings in Taungoo (M7.6)

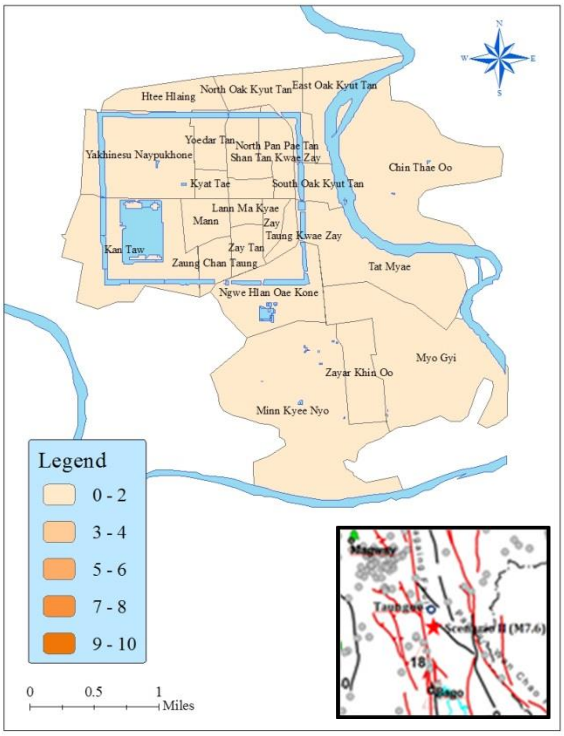


Figure (B-42) Slight Damage of Brick Masonry Buildings in Taungoo (M 7.6)

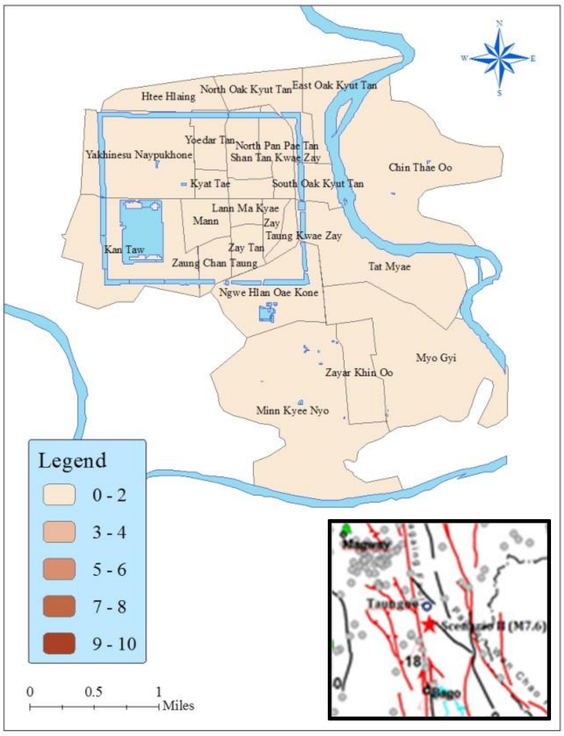


Figure (B-43) Moderate Damage of Brick Masonry Buildings in Taungoo (M 7.6)

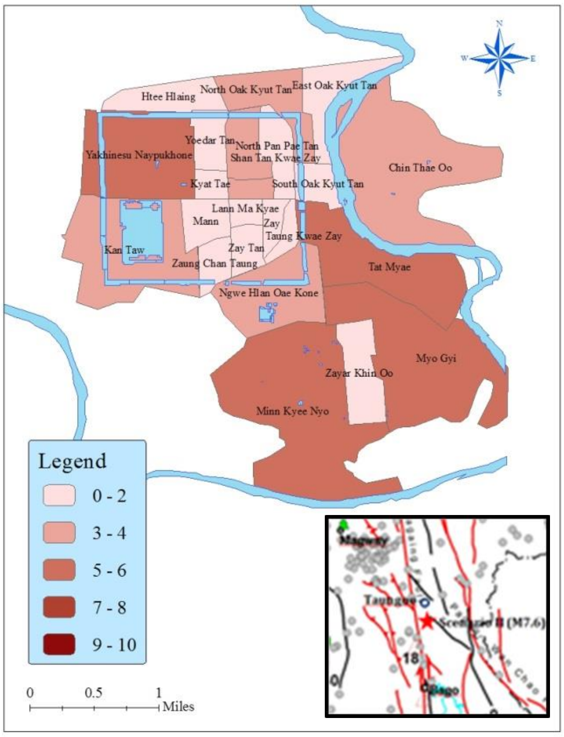


Figure (B-44) Extensive Damage of Brick Masonry Buildings in Taungoo (M 7.6)

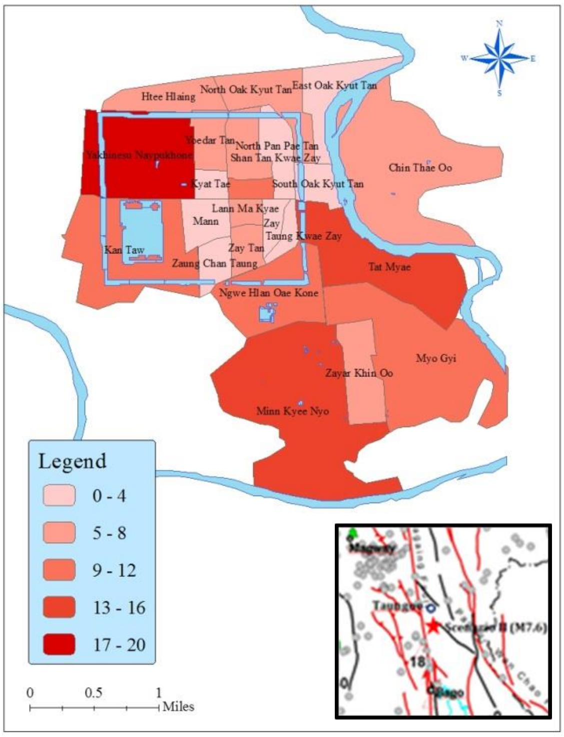


Figure (B-45) Complete Damage of Brick Masonry Buildings in Taungoo (M 7.6)

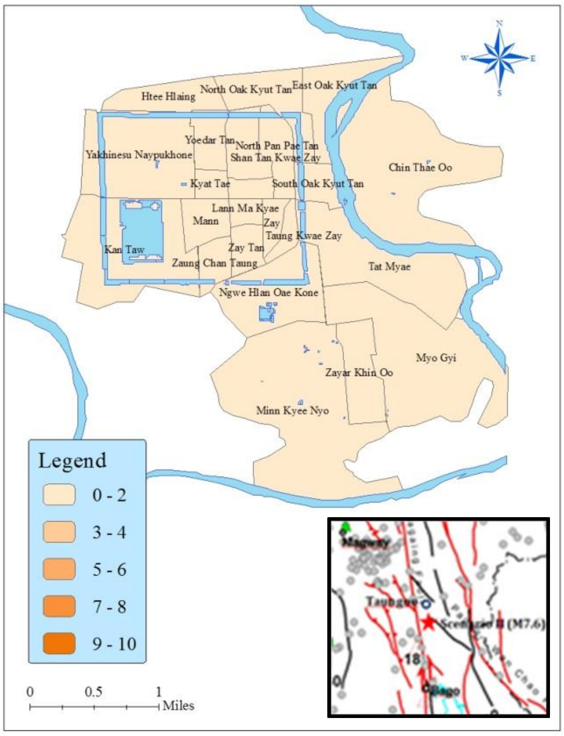


Figure (B-46) Slight Damage of Mixed-use Buildings in Taungoo (M 7.6)

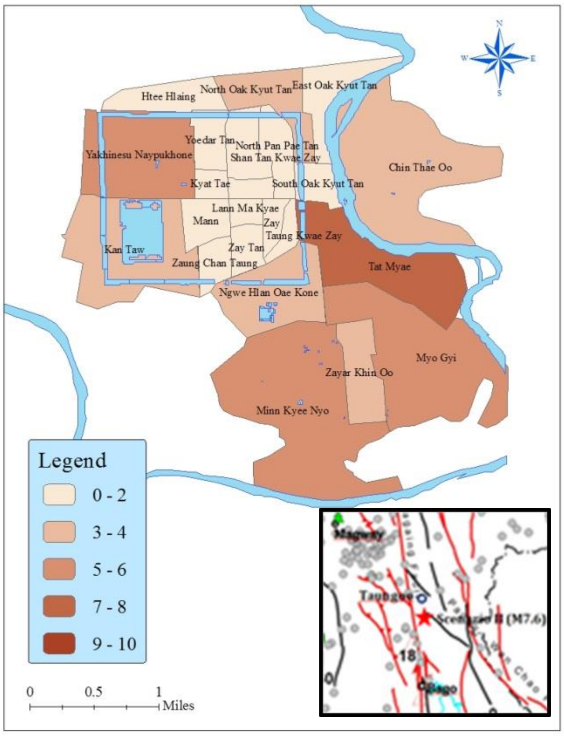


Figure (B-47) Moderate Damage of Mixed-use Buildings in Taungoo (M 7.6)

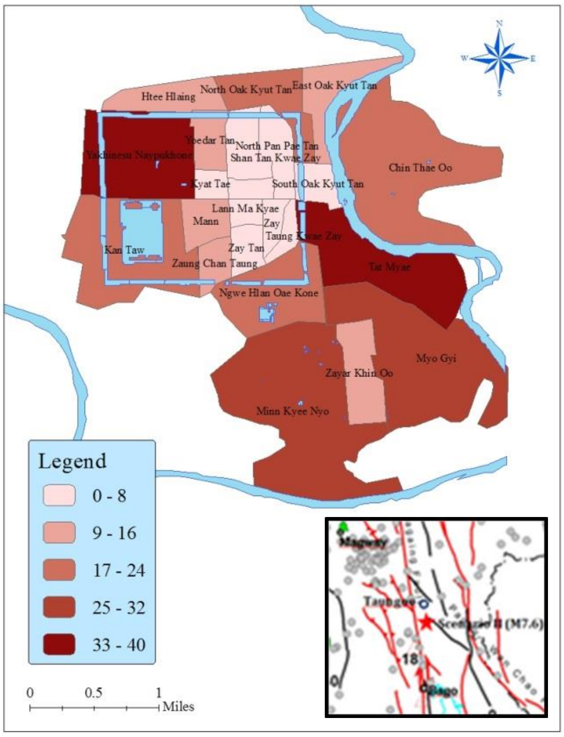


Figure (B-48) Extensive Damage of Mixed-use Buildings in Taungoo (M 7.6)

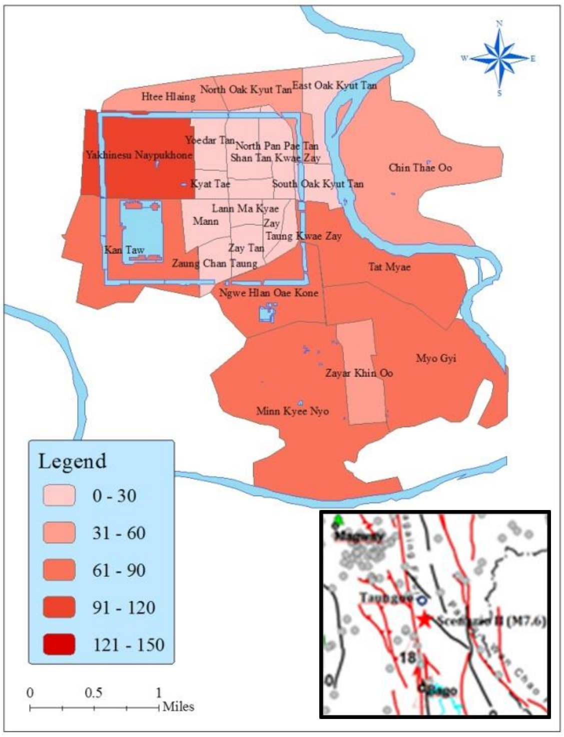


Figure (B-49) Complete Damage of Mixed-use Buildings in Taungoo (M 7.6)

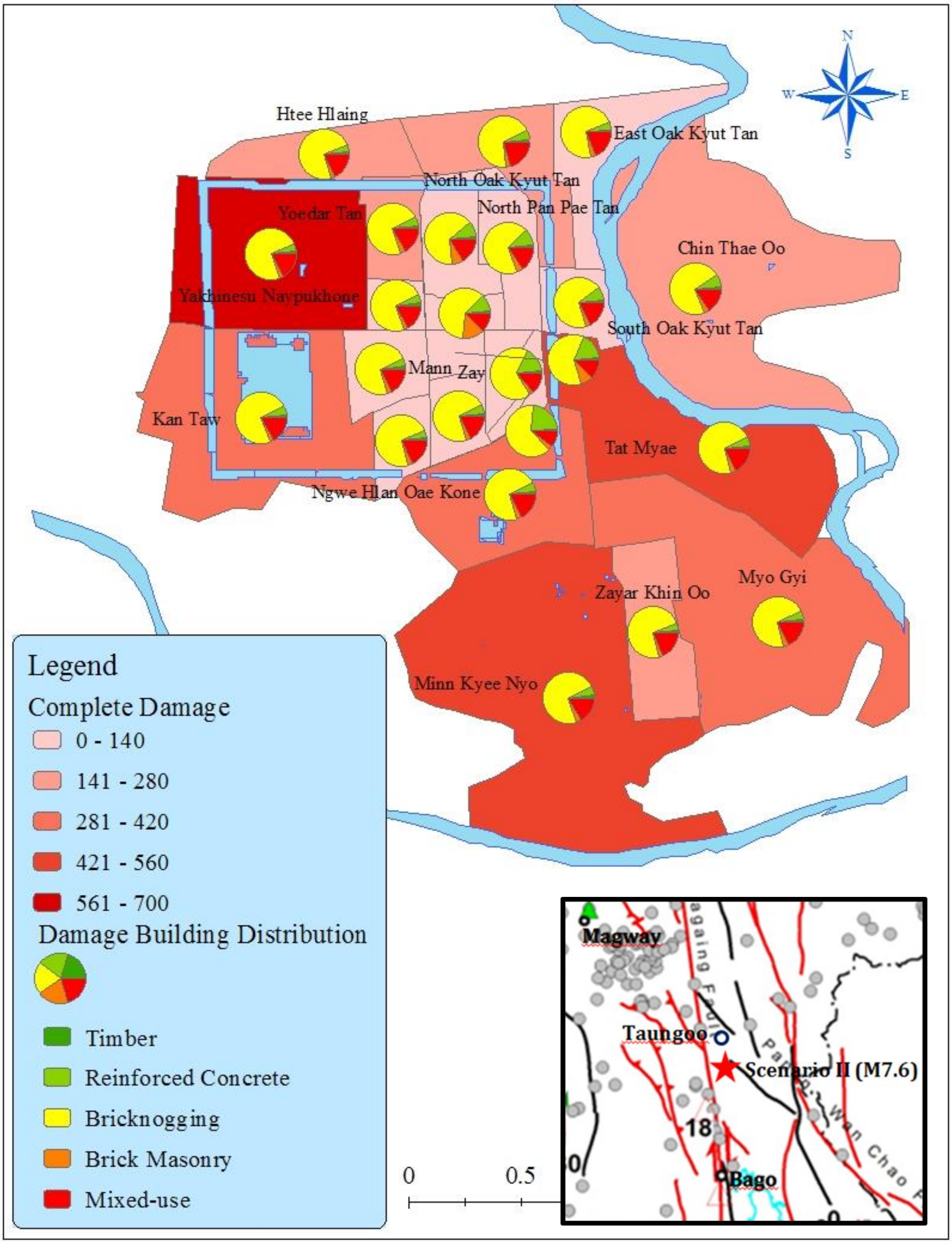


Figure (B-50) Complete Damage Building Distribution by Structural Type (M 7.6)