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## ABSTRACT

The World Bank's (WB) Southeast Asia Disaster Risk Management Project for Myanmar has the overall goal of improving the drainage system and structural performance of selected public facilities in Yangon, as well as enhancing disaster response. The project is comprised of the following five components:

- Component C1: Strengthening Financial Planning for Disaster Resilience
- Component C2: Urban Flood Risk Management
- Component C3: Safer Public Facilities and Critical Infrastructure
- Component C4: Project Management
- Component C5: Contingent Emergency Response

One of the subcomponents under Component C3 is dedicated to the building regulatory and vulnerability assessment (VA) with the goal of strengthening the instructional capacity of the Yangon City Development Committee (YCDC). The project described in this report focuses on the building vulnerability portion of this subcomponent, which is used to further refine the objectives of and serve as a bridge to the building regulatory part.

The present document provides a literature review of the structural VAs conducted in Yangon. As part of this report, a number of technical briefs, research reports, and articles were read and analyzed. A companion summary report highlights the key findings and presents conclusions and recommendations.

The hazard environment impacting a city can be classified according to two types of hazards: acute or chronic. Acute natural hazards (earthquake, cyclone, flood, landslide, tsunami, and volcano eruption) have a low probability of occurrence but a large impact. Chronic hazards (urban fire, epidemic disease, public health, and building collapse not related to acute hazard) have a higher likelihood of occurrence but impact a smaller segment of the population. To develop a resilient city and community, both classes of hazard need to be addressed. This report focuses specifically on earthquakes, cyclones, floods, and urban fires.

An important component of resilience is the development of a disaster risk management (DRM) program. DRM consists of four areas: mitigation, preparation, response, and recovery. VA can be used to develop any of the four areas. However, experience has shown that mitigation is by far the most cost-effective and functional approach to risk management. Various studies have confirmed that each dollar spent as part of mitigation leads to a multidollar reduction in future costs. Mitigation can comprise strengthening the existing built environment, mandatory implementation of robust building codes, and improved construction quality management.

The objective of this project is to present YCDC with a comprehensive analysis of the risk environment based on the available literature. The review shows that various government agencies, international organizations, and participating individuals have made significant intellectual and financial contributions to the study of the risk environment in the city, and several high-quality technical reports have been prepared. There is universal agreement that Yangon is vulnerable to the four natural hazards considered in this report and that it is important to use the available data to advance DRM through mitigation.

The current national building code is a robust document, modeled after well-accepted international standards. Based on the literature review and on discussions with various stakeholders during the mission, it is also clear that the engineering staff at YCDC is dedicated, well-qualified, and able to implement the required measures. In addition, members of the engineering society, the construction industry, and real

estate organizations concur on the need for a level playing field, mandated code compliance, improved permitting and inspection programs, and more accountability.

The primary recommendation of this report is therefore for YCDC's governing body to initiate the Building Regulatory Capacity Assessment (BRCA) program as a first step in addressing the city's vulnerability and for the ultimate goal of creating a resilient community.

# 1. INTRODUCTION

## 1.1 Overview

For Myanmar, the WB report Global Facility for Disaster Reduction and Recovery (GFDRR, 2012) states that the annualized losses from natural disasters are close to 1% of the country's total gross domestic product, making it one of the most vulnerable countries to natural disasters. Among the cities in Myanmar, Yangon City (YC) is more susceptible to multiple types of disasters with consideration of disaster loss amount. Due to its location in the Yangon Region, it is also considered very vulnerable to a number of natural hazards, as described later. Figure 1 (Myanmar Information Management Unit (MIMU), 2015) illustrates the country's multihazard profile.

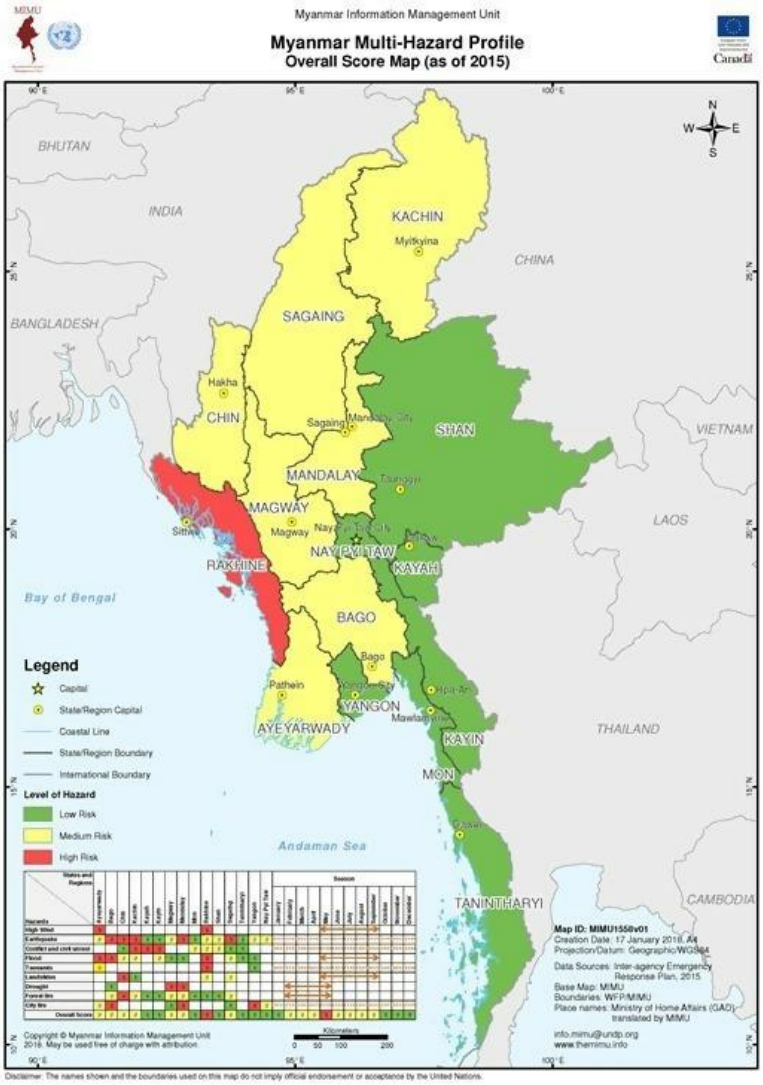


Figure 1. Natural disaster vulnerability map for the country (MIMU, 2015).

The fast-growing city of Yangon has a population of over five million people, is strategically located, and serves as the country's largest city, financial capital and engine of economic growth. Tourism is a major industry for the city. Currently, over one million people visit YC annually, and more than seven million visitors are expected by 2020. One of the key attractions of Yangon City is its buildings, including a strong

architectural heritage and historical religious structures. The city's rich architectural heritage has been preserved largely due to slow development over the years. Yangon's built environment is vulnerable to a number of natural hazards, including earthquakes, floods (natural and man-made), wind storms (cyclones), and fire, all of which have caused damage to its structures in the past.

The Sagaing fault, running north-south through the country, is located approximately 35 kilometers (km) east of the city. In 1930, a magnitude (M) 7.3 earthquake struck Myanmar—the largest earthquake to impact Yangon to date. With the epicenter approximately 75 km from the city, the earthquake resulted in 50 fatalities in the city and 500 countrywide, damaging many buildings including the General Post Office and Railway Headquarters (Brown et al., 1933). Given the vulnerability of the built environment, an earthquake of similar magnitude and with epicenter closer to the city today could have devastating consequences.

The city is geographically close to the Andaman Sea and the Bay of Bengal and thus susceptible to tropical storms and high winds. In 2008, Cyclone Nargis, the worst natural disaster in the history of the country, resulted in 1,640 fatalities in the city (140,000 countrywide, mainly in the delta region) and caused over US$10 billion in damages. The Yangon Region (among four others) was declared a disaster area, and 284 temples were destroyed in this region alone. The cyclone damage was caused by high wind speeds, heavy rain, and storm surge, resulting in widespread flooding (United Nations Environment Programme (UNEP), 2009).

Flooding is a common occurrence for the country and the city. It can be caused by natural events—i.e., (1) heavy rainfalls and tropical storms during monsoon seasons, (2) flooding rivers (the city is surrounded by a number of rivers), and (3) high tides—or by man-made creations such as the city's antiquated drainage system, which can become clogged and unable to properly drain rainwater. Annual floods have resulted in damage to both buildings and agriculture. During the 2018 monsoon season, flooding occurred in many residential townships within the city due to heavy rain, high tides, and high river levels, causing fatalities and damage to buildings.

Between 200 and 300 fires break out annually in the Yangon Region, which is classified as a high-risk zone for fire (MIMU, 2015). There are many contributing factors to the large number of fires in YC, including congested housing, indoor electrical deficiencies, and the use of indoor fuel. In 2005, a fire affected over 9,000 people and caused damage totaling over US$50,000 (United Nations Human Settlements Programme (UN-Habitat), 2011). A 2017 fire destroyed the iconic Kandawgyi Palace Hotel (primarily constructed of teak, in traditional Burmese style), resulting in fatalities and injuries.

The vulnerability of the city to natural disasters is exacerbated by several factors, including:

- Many buildings were constructed in the late 19th century and designed based on British Standards and Codes. As such, there was scant knowledge of seismic and wind forces and minimal provisions to design for them. The exposure vulnerability is amplified because of the importance of the buildings and the large number of occupants.
- A robust building code has been developed by qualified Myanmar engineers based on internationally recognized standards, such as the American Society of Civil Engineers (ASCE) 7 (ASCE, 2006). The code has provisions for natural hazards, such as earthquakes and wind, as part of the structural sections. In addition, fire safety measures (sprinkler spacing and minimum cover for fire rating) are listed in the architectural sections. However, the code provisions have not yet been adopted into the law. As such, there is no legal mandate for regulation and enforcement. The city is also considering implementing electronic permitting and plan checks in the near future.
- The city's population has been increasing rapidly. As typical in many developing countries, internal migration to urban areas for citizens looking for better economic opportunities has led to housing shortages. In turn, the lack of available housing and finances has led to the development of informal

settlements. These typically self-built units lack many traditional structural safety features as other improvements take priority over strengthening measures when residents have limited financial resources.

### 1.2 Project scope

Myanmar is the largest country in Southeast Asia by area. It has a population of over 50 million and is strategically located. Thus, it is not surprising that many countries and aid organizations have undertaken several projects in the country. Given the importance of YC, many of the studies conducted have focused on the city. In particular, there is a rich collection of reports that analyze various aspects of natural hazards and the associated vulnerabilities related to Yangon. At the same time, the country is considering major revisions to its regulatory structure. As a prelude to undertaking this regulatory reform, it is crucial to have a complete picture of existing and ongoing natural hazard studies and vulnerability reports to serve as a lynchpin for the subsequent regulatory structure.

Accordingly, the WB initiated a project to compile, review, and assess the available studies related to natural hazards in Yangon. The present document serves as the final project report.

The following limitations are noted:

- There are a number of relevant projects in progress at the time of writing. For these projects, final or even interim reports might not be available. In such cases, a brief description of the project scope and goals is presented.
- For a number of previous natural disasters, such as the 2008 Cyclone Nargis, damage assessment data were not documented. If such data became available in the future, it could enrich the material presented in this report.
- The project scope is limited to the review of existing reports; no independent investigation related to natural hazards and their impact on Yangon was undertaken.
- Given the project scope, no detailed reviews of the existing permitting process or regulatory process are presented. However, based on the review of available hazard and vulnerability reports, recommendations relevant to this topic are included in this report. Similarly, the report does not consider informal settlements in detail. However, since these components form an integral part of the city's fabric and contribute to its resilience, brief discussions on informal housing are included when available in the studies or accessible through independent web-based search.
- Finally, the area of study is limited to Yangon City. Yangon is comprised of four districts and 33 townships (see Figure 2). It is part of the larger Yangon Region, which has 12 additional townships (not part of this study).

### 1.3 Report organization

This report is divided into eight chapters and includes an appendix. Chapter 2 presents a detailed discussion of the four natural hazards (earthquake, wind, flood, and fire) examined in this report. Chapters **Error! Reference source not found.** and **Error! Reference source not found.** introduce the exposure environment in Yangon and the fragility functions for the built environment. This is followed by discussions on pre-event assessment methodology in chapter **Error! Reference source not found.** and post-event damage assessment in chapter **Error! Reference source not found.**. Chapter **Error! Reference source not found.** presents information on DRM and response. A discussion of relevant laws and regulations is presented in chapter **Error! Reference source not found.**. Chapter **Error! Reference source not found.** contains a brief discussion of building regulatory assessment and reform, intended as an initial discussion

of the subsequent project on building regulatory resilience for the city. Chapter **Error! Reference source not found.** presents a summary of findings and conclusions based on the analysis of available material. This is followed by references listed in chapter **Error! Reference source not found.**. Finally, **Error! Reference source not found.** summarizes findings from a mission undertaken in late February 2018.

The primary scope of the project is the review of existing data, reports, and other supporting material. To that end, in each chapter, material from each document is summarized without drawing conclusions. Any conclusions, findings, and recommendations by the authors are presented as discussion points in the last section of each chapter.

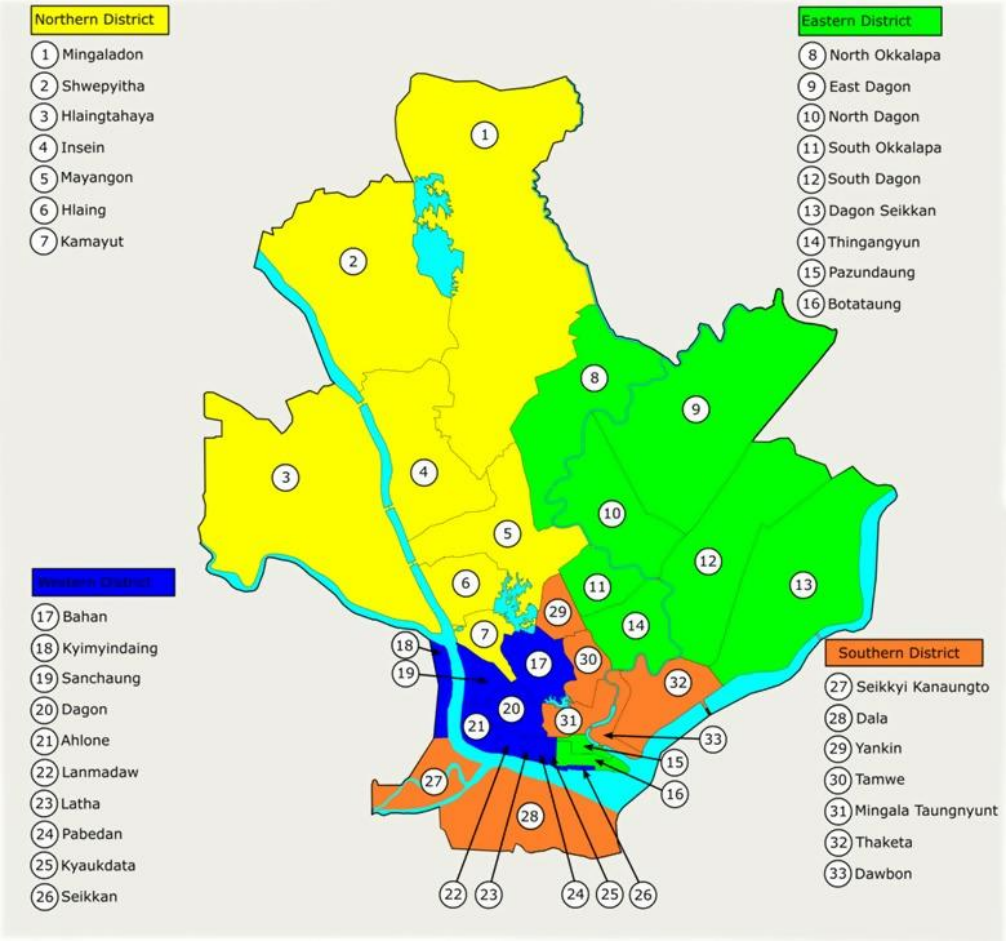


Figure 2. Map of Yangon districts and townships (YCDC).

# 2. NATURAL HAZARDS IN YANGON

## 2.1 Introduction

The determination of natural hazard intensity is a key input for conducting vulnerability analyses of built environments. To quantify and compare relative risk, both a method and a metric need to be developed. Deterministic and probabilistic hazard metrics are commonly utilized for this purpose. For example, to detect earthquake hazard, the deterministic hazard could be the maximum magnitude earthquake from a given fault, whereas the probabilistic earthquake considers aggregation and the probability of different magnitudes from various faults. The metrics used for earthquake, wind, and flood could be peak ground acceleration (PGA) in gravity (g), 3-second (sec) gust wind speed in meters (m)/sec, and inundation depth in m, respectively. In the probabilistic realm, expected values for the city can be established. For example, for a 475-year earthquake and a 100-year flood, relating the selected numerical value of interest to the hazard return interval.

Key findings and results from the review of sources related to natural hazards affecting YC are summarized in this section. Although four natural hazards (earthquake, wind, flood, and fire) are discussed, the sections on earthquake and flood include significantly more documents because these hazards have a larger impact on the city and are therefore studied in more detail.

## 2.2 Earthquake hazard

### *2.2.1 Overview*

Significant research has been undertaken in Yangon to establish and disseminate a seismic hazard profile for the city. Although the city has not experienced a large earthquake for over 80 years, the importance of this hazard cannot be underestimated. Both Port-au-Prince, Haiti, and Katmandu, Nepal, had not experienced any major earthquakes for many decades before they were struck by moderate-major events in 2010 and 2015, respectively. These events resulted in a large number of fatalities and collapsed buildings.

The earthquake hazard is particularly acute for a number of townships in YC where buildings are constructed on soft landfills near the river. Seismic waves attenuate as they propagate from the earthquake epicenter. However, soft underlying soil tends to amplify the ground motion, resulting in larger motions and larger forces imparted on buildings. Non-ductile buildings constructed without the ability to absorb these amplified motions safely can sustain damage or even collapse.

Earthquake hazards at a site can be due to several underlying factors, including (1) ground motion, (2) site liquefaction, (3) landslide and lateral spreading, and (4) ground displacement. Given the topology of the city and its distance from the governing fault, the latter two hazards do not apply. However, both ground shaking and liquefaction must be considered.

### *2.2.2 Historic events and plate tectonics*

Earthquakes affecting YC primarily occur along the 1,000-km-long Sagaing fault. The western part (Indian plate) moves north with respect to the eastern half of the Eurasian plate at a rate of approximately 24 millimeters (mm)/year. This is a strike-slip, right lateral fault, which is similar in mechanism, length, and slip rate to the well-known San Andreas Fault in California. A list of historical earthquakes in the area is presented by Wang et al. (2014) in **Error! Reference source not found.**. In addition to this fault, a number of other faults are also present that can impact the study area, as discussed by Tun et al. (2012) (see **Error! Reference source not found.**).

Swe (2018) studied the renovation records of five pagodas to establish a list of the historic earthquakes in the Yangon-Bago areas (see **Error! Reference source not found.**). As shown, a significant earthquake could be anticipated approximately every 100 years. The authors also studied scenario earthquakes and

determined that the PGA for a M7.0 earthquake would result in PGA of 0.2–0.3 g for hard underlying soil in Yangon.