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Earthquake Risk Analysis for Disaster Management and Mitigation in Central Lombok

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Abstract:
This research focuses on analyzing the risk of earthquake disasters in Central Lombok Regency for disaster management and mitigation purposes that can be implemented in the future. This disaster risk analysis has been prepared using a methodology adapted to the Regulation of the Head of the National Disaster Management Agency Number 02 of 2012 concerning General Guidelines for Disaster Risk Analysis, as well as referring to other guidelines applicable at national level ministries/institutions. Central Lombok Regency faces significant risks related to earthquakes, especially in the coastal, southern and central areas. The risk index value is obtained from data analysis related to the hazard, vulnerability and capacity components for each potential disaster grouped into 3 (three) levels/classes, namely 0-0.333 for low class, > 0.333-0.666 for medium class, and >0.666-1 for high class. The index values are different for each disaster, except for the regional capacity index which applies the same to all regions. The Central Lombok Regency disaster risk assessment was carried out at the village/sub-district level. Detailed results of the analysis of each disaster risk assessment index for all potential disasters in Central Lombok Regency are described for each component determining disaster risk assessment. The results of this research show that the highest risk of earthquake disasters is in East Praya at 31%, then the moderate disaster risk is in the Jonggat and Pringgarata areas at 65%, and the low risk is in the North Batuliang area at 68%.

Keywords: *Risk Analysis, Earthquake, Central Lombok, Strategy, Management, Disaster Mitigation*

Introduction

Geographically, Indonesia is in the category of regions that are vulnerable to various types of natural disasters, which can pose a threat to its population due to a mixture of natural factors and human intervention. One example of a disaster that often occurs in Indonesia is the Earthquake, as experienced by West Nusa Tenggara, especially in Lombok in 2018. This incident has raised concerns at all levels of society, especially the government which has an important role in post-disaster prevention and management efforts.

Five years after the 7.0 magnitude earthquake shook West Nusa Tenggara, especially the island of Lombok, on July 5, 2018, the people of Lombok still feel a deep sense of grief. Some of them continue to reside in temporary shelters due to lingering trauma, and small earthquakes still frequently occur to this day. The West Nusa Tenggara Islands, particularly Lombok, are tectonically active seismic regions. Lombok remains vulnerable to the potential for earthquakes due to its location between earthquake sources to the south and north.

To the south, there is a subduction zone of the Indo-Australian tectonic plate pressing beneath Lombok Island. To the north, there is the geological structure of the Flores Thrust Fault, stretching from the Bali Sea eastward to Flores. As a result, Lombok Island is indeed susceptible to earthquakes, particularly along the Flores Thrust Fault[1].

This view aligns with the explanation provided by Wekke, stating that the earthquakes occurring on Lombok Island are caused by the movement of the Australian tectonic plate shifting northwest to north. The cause of these earthquakes can be related to the complexity of interactions between tectonic plates in the region, including subduction in the south and thrust fault structures in the north. Overall, understanding the geology and tectonics of the region helps explain why Lombok Island is susceptible to earthquakes[2].

Central Lombok regency plays a role as an administrative region located at the center of Lombok Island. Geographically, it is surrounded by two other regencies: West Lombok to the west and north, as well as East Lombok to the east and north. Meanwhile, to the south, the regency is bordered by the Indian Ocean. Central Lombok Regency holds a significant role as one of the prominent tourist destinations in West Nusa Tenggara Province. The government has designated it as a Super Priority Tourism Destination (DPSP) and a Special Economic Zone (KEK) based on the Republic of Indonesia Law Number 39 of 2009 concerning Special Economic Zones. This designation undoubtedly has implications for the need for disaster preparedness in the region. Apart from the high human activities, the complexity of infrastructure, and the presence of various facilities, investments are also concentrated in that area.

From a geological perspective, the southern part of Central Lombok Regency features active faults or fractures influenced by tectonic conditions. This is due to the presence of the Indo-Australian plate collision zone with the Eurasian plate in the south, the Flores back-arc thrust fault in the north, and the existence of local faults. In addition, the northern part of Central Lombok Regency is situated at the foothills of Mount Rinjani, making it vulnerable to various geological disasters such as earthquakes, the threat of Mount Rinjani eruptions, landslides, as well as non-geological disasters like floods, flash floods, and drought.

According to data from BMKG, on Friday, August 19, 1977, there was a recorded earthquake with a magnitude of 7.0. The earthquake's epicenter was 320 km southwest of Waingapu and resulted in a tsunami with a height of up to 15 meters. The impact of this earthquake included the occurrence of a tsunami in Teluk Awang, Central Lombok, with a height of 10 meters. After 41 years, on Sunday, August 5, 2018, at 18:46:37 WIB, another earthquake with a magnitude of 7.0 occurred. The earthquake's epicenter was at a depth of 15 km and located on land 18 km northwest of East Lombok. According to the document on the Rehabilitation and Reconstruction Plan Post-Disaster for Central Lombok Regency in 2018, the impact of the earthquake has affected Central Lombok Regency. This resulted in damages in 5 main sectors, namely: **Housing Sector**: The number of damaged units is 26,730 (RB: 5,133 units, RS: 3,734 units, RR: 17,503 units). **Infrastructure Sector**: The number of damaged units is 33. **Social Sector**: The number of damaged units is 504. **Economic Sector**: The number of damaged units is 28. **Cross-Sectoral**: The number of damaged units is 42. These impacts reflect the significant damage across various sectors, and the Rehabilitation and Reconstruction Plan is expected to assist in the recovery and rebuilding of Central Lombok Regency post the earthquake disaster.

Even though Indonesia is an area frequently affected by earthquakes and prone to disasters, the number of casualties and material losses in earthquake events in several regions of Indonesia indicates that disaster management in Indonesia still has weaknesses[3]. More intensive efforts are required in learning about disaster management, both in the pre-disaster phase, during the occurrence of disasters, and post-disaster, taking into account a series of natural disaster events that have occurred in Indonesia. Additionally, the roles of institutions and human resources need to be strengthened[4].

The budget allocation by the West Nusa Tenggara Provincial Government for disaster management in 2018 was recorded at Rp.23,617,863,503. However, this amount is still very limited for handling disasters like the 2018 Lombok earthquake, which required funds totaling Rp.16,629,707,602,433[5]. The mentioned amount is still tentative due to the difficulty in calculating the losses and costs arising from natural disasters[6]. Therefore, recognizing the limitations of disaster budgets in the region, budgetary strategies are needed to implement the protection of the community from threats, risks, and the impacts of disasters[7]. This research focuses on the analysis of earthquake disaster risk in Central Lombok Regency for the purpose of future disaster management and mitigation applications.

Research Method

Disaster risk assessment is the most important part as the basis for implementing disaster mitigation in Central Lombok Regency. Disaster risk assessment (KRB) is an approach to demonstrate the potential negative impacts that may arise due to a potential threatening disaster. The potential negative impacts are calculated based on the level of vulnerability and the area's capacity. Disaster risk assessment is closely related to hazard, vulnerability, and capacity assessments. The relationship between these three components and the risk or impact caused by a disaster can be seen in the following formula:

$$\text{Risk [R]} = \frac{\text{Hazard [H] X Vulnerability [V]}}{\text{Capacity to cope [C]}}$$

Explanation:
R: Risk H: Hazard
V: Vulnerability C: Capacity

Vulnerability and capacity are inversely related in determining disaster risk. Risk occurs due to the presence of hazards, high vulnerability to disasters, while the region's capacity is at a low level. The higher the vulnerability and the lower the capacity of the area, the higher the risk or negative impact caused by the disaster. Risk assessment is one of the tools to determine the potential magnitude of hazards, vulnerability, capacity, and risk in Central Lombok Regency. Based on the assessment of these components, the potential number of people exposed, property losses, and environmental damage due to disasters are observed. The results of this assessment are expected to serve as a sufficient basis for the region to formulate disaster mitigation policy recommendations.

Disaster risk analysis in Central Lombok Regency is conducted by considering hazard, vulnerability, and capacity factors. The analysis of these components reveals the potential negative impacts that may occur due to potential disasters that could affect the region. These potential negative impacts include an evaluation of the extent of potential hazards, the number of people possibly exposed, material losses, and environmental damage. Through the calculation of all these negative potentials, levels of hazard, vulnerability, and capacity can be obtained, collectively determining the level of disaster risk.

In addition to determining the risk levels, this analysis is expected to generate a risk map that identifies risks for each type of disaster that may occur in a region. The study and disaster risk map are anticipated to serve as a sufficient basis for the district government in formulating disaster mitigation policy recommendations. At the community level, the study's results are expected to provide a strong foundation for planning efforts to reduce disaster risk, especially at the hamlet/village level.

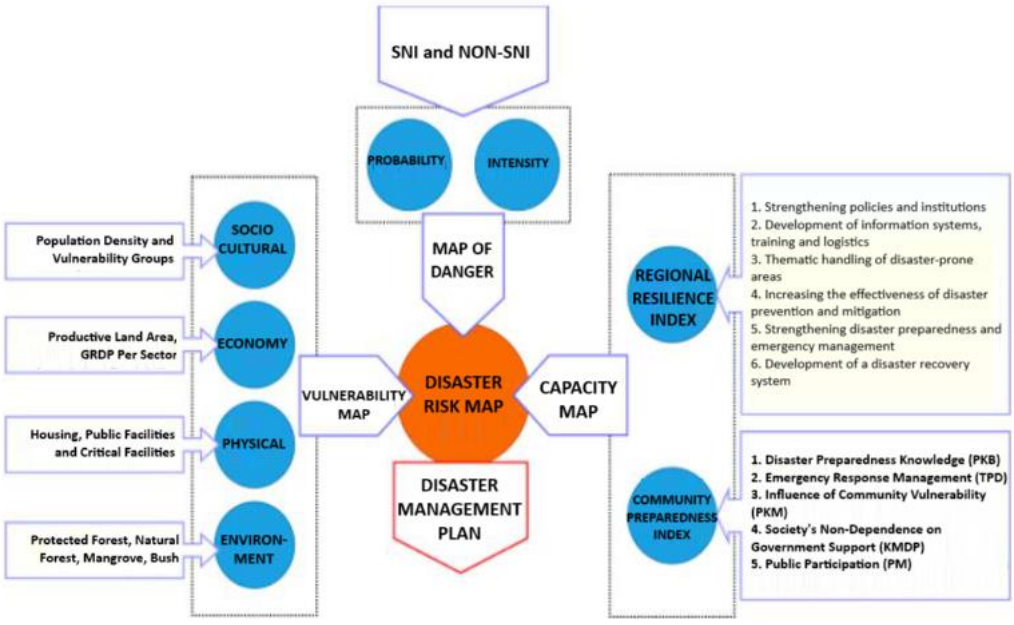

Figure 1. Risk Analysis Method

Disaster risk analysis has been prepared using a methodology tailored to the Head of the National Disaster Management Agency Regulation Number 02 of 2012 regarding the General Guidelines for Disaster Risk Analysis, as well as referring to other relevant guidelines at the national level ministries/institutions. This regulation provides the foundation for conducting disaster risk analysis, including the method of disaster risk analysis and the basic parameters used to calculate hazards, vulnerabilities, and capacities for each potential disaster in Central Lombok Regency.

The process of disaster risk analysis begins with data collection in Central Lombok Regency that is relevant to the analysis and continues until the production of disaster risk study results. This data is

processed to generate the Disaster Risk Analysis index. From the index results, hazard maps, vulnerability maps, capacity maps, and disaster risk maps are created. Hazard maps are obtained from the components of the probability and intensity of disaster events, while vulnerability maps consist of social-cultural, economic, physical, and environmental components. Capacity maps are influenced by institutional policy, early warning, capacity enhancement, and mitigation components. The detailed process of this disaster risk analysis can be seen in Figure 1. The figure illustrates the basis for determining disaster risk maps within the scope of the analysis.

The acquisition of disaster risk maps is obtained through the process of developing hazard maps, vulnerability maps, and capacity maps. This mapping serves as a crucial foundation in the creation of the Disaster Risk Study document, which serves as a reference in disaster mitigation planning. In the study's table, a recapitulation is presented at the village, sub-district, and regency levels. Based on these two outputs, it can be determined which villages have high-risk levels, enabling the implementation of disaster risk reduction efforts to be more targeted.

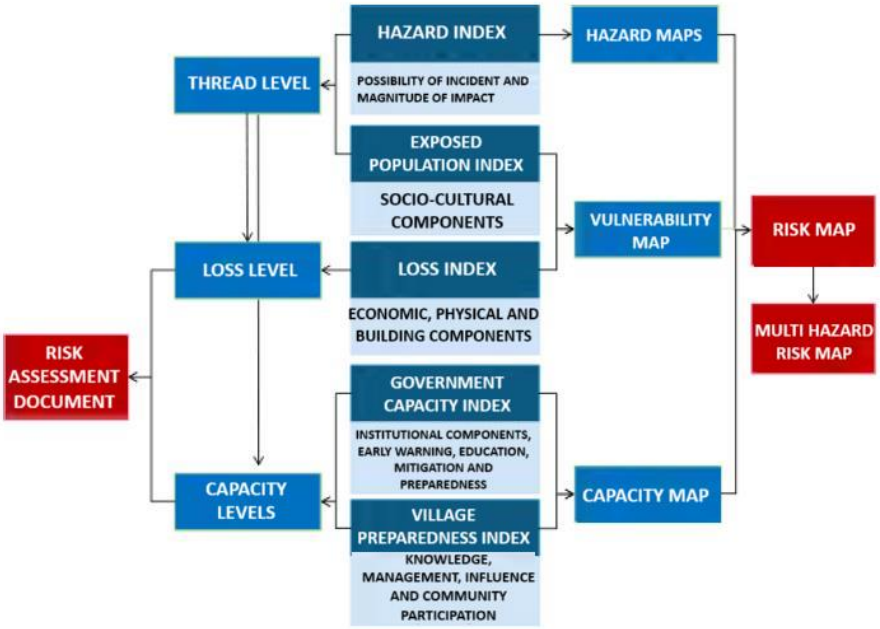

Figure 2. Risk Management Process Diagram
Source: Regulation of the Head of the National Disaster Management Agency Number 2 of 2012

Disaster Risk Assessment Index

The index values are obtained from the analysis of data related to hazard, vulnerability, and capacity components for each potential disaster, grouped into 3 (three) levels/classes: 0-0.333 for low class, > 0.333-0.666 for moderate class, and > 0.666-1 for high class. The index values differ for each disaster, except for the regional capacity index, which is the same for the entire area. The disaster risk assessment in Central Lombok Regency is conducted down to the village/urban village level. Detailed results of the analysis for each index of disaster risk assessment for all potential disasters in Central Lombok Regency are outlined for each component determining the disaster risk assessment.

Discussion

Hazard analysis forms the foundation for determining hazard maps and levels in Central Lombok Regency. This hazard study focuses on the extent of the area that can be exposed to each potential disaster. The number and extent of hazards refer to the area data sourced from the Regency/District in Figures 2019 published by the Central Statistics Agency. The potential extent of hazards is calculated based on different parameters for each type of disaster.

These parameters follow the General Guidelines for Disaster Risk Analysis as stated in the Head of the National Disaster Management Agency Regulation Number 2 of 2012, as well as other guideline references from ministries/agencies at the national level. Based on these parameters, hazard classes and hazard areas are obtained for each potential disaster. The magnitude of potential hazard areas and classes for all potential hazards that may occur in Central Lombok Regency can be found in the following Table 1.

Table 1. Potential Disaster Threats in Central Lombok Regency and Their Extent

Category	*Extent of Hazard (Ha)*		
	Low	*Medium*	*High*
Earthquake	50382	48085	17696
Tsunamis	639	808	1827
Landslide	19693	959	5523
Volcanic Eruption	3766	53	-
Extreme weather	6	29897	86561
Extreme Waves and Abrasion	-	-	1665
Drought	13158	32141	70894
Forest and Land Fires	3682	33138	4013
Flood	1705	1908	5743
Epidemics and Disease Outbreaks	16532	36704	63317

The table 1 above provides information on the hazard extent and hazard classes for all potential hazards that may occur in Central Lombok Regency. In general, hazard potentials in Central Lombok Regency are classified into low, moderate, and high classes. The determination of hazard classes is obtained by considering the minimum to maximum hazard classes from the hazard assessment results at the sub-district level.

Geologically, earthquakes are natural events that have been occurring for hundreds of millions of years. In fact, the formation of Lombok Island, which occurred approximately 11 - 10 million years ago, also involved seismic events. Earthquakes pose a serious threat to life because they can have highly fatal impacts, especially if the population residing in active tectonic areas does not take anticipatory measures and necessary risk reduction efforts.

Throughout the history of earthquakes, the earthquakes themselves have never directly caused human deaths. What actually causes fatalities is the collapse of buildings constructed by humans. With an understanding of disaster risks, it is hoped that the government, together with the community, can adapt to the potential disasters and consistently undertake mitigation efforts, both in terms of building construction and knowledge dissemination. In analyzing the danger or threat of an earthquake, several related parameters are used. These parameters have an influence on the potential damage that may arise from an earthquake. The selection of these parameters refers to various existing Technical Guidelines while still taking into account the logical characteristics of the earthquake itself, as outlined in Table 2.

Table 2. Parameters for Earthquake Threat Analysis

Data Type	***Data Form***	***Source***
Administrative Limits	GIS Vector (Polygon)	BIG/Bapperida
DEM 30 Meter	Raster	LAPAN/NASA/JAXA
Peak Ground Acceleration (PGA) in bedrock (SB) for a probability of exceedance of up to 10% in 50 years (Indonesian earthquake source and hazard map 2017)	GIS Vector (Polygon)	Ministry of PUPR/PusGen
Reference value AVS30 (Average Shearwave Velocity in the upper 30m)	Tabular	BMKG/PusGen

From the results of overlaying several parameters, it can be concluded that Central Lombok Regency is dominated by a range of threat levels from low to high. Areas with the highest threat index are located along the coast, especially in the southern and central parts of the regency, particularly around the Southwest Praya and Central Praya Sub-districts. This is likely due to the presence of dominant earthquake sources (generators) in the southern and central regions of Central Lombok Regency, triggered by the Subduction Zone and Flores Thrust Fault.

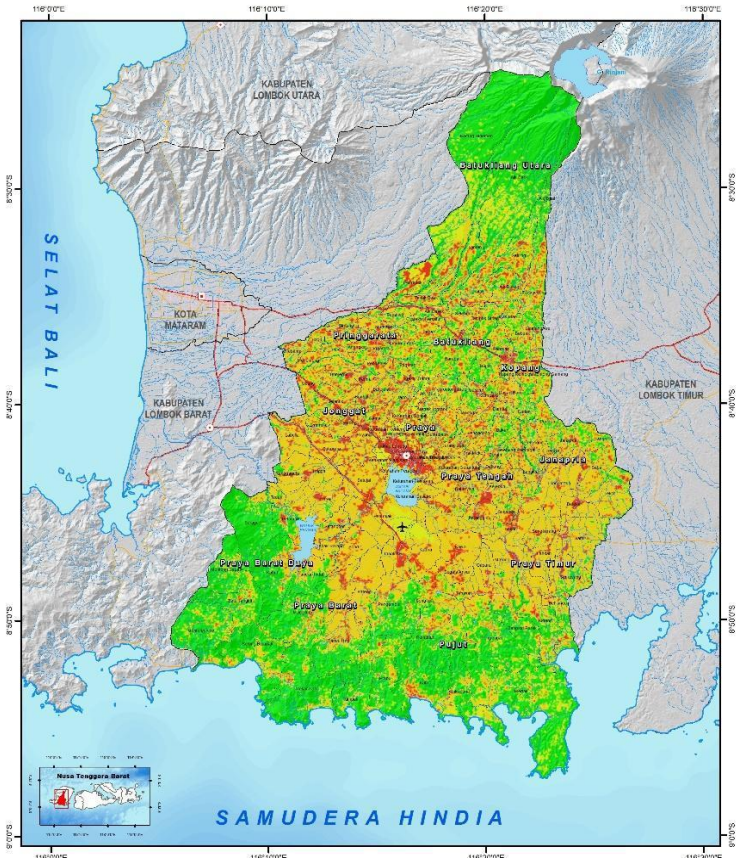

Figure 2. Earthquake Hazard Map of Central Lombok Regency

Overall, Central Lombok Regency is dominated by earthquake threats ranging from low to high levels. Looking at the distribution of hazards, East Praya Sub-district shows the highest percentage of high threat area, reaching 31% of its total area. Meanwhile, North Batukliang Sub-district has the lowest percentage of threat area, which is 2% of its total area. Meanwhile, the data on the extent of earthquake threats according to sub-district regions in Central Lombok can be seen in the following Table 3.

Table 3. Area of Earthquake Threats per Sub-district

Subdistrict	*Threat*	*Area*	*Total Affected Area (Ha)*	*Percentage Of The Sub-District Area*	*Percentage Of The Affected Sub-District Area*
Batukliang	Low	2301	5027	46%	100%
	Medium	2409		48%	
	High	317		6%	
Batukliang Utara	Low	11086	16326	68%	100%
	Medium	4916		30%	
	High	352		2%	
Janapria	Low	2410	12763	19%	100%
	Medium	7590		59%	
	High	2763		22%	
Jonggat	Low	858	6822	13%	100%
	Medium	4402		65%	
	High	1563		23%	
Kopang	Low	2309	5612	41%	100%
	Medium	2305		41%	
	High	998		18%	
Praya	Low	19420	45248	43%	100%
	Medium	20619		46%	
	High	5210		12%	
Praya Barat	Low	6832	15703	45%	100%
	Medium	6007		40%	
	High	2235		15%	
Praya Barat Daya	Low	29831	77351	39%	100%
	Medium	35629		46%	
	High	11891		15%	
Praya Tengah	Low	21521	57683	37%	100%
	Medium	28394		49%	
	High	7768		13%	

Praya Timur	Low	1294	8393	15%	100%
	Medium	4474		53%	
	High	2625		31%	
Pringgarata	Low	1238	3589	26%	100%
	Medium	3041		65%	
	High	410		9%	
Pujut	Low	13771	22892	60%	100%
	Medium	5885		26%	
	High	3327		14%	

Based on the calculation of the population in areas that may be exposed, it can be concluded that all villages in Central Lombok Regency generally have the potential to be affected by earthquakes. The difference lies in the index, where most villages have a low threat level. Only a small number of villages have a moderate threat level, and no village falls into the high threat level.

Conclusion

The conclusion that can be drawn from this research is that Central Lombok Regency faces significant risks related to earthquakes, especially in the coastal, southern and central areas. This factor demands an effective mitigation strategy. The risk index value is obtained from data analysis related to the hazard, vulnerability and capacity components for each potential disaster grouped into 3 (three) levels/classes, namely 0-0.333 for low class, > 0.333-0.666 for medium class, and >0.666-1 for high class. The index values are different for each disaster, except for the regional capacity index which applies the same to all regions. The Central Lombok Regency disaster risk assessment was carried out at the village/sub-district level. Detailed results of the analysis of each disaster risk assessment index for all potential disasters in Central Lombok Regency are described for each component determining disaster risk assessment. The results of this research show that the highest risk of earthquake disasters is in East Praya at 31%, then the moderate disaster risk is in the Jonggat and Pringgarata areas at 65%, and the low risk is in the North Batukliang area at 68%.

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