

Natural Disaster Mitigation of Road and Bridge Infrastructure in Bogor Regency, West Java

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Abstract

Bogor Regency, West Java, is an area with high vulnerability to natural disasters, especially floods and landslides, which threaten the sustainability of its road and bridge infrastructure. This transportation infrastructure plays a vital role as the lifeblood of the economy and evacuation access. This research aims to analyze the disaster risk to road and bridge infrastructure in Bogor Regency and evaluate applied and potential mitigation strategies. The research methods include literature review, secondary data analysis (BPBD risk map, historical disaster data, planning documents), field observations focused on vulnerable locations, and interviews with stakeholders (BPBD, PUPR Office, community). The results showed that the main threats in the form of flash floods and inundation in the north-eastern region (Jonggol, Cileungsi, Citeureup sub-districts) and landslides in the hilly south-central region (Megamendung, Cisarua, Cijeruk, Leuwiliang sub-districts) caused structural damage, erosion, access breaks, and logistical disruptions. Existing mitigation strategies include the construction of physical structures (embankments, gabions, retaining walls, slope reinforcement), river normalization, drainage improvement, and installation of landslide early warning devices. However, challenges such as budget constraints, development pressure on catchment areas, infrastructure maintenance, and climate change dynamics still hamper their effectiveness. This research recommends an integrated approach: (1) Strengthening of high-risk based structures with erosion/inundation resistant materials; (2) Application of Nature-Based Solutions (NBS) such as intensive slope revegetation and biopores; (3) Integration of



infrastructure- specific Early Warning Systems; (4) Application of the post-disaster "Build Back Better" (BBB) concept; (5) Cross-sector coordination and increased community participation in monitoring. Sustainable investment and strict spatial policies are key to resilient road and bridge infrastructure in Bogor Regency.

Keywords: Road Infrastructure, Bridge Infrastructure, Flood, Landslide, Bogor Regency.

Introduction

Bogor Regency is one of the level II regions in West Java Province. Bogor Regency has a large area of 266,381 hectares (BPS, 2018). In addition, Bogor Regency also has the largest population in West Java Province, namely 5,765,583 people (BPS, 2018) spread across 40 sub-districts, 19 villages, and 416 villages. Bogor Regency is one of the priority locations in the 2015-2019 National Medium-Term Development Plan (RPJMN) in reducing the disaster risk index.



Figure 1: Map of Bogor Regency area

Based on the Indonesian Disaster Prone Index (IRBI) published by BNPB in 2013, Bogor Regency is ranked 281st at the national level and 19th at the West Java Province level with a high disaster risk class. This level of risk is influenced by several factors such as the level of hazard, vulnerability and capacity in Bogor Regency. Indonesian Disaster Information Data (DIBI) for the period 1830 - 2018 shows that there are 5 (five) types of disasters that have occurred in Bogor

Regency, namely floods, tornadoes which are part of extreme weather, drought, earthquakes and landslides. Floods, landslides and tornadoes are the most common disasters in Bogor Regency. In addition to these disasters, there are other potential disasters such as flash floods, forest and land fires (Karhutla), and volcanic eruptions. Disaster conditions in Bogor Regency

Bogor Regency is caused by several influencing factors such as regional topography, geology and climate. Bogor Regency is an area with topography in the form of hills to mountains which are passed by several rivers. There are at least 6 (six) Watersheds (DAS) whose position stretches and flows from the mountainous area in the South to the North. This causes areas in the northern region, especially areas close to the river, to have the potential for flooding. While the southern part is a hilly and mountainous area, there are at least 2 (two) active volcanoes, namely Mount Gede and Mount Salak. Such regional conditions also cause some areas of Bogor Regency to be prone to landslides where landslides that occur in upstream areas can also potentially cause flash floods. Bogor Regency also often experiences extreme weather which usually occurs due to the transition from the dry season to the rainy season. In these conditions, there is the potential for tornadoes. In addition, Bogor Regency also has the potential for earthquake disasters, the specific characteristics of which cannot be separated from the potential for earthquakes in West Java Province. This is because there are three faults, namely the Lembang, Cimandiri, Baribis and Garsela Faults. Although known as the City of Rain, Bogor Regency is not immune to drought, which often occurs during the long and prolonged dry season. This condition also has the potential to cause easy forest and land fires in Bogor Regency.

Bogor District, as one of the largest and most dynamic districts in West Java, faces a double pressure: rapid population growth/development and high vulnerability to hydrometeorological and geological disasters. Its location adjacent to Jakarta, varied topography (lowlands to mountains), very high rainfall (>3000 mm/year), and crossed by major rivers (Ciliwung, Cisadane) and their tributaries, make floods and landslides a major threat. Road and bridge infrastructure, as critical components for mobility, logistics distribution, evacuation, and post-disaster recovery, are highly vulnerable to the impacts of these disasters. Damage to this infrastructure not only incurs direct economic losses due to repairs, but also massive indirect losses through the disruption of supply chains, access to emergency services and socio-economic activities. This research focuses on identifying vulnerabilities, evaluating existing mitigation strategies, and formulating strategic recommendations to improve the resilience of road and bridge infrastructure to natural disasters, particularly floods and landslides, in Bogor Regency.



METHODOLOGY

The type of data used in this research is qualitative data, in the form of expressions, words and sentences. Furthermore, the data sources used in this research are secondary data sources. Supranto (2007: 120) states that "Secondary data is data obtained either unprocessed or unprocessed, either in the form of numbers or data that has been processed.

has been processed, both in the form of numbers and descriptions". The data collection techniques used are:

1. Literature Study

Namely data collection techniques carried out by reading and studying literature or reading sources that have to do with the problem under study. Tracking written documentation is part of the approach in research in examining new knowledge.

2. Documentation Study

Documents are records of events that have passed. Documents can be in the form of writings, pictures, or works of a person. Documents related to this research include the work program of the Regional Disaster Management Agency (BPBD).

RESULTS AND DISCUSSION

Bogor Regency is ranked 281st at the national level and 19th at the West Java Province level with a high disaster risk class. One of the bases for the need for disaster management efforts is by looking at disaster events that have occurred in Bogor Regency. The history of disaster events is seen based on Indonesian Disaster Data and Information (DIBI) issued by BNPB, as seen in table 1.

No.	Type of Disaster	Number of Events	Victims			House (unit)				Damage (unit)		
			Dead & Missing	Injured	Displaced	Severely	Medium	Ring ar Deer	Submerged	Health Facilities	Worship Facility	Education Facility
1	Tornado	167	6	48	17.611	1.197	1.211	7.359	-	-	39	27
2	Flood	77	32	239	54.767	681	49	3.101	14.895	1	39	16



3	Earthquake	4	7	20	778	450	71	1.961	-	-	5	8
4	Drought	18	-	-	368.158	-	-	-	-	-	-	-
5	Landslides	187	120	103	6.614	773	193	997	-	1	15	10
Total		453	165	410	447.928	3.101	1.524	13.418	14.895	2	98	61

Table 1. History of Disaster Events in Bogor Regency 1830-2017

Based on disaster event data from DIBI, there are 5 (five) types of natural disasters that have occurred in the Regency area in the period 1830 - 2017, such as tornadoes, floods, earthquakes, droughts and landslides. The disasters that have occurred have caused impacts, both casualties, property losses and environmental / land damage as well as causing psychological impacts on the community.

The results of the disaster risk assessment in Bogor Regency show that disasters that have a high risk are floods, flash floods, extreme weather (tornado study), earthquakes, droughts, landslides. Meanwhile, forest and land fires (karhutla) and the eruption of Mount Salak are at moderate risk. While the eruption of Mount Gede is in the low risk category. A summary of disaster risk classes in Bogor Regency can be seen in Table 2 below.

No	Type of Disaster	Hazard Class	Vulnerability class	Capacity Class	Risk Class
1	Flood	High	High	Low	High
2	Flash flood	High	High	Low	High
3	Extreme weather	Medium	High	Low	High
4	Earthquake	High	High	Low	High
5	Forest and land fires	Medium	Low	Low	Medium
6	Drought	High	High	Low	High
7	Eruption Mount Gede	Low	Low	Low	Low
8	Eruption Mount Salak	Medium	Medium	Low	Medium

9	Landslide	High	High	Medium	High
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Table.2. Disaster risk class in Bogor Regency

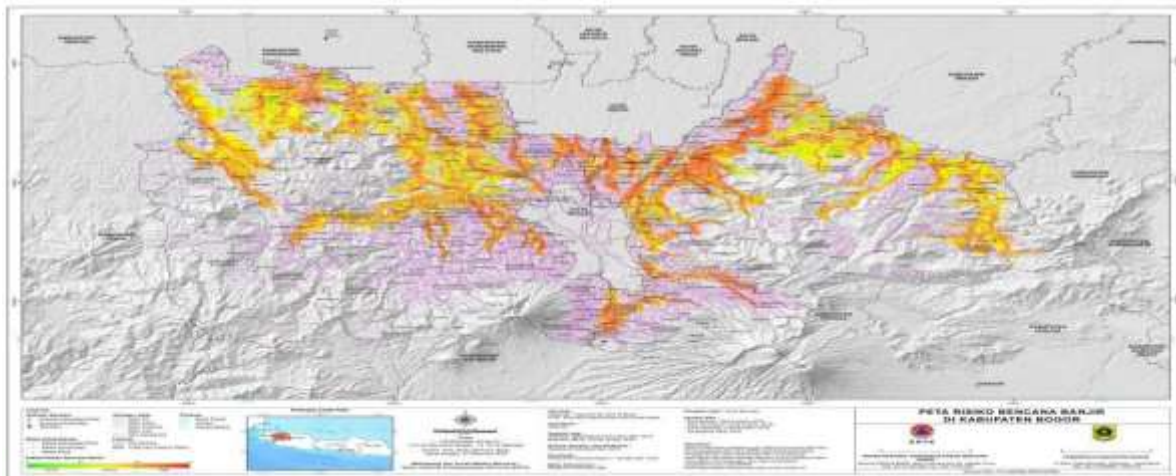
The Bogor Regency disaster risk assessment was conducted on 9 (nine) types of disasters in Bogor Regency. The results of the risk assessment in Table 2 show that the eight disasters studied have different disaster risks. In addition, 6 out of 9 disasters in Bogor Regency are seen to have a high risk class, namely floods, flash floods, extreme weather (tornadoes), earthquakes, droughts and landslides. Moderate disaster risk is found in forest and land fires (Karhutla) and the eruption of Mount Salak. While low risk is found in the eruption of Mount Gede. This gives an overview of the causes of damage to road and bridge infrastructure due to natural disasters.

The disasters described in this summary are those that have a high level of risk of damage to road and bridge infrastructure as follows:

Floods

The risk level of flooding is high in 281 out of 436 villages in Bogor Regency. Some areas in Bogor Regency that have a high risk of flooding include

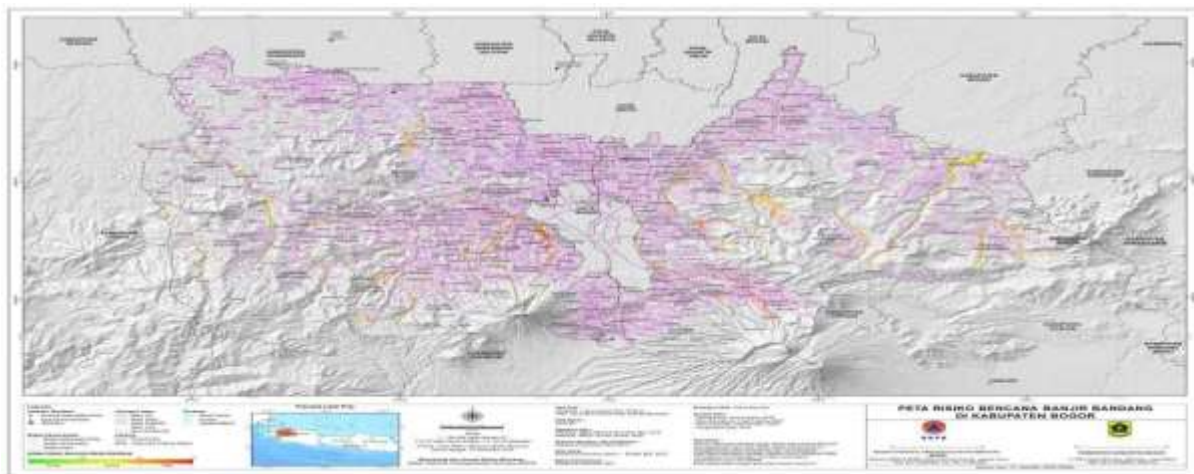
including Ciburuy Village in Cigombong Subdistrict, Pasir Jambu Village in Sukaraja Subdistrict, Bojong Koneng Village in Babakan Madang Subdistrict, Puspasari Village in Citeureup Subdistrict, Kalongsawah Village in Jasinga Subdistrict where these areas are located in watershed areas that are prone to and have the potential for flooding such as the Ciliwung River and the Cidurian River which are located in the northern and western parts of Bogor Regency.



Map of flood disaster risk in Bogor Regency

Flash Flood

A high level of flash flood disaster risk is found in 90 out of 436 villages in Bogor Regency. Some areas in Bogor Regency that have a high flash flood risk include Neglasari Village, Koleang Village, and Jasinga Village in Jasinga Sub-district, Bojong Koneng Village in Babakan Madang Sub-district, Cibeureum Village in Cisarua Sub-district and several other villages. These areas are not only passed by rivers such as the Cidurian River, Ciliwung River and Citeureup River in the western and southern parts of Bogor Regency, which are prone to and have the potential for flash floods, but also have narrowed upstream rivers and high potential for landslides.



Flash flood disaster risk map in Bogor Regency

Extreme Weather

The level of risk of extreme weather disasters, in this case tornadoes with a high category, is found in 428 out of 436 villages in Bogor Regency. These villages are scattered throughout Bogor Regency, especially the North and Central regions which have high land openness with sloping and broad topographic conditions.

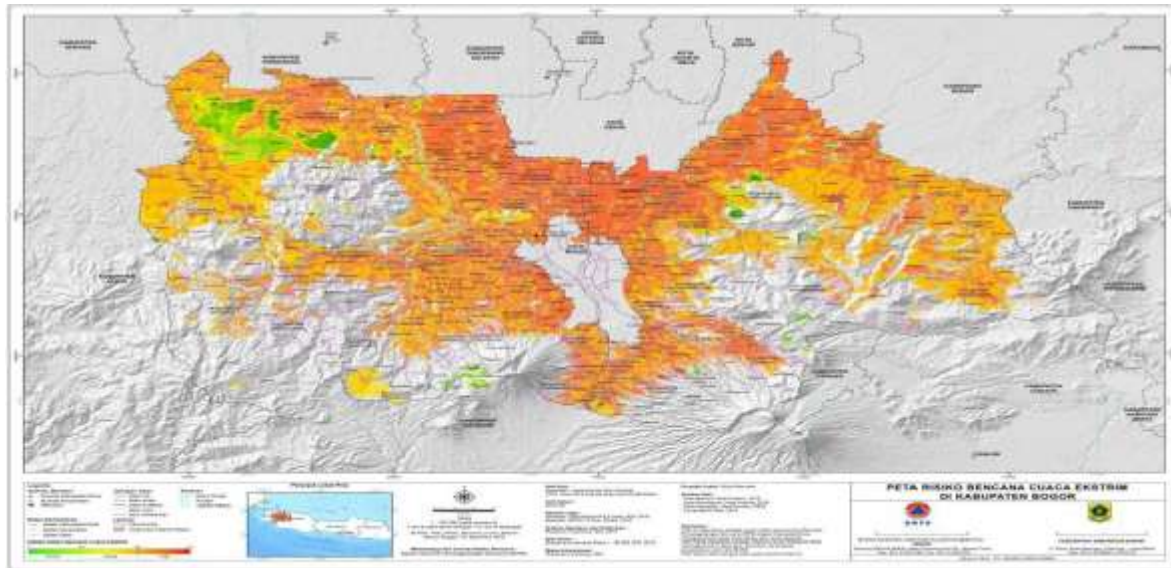


Figure 4. Extreme weather disaster risk map in Bogor District

This will certainly greatly affect the security of existing infrastructure. Therefore, it is important to always check the safety of the infrastructure periodically and check the condition of the infrastructure after a disaster event.

Cases of damage to road and bridge infrastructure due to disasters in Bogor Regency
Bojong gede sub-district

A landslide occurred in RT 12/10, Kedung Waringin Village, Bojong Gede Sub-district, on Monday evening, January 6, 2025. The landslide was triggered by heavy rain that flushed the area with high intensity for several hours, as well as unstable soil structure. The incident occurred at around

23.00 WIB. According to the Bogor Regency BPBD TRC team report, the landslide covered the road area and residents' parking lot with a size of about 30 meters long, 6 meters wide, and 5 meters high.

meters long, 6 meters wide, and 5 meters high. However, there were no reports of injuries, affected victims, or refugees due to this landslide. The affected public facility is the main access road in the RT 12/10 area, which is now covered by landslide material.

Babakan Madang sub-district

On September 15, 2022 in Bojong Koneng Village, Babakan Madang Subdistrict, Bogor

Regency, there was a land shift that caused damage to 23 buildings and part of the road along 1 km. The incident resulted in

24 residents fled to relatives' homes. The BPBD of Bogor Regency revealed that the land shift was likely caused by heavy rain that fell for three consecutive days in the area. The Geospatial Information Agency (BIG) states that there are 10 sub-districts in Bogor Regency that are at high risk of disasters due to land movement, namely Sukajaya, Nanggung, Leuwiliang, Citeureup, Babakan Madang, Sukamakmur, Tamansari, Tenjolaya, Cijeruk, and Cigombong.

Jasinga sub-district

On April 24, 2023, heavy rain that lasted for a long time caused the Cidurian River to overflow, resulting in the damage of two bridges in Kalongsawah Village, Jasinga Sub-district. The overflowing river even submerged houses with a height of 30 cm to 60 cm. At least 28 houses were flooded in Parungsapi Village. Three houses suffered wall damage, leaving eight people displaced in Petey Village.

Vulnerability of Road and Bridge Infrastructure

Based on the above cases, it is known that the majority of road and bridge damages caused by natural disasters are mostly caused by extreme weather that causes landslides or soil shifts. Where high rain intensity causes inundation that damages the pavement structure, erosion of the road base / embankment, and hydrodynamic pressure on the bridge foundation. Bridges over the Ciliwung, Cisadane, Cikeas and Cileungsi Rivers are particularly vulnerable. The north- eastern (lowland) areas such as in the sub-districts of Jonggol, Cileungsi, Citeureup, Klapanunggal, and Gunung Putri are disaster hotspots. In addition, landslides cause road breaks, damage to road structures (cracks, subsidence), buried roads, and the threat of collapse on bridges with foundations on unstable slopes. Road sections in the Puncak corridor (Megamendung, Cisarua), Cijeruk, Caringin and Leuwiliang are particularly vulnerable. In addition to extreme weather, floods and landslides are also suspected to be caused by land use change (forest / infiltration into settlements / plantations), river sedimentation, inadequate / blocked road drainage and old infrastructure.

Mitigation Strategies Applied

In an effort to handle damage to road and bridge infrastructure. The Bogor Regency Government through the Public Works and Spatial Planning Office and other related agencies have



carried out handling measures both emergency and permanent, among others as follows:

Construction or rehabilitation of embankments, gabions and retaining walls on landslide-prone road slopes such as Jalan Raya Puncak. In addition, reinforcement of slopes with reinforced concrete or stabilized soil systems (soil nailing, ground anchor) needs to be done at critical locations.

River normalization and dredging of sedimentation under bridges to maintain channel capacity and reduce pressure on bridge foundations.

Improvement of road drainage systems (culverts, side channels) in areas prone to inundation/flooding.

Strengthening bridge structures (foundations, pillars), especially those that are old or damaged.

Where the above handling activities are carried out in stages and carried out in areas that are considered disaster-prone as stated in the RPJMD, strategic plan and annual work plan of the Bogor Regency PUPR Office.

Integrated Mitigation Strategy Recommendations

Based on the analysis, an integrated approach is needed to improve disaster resilience by implementing the following steps:

Strengthening high-risk based structures, including strengthening/rehabilitation of roads & bridges in high-risk segments with the use of more erosion and inundation resistant materials for pavement in flood-prone areas. In addition, bridge designs with longer spans and deeper foundations to anticipate riverbed degradation and major floods;

The need to expand nature-based solutions (NBS) by intensively revegetating hillsides/cliffs through massive planting of deep-rooted and strong vegetation such as calliandras, vetiver on critical slopes above/below roads, not just ground cover;

Construction of biopores and infiltration wells along roads and parking lots to increase local rainwater infiltration.

Development of Constructed Wetlands in low-lying areas prone to inundation, near roads, as buffers and infiltration.

Creation of an infrastructure-integrated early warning system with the installation of real-time rainfall sensors to monitor river water discharge and land movement integrated with the PUPR and BPBD monitoring systems.

Implementation of "Build Back Better" (BBB) Post-Disaster, where every post-disaster



repair / reconstruction must integrate higher resilience standards, not just restore to its original condition.

Building strong synergy coordination between the PUPR Office, BPBD, DLH, and Bappeda in planning, financing, and implementation as well as involving community groups in monitoring the condition of roads, bridges, drainage, and mitigation structures in their neighborhoods, as well as early reporting;

Strict law enforcement against spatial planning violations in catchment areas and critical slopes.

CONCLUSION

Road and bridge infrastructure in Bogor Regency faces significant pressure from the threat of floods and landslides. Mitigation strategies that have been dominated by hard engineering approaches have proven necessary but not sufficient, facing challenges of budget, maintenance and environmental pressures. The research concludes that improving resilience requires an integrated approach that incorporates risk-based structural strengthening at the highest priority locations; significant expansion of nature-based solutions such as intensive slope revegetation and infiltration water management to address root hydrological and geotechnical issues; implementation of integrated early warning systems (infrastructure-specific to enable early action) and strong cross-sector policy coordination and spatial planning enforcement. Continued investment in this proactive, risk-based mitigation is imperative to ensure the continued vital function of Bogor Regency's transportation infrastructure, public safety and economic resilience into the future.

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