

INDEX AND RISK LEVEL OF LANDSLIDES ON ROAD AND BRIDGES LOCATED ON NATIONAL ROADS (CASE STUDY: KERINCI DISTRICT AND SUNGAI PENUH CITY, JAMBI PROVINCE)



Mutiara Sari¹✉, Mona Foralisa Toyfur¹✉  and Febrian Hadinata¹

¹Civil Engineering Department, University of Sriwijaya, Palembang, Indonesia



ABSTRACT

The regency of Kerinci and The city of Sungai Penuh are among the areas prone to landslides, which can impact roads and bridges on national roads. This study aims to determine the index and risk level of landslides on roads and bridges located on national roads in both regions. The index and risk level assessment are carried out by analyzing disaster risk factors, namely: hazard, exposure, vulnerability, external context and capacity. Assessment methods and variables are taken based on the Guidelines for the Implementation of Risk Analysis for Natural Disasters Affecting Roads and Bridges. The mapping of landslide risk based on the Geographical Information System (GIS) is compiled based on scoring and weighting all parameters, as well as an overlay among all constituent parameters. Based on the sampling results of ten samples of national road sections in the Kerinci Regency and Sungai Penuh City, the risk level of hazard, exposure, vulnerability, external context and road management capacity is divided into two classes, namely the Low class about 7.19 km (= 8.72 %) with seven short roads located within the city and the Medium class, which is 75.31 Km (= 91.28 %), with three roads connecting the cities.

Received 15 May 2021

Accepted 28 May 2021

Published 7 June 2021

Corresponding Author

Mona Foralisa Toyfur, MonaForalisaToyfur@gmail.com

DOI [10.29121/ijetmr.v8.i6.2021.960](https://doi.org/10.29121/ijetmr.v8.i6.2021.960)

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Copyright: © 2021 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords: GIS, Landslides, National Roads, Risk Assessment

1. INTRODUCTION

The economic growth of a developing country depends on a good level of road transportation that be accessed to facilitate business activities [Dimnwobi et al. \(2017\)](#). There is a causal relationship between investment in transportation infrastructure and economic development [Aschauer \(1991\)](#). Transport infrastructure has a long-term positive impact on economic development [Alam et al. \(2020\)](#). Road construction, as a form of human activity, has an influence on landslides. Road construction that results in changes in slope angle and additional loads on the slopes, as well as



steep topography and high rainfall, causes a high potential for landslides [Safeland \(2011\)](#).

Disaster is an event or series of events that threatens and disrupts the life and livelihood of the community which is caused either by natural factors and / or non-natural factors as well as human factors resulting in casualties, environmental damage, property loss and psychological impacts [of the Republic \(January 11, 2021\)](#). Landslide is a form of erosion where soil displacement occurs at one time and involves a large volume of soil. Landslides occur due to the sliding of a volume of soil above an impermeable layer that is water-saturated [Munir \(2006\)](#). Indonesia is often hit by landslides due to rainfall and earthquakes [Cepeda et al. \(2010\)](#).

Kerinci Regency is one of the areas in Jambi Province, which is prone to landslides, floods and other disasters. 75 percent of the Kerinci area is categorized as disaster-prone [Karim et al. \(2019\)](#). Many disasters have occurred in Kerinci, especially entering the rainy season. Landslides are disrupting traffic flow in Kerinci Regency as it covers the road. Therefore, special attention is needed to minimize the occurrence of landslides in Kerinci Regency and Sungai Penuh City.

There are 7 national roads in Kerinci Regency and 5 national roads in Sungai Penuh City. There were 13 landslides in 2020 and 2021 on national road sections in both Kerinci regency and Sungai Penuh City [Jambi_National_Road_Implementation_Agency \(2021\)](#). The frequency of continuous landslides is found on the Sanggaran Agung-Sei Penuh road section with a length of 16.77 kilometers, which is the main transportation route connecting Kerinci district with Sungai Penuh City; the Sungai Penuh-Siulak Deras/Letter W road section with 22.24 kilometers and Sungai Penuh-West Sumatra border with a length of 36.30 kilometers which is the main transportation route that connects the City of Sungai Penuh with West Sumatra Province. The road section is a national road as stipulated in the (Decree of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 248/KPTS/M/2015 concerning the Designation of Roads in the Primary Road Network according to their Function as Arterial Roads (JAP) and Collector-1 Roads, 2015), as it has a strategic function in supporting connectivity between provinces.

Geographical, geological and hydrological conditions of Kerinci Regency and Sungai Penuh City are natural factors that cause landslides along these national roads, and these natural phenomena have a negative impact on road users. One of the most effective methods to prevent and minimize damage due to landslides is to carry out comprehensive planning and risk assessment [Skrzypczak et al. \(2020\)](#). The high potential for landslides in Kerinci Regency requires a risk analysis of landslides. Therefore, to minimize the occurrence of disasters that will cause losses in the form of material and property and the safety of the surrounding population, it is necessary to analyze the risk of landslides in the area to determine the potential distribution of landslides, especially on national roads. The risk management has also been included as one of the variables in the analysis of green road project management [Chang and Lin \(2018\)](#).

[Ministry_of_Public_Works \(2014\)](#) provide an implementation guideline used to explain the steps taken in carrying out a natural disaster risk analysis for roads and bridges such as providing guidance for road work units/Technical Implementing Units in conducting risk analysis in order to obtain an overview of the risk level of road network elements as input for road and bridge planners in mitigating natural disasters and providing guidance in making natural disaster risk maps for road infrastructure and bridges. In this guideline, the assessment uses the risk index concept. Risk assessment is carried out to find out how much damage or loss is likely to be experienced in the event of a disaster. The natural disaster risk index model is divided into five component factors in the risk function for each type of threat, namely the hazard factor, the exposure factor, the vulnerability factor, the external context factor and the capacity factor. The threats considered are the threat of earthquakes, floods, volcanic eruptions, landslides and tsunamis. Sub contractors are the components of the factors that affect each factor and indicators are a parameter used to describe the influence of factors on the value of the risk index. There are three classification results for each

indicator, namely the low, medium and high.

2. METHODOLOGY

The research that will be carried out is a risk study to find out how much the possibility of damage or loss that will be experienced in the event of a landslide, this study uses the concept of a risk index. The risk index concept is an assessment done by indicating a specific scale or rating of disaster risk. Each indicator is given a certain predetermined description and is described by an index value. Each indicator index value will contribute to the landslide risk index value.

The data entered will be assessed in the form of an index value, which is the conditioning of each indicator in the form of a certain value, which is not the actual value, but is a comparison of the conditions of each indicator. Each condition/characteristic of the indicator has a different index value, which the results will be displayed in 3 (three) classifications, namely: low, medium and high. The Landslide Disaster risk index model is used as the risk analysis. The list of indicators for each sub-factor and factor of landslide can be seen in [Table 1](#).

From [Table 1](#) above, it can be seen that each indicator has an equal contribution to the risk index value. The weight of the indicator is obtained from the following :

$$W = \frac{100\%}{n} \quad (1)$$

Notes:

w = Weight of indicator

n = number of indicator

FACTOR	Weight %*)	SUB FACTOR	Weight %**)	Indicator Code	Weight %***)	INDICATOR	
A	B	C	D	E	F	G	
HAZARD	12.50	Soil Vulnerability Index	12.50	L.1	4.17	Locations of roads on the map of ground motion threat	
				L.2	4.17	Daily rainfall	
				L.3	4.17	The frequency of landslides around the road	
EXPOSURE	16.67	Physical	8.33	L.4	4.17	Road length	
				L.5	4.17	Total length of the bridge	
		Population Economics	4.17	4.17	L.6	4.17	Traffic volume
					L.7	4.17	Product Domestic Regional Bruto (PDRB) of Province/District/City located nearby roads
					L.8	4.17	Existing road conditions
VULNERABILITY	41.67	Physical	41.67	L.9	4.17	Existing bridge conditions	
				L.10	4.17	Road terrain classification	
				L.11	4.17	Number of bridges on roads	
				L.12	4.17	Subgrade type	
				L.13	4.17	Soil capacity around the bridge	
				L.14	4.17	Availability of alternative routes/roads	
				L.15	4.17	Slope water system	

Continued on next page

Table 1 continued

				L.16	4.17	Slope/cliff safety building
				L.17.	4.17	Availability of drainage system
EXTERNA L CONTEXT	12.50	Economics	4.17	KE.1	4.17	Economics development of city functions
		Politics	4.17	KE.2	4.17	City functions in politics/government
		Human Activities	4.17	KE.3	4.17	Pool printing on road slopes
CAPACITY	16.67	Planning	4.17	KAP.1	4.17	Institutional readiness for emergency response and recovery
		Human Resource	8.33	KAP.2	4.17	Availability of resources
				KAP.3	4.17	PDRB of Province/District/City nearby
		Access and Mobil- ity	4.17	KAP.4	4.17	Access and mobility of resources

Each indicator in the risk index model has a value according to its condition, which is called the indicator index value. Mathematically, the risk index model (model R) used is formulated in Equation (2), which is the EDRI: Earthquake Disaster Risk Index Davidson (1997).

$$Ri = \sum W_{Hi}Hi + \sum W_{Ei}Ei + \sum W_{Vi}Vi + \sum W_{Exi}Exi + \sum W_{Ci}Ci \quad (2)$$

Notes:

Ri = Risk index value for disaster i

Hi = Index value for hazard indicator

Ei = Index value for exposure indicator

Vi = Index value for vulnerability indicator

Exi = Index value for external context indicator

Ci = Index value for capacity indicator

W = Weight for each factor

i = Type of threat (example: landslide, earthquake, flood, etc)

Risk factors consist of hazard, exposure, vulnerability, external context and capacity. Each risk factor is assessed by the indicator index value contained in each factor and sub-factor. Each indicator index value is directly proportional to the risk index value, except for capacity. The indicator index value is inversely proportional to the risk index value.

In this guideline, the indicator of index value for the capacity factor is given in the form of a risk index value, which is inversely proportional to the value for other factors. The better the index value for capacity, the smaller the risk index value will contribute to the risk index value. Each indicator will be multiplied by one weight value. The risk index value is the sum of all the weighted values multiplied by the indicator index value. The weight of each indicator has an equal contribution to the value of the disaster risk index.

After obtaining the maximum and minimum risk index value, it is then can be classified to obtain the risk level. The range of classification for the risk index value can be seen in Figure 1.

Notes:

Ri min = minimum risk index value

Ri max = maximum risk index value

Ri c = the difference between maximum and minimum risk index value

$$= Ri \max - Ri \min \quad (3)$$

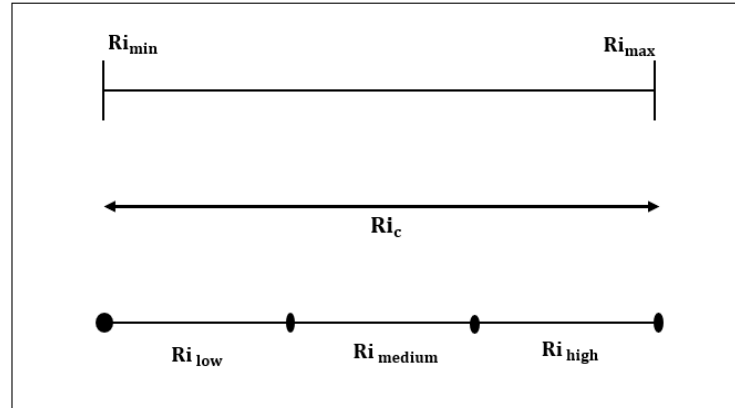


Figure 1 Description of risk index value range calculation

- The lower limit of the value range is obtained from the following calculation:

$$Ri_{low} = Ri_{min} \quad (4)$$

$$Ri_{medium} = Ri_{min} + (1/3 \times Ri_c) \quad (5)$$

$$Ri_{high} = Ri_{min} + (2/3 \times Ri_c) \quad (6)$$

- The upper limit of the value ranges is obtained from the following calculation:

$$Ri_{low} = Ri_{min} + (1/3 \times Ri_c) \quad (7)$$

$$Ri_{medium} = Ri_{min} + (2/3 \times Ri_c) \quad (8)$$

$$Ri_{high} = Ri_{max} \quad (9)$$

The range of risk index value classification will divide the value into three level; high, medium and low. The research is limited to National Roads, which are scattered in Kerinci Regency and Sungai Penuh City. These sections of the National Road are in areas prone to landslides. Details of the National Roads in question are shown in [Table 2](#).

Table 2 List of Roads						
No.	Road Number		Road Name	Road Length (Km)	Jap (Km)	Jkp-1 (Km)
1	37		Sanggaran Agung - Sei Penuh	16.77	-	16.77
2	37	11 K	Jln. Diponegoro (Sungai Penuh)	0.25	-	0.25
3	37	12 K	Jln. Cokroaminoto (Sungai Penuh)	0.61	-	0.61
4	37	13 K	Jln. M. Yamin (Sungai Penuh)	0.58	-	0.58
5	37	14 K	Jln. Martadinata (Sungai Penuh)	2.60	-	2.60

Continued on next page

Table 2 continued

6	37	15	K	Jln. Sultan Thaha (Sungai Penuh)	1.70	-	1.70
7	38			Sungai Penuh - Bts. Prov. Sumbar	36.30	-	36.30
8	38	11	K	Jln. A. Yani (Sungai Penuh)	0.33	-	0.33
9	38	12	K	Jln. Soekarno-Hatta (Sungai Penuh)	1.12	-	1.12
10	43			Sungai Penuh - Siulak Deras/Letter W	22.24	-	22.24
				SUB TOTAL	82.50	-	82.50

The research to be carried out is a descriptive analysis combined with the Geographical Information System (GIS) approach, so that the results obtained can be displayed in the form of a qualitative map. The landslide risk index model on roads and bridges is used because this model uses relative proportions and a simple concept that makes it easy for users to analyze and make decisions.

3. RESULTS AND DISCUSSION

Information technology, especially technology related to Geographical Information Systems (GIS) is very helpful in providing information. Geographical Information Systems (GIS) can be used to overlay various indicators that cause landslides on roads.

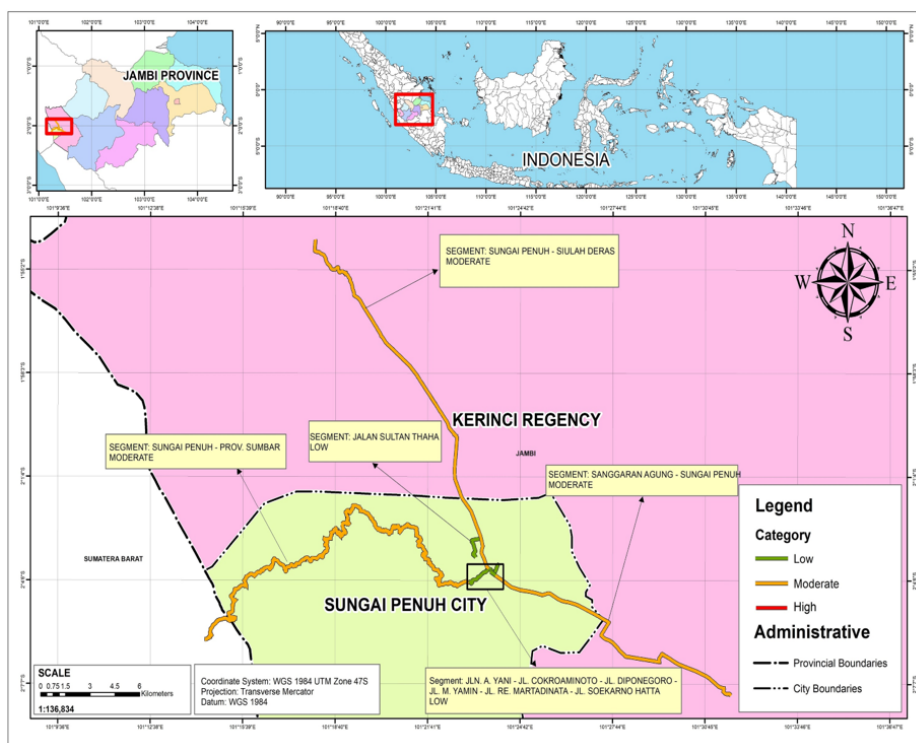


Figure 2 Map of Landslide Risk Index on National Roads in Kerinci Regency and Sungai Penuh City

Based on the formulation of previous research, landslide risk is assessed through a disaster risk index of each hazard risk factor, exposure, vulnerability, external context, and the capacity of road managers during the emergency response and recovery period formulated in the equation above. The Risk Index Map is constructed using Spatial Analysis - Overlay - Intersect of each factor. There are 3 (three) classifications of the indicator index for each indicator

used, namely the low, medium, and high. Based on the spatial analysis that has been carried out, a map of landslide hazard on national road is obtained which can be seen in [Figure 2](#).

Based on the results of the analysis carried out, it is known that the length of 7.19 km or 8.72% has a low risk level and 75.31 km or 91.28% is at a moderate risk level. There are no national roads in Sungai Penuh City and Kerinci Regency, which have a high level of risk. The results of risk analysis can be seen in [Tables 3, 4 and 5](#).

Table 3 Value Limits for Each Level of Risk

Risks	Upper and Lower Limit Value
R low	1.08 – 1.69
R medium	1.69 – 2.31
R high	2.46 – 2.92

Table 4 National Road Risk Level in Sungai Penuh City and Kerinci Regency

No.	Road Length (Km)	Road Name	Risk Index (R)	Risk Level
1	16.77	Sanggaran Agung - Sei Penuh	1.71	Medium
2	0.25	Jln. Diponegoro (Sungai Penuh)	1.25	Low
3	0.6	Jln. Cokroaminoto (Sungai Penuh)	1.25	Low
4	0.59	Jln. M. Yamin (Sungai Penuh)	1.25	Low
5	2.61	Jln. Martadinata (Sungai Penuh)	1.25	Low
6	17	Jln. Sultan Thaha (Sungai Penuh)	1.25	Low
7	36.3	Sungai Penuh - Bts. Prov. Sumbar	1.96	Medium
8	0.31	Jln. A. Yani (Sungai Penuh)	1.25	Low
9	1.13	Jln. Soekarno-Hatta (Sungai Penuh)	1.25	Low
10	22.24	Sungai Penuh - Siulak Deras/Letter W	1.79	Medium

Table 5 Classification and Indicator Index Value

Risk Classification	Length (Km)	Percentage (%)
Low	7.19	8.72
Medium	75.31	91.28
High	-	-

4. CONCLUSION

There are only two classes of landslide hazard index values in Sungai Penuh City and Kerinci Regency, namely low and medium. Seven roads that are classified as low, namely Jln. Diponegoro, Jln. Cokroaminoto, Jln. M. Yamin, Jln. Martadinata, Jln. Sultan Thaha, Jln. A. Yani, Jln. Soekarno-Hatta, while 3 (three) roads are classified as medium, namely the Sanggaran Agung - Sei Penuh, Sungai Penuh - West Sumatra border and Sungai Penuh - Siulak Deras / Letter W. The Risk Level of Landslide Hazard on National Roads in Sungai Penuh City and Kerinci Regency based on the level of hazard risk, exposure, vulnerability, external context and road management capacity, is divided into two classifications, i.e: (a) Low, which is about 7.19 Km (8.72%), and (b) Medium, with a length of 75.31 Km (91.28%).

REFERENCES

- Alam, K. M., Li, X., Baig, S., Ghanem, O., & Hanif, S. (2020). Causality between transportation infrastructure and economic development in Pakistan: An ARDL analysis. *Research in Transportation Economics*, 100974–100974. Retrieved from <https://dx.doi.org/10.1016/j.retrec.2020.100974>
- Aschauer, A. (1991). *Transportation Spending and Economic Growth*. Washington DC: American Public Transit Association.
- Cepeda, J., Smebye, H., Vangelsten, B., Nadim, F., & Muslim, D. (2010). *Landslide risk in Indonesia*. Jakarta: ISDR.
- Chang, A., & Lin, J. (2018). Defining green road project management scope by PDRI. *International Journal of Engineering Technologies and Management Research*, 94–102.
- Davidson, R. (1997). *An Urban Earthquake Disaster Risk Index. California: The John A. Blume Earthquake Engineering Centre*.
- Dimnwobi, S. K., Nwokoye, E. S., Ekésiobi, C. S., & Igbanugo, C. I. (2017). Transportation infrastructure and diversification of Nigeria's economy: implications for the developmental state. *The Nigerian journal of economic and social studies*, 59(3), 309–330.
- Jambi_National_Road_Implementation_Agency. (2021). *Recapitulation of Landslide Location in Jambi Province*. Jambi: BPJN Jambi.
- Karim, K., Lova, A. N., Budaya, I., Yanita, P., & Ahmad, M. (2019). Shopping Life Style and Fashion Involvement on Buying Interest of Fashion Product with Motivation as Intervening Variable in the High Income Community of Siulak Mukai. *Journal of Economics and Business*, 2. <https://dx.doi.org/10.31014/aior.1992.02.01.62>
- Minister of Public Works and Public Housing of the Republic of Indonesia Number 248 / KPTS / M / 2015 concerning the Designation of Roads in the Primary Road Network according to their Function as Arterial Roads (JAP) and Collector-1 Roads. (2015). Retrieved from <https://binamarga.pu.go.id/v3/uploads/files/110/763eb93f0e70f3cbf90b3e2ae120885a.pdf>
- Ministry_of_Public_Works. (2014). *Guidelines for the Implementation of Risk Analysis for Natural Disasters Affecting Roads and Bridges*. Jakarta: Directorate General of Highways.
- Munir, M. (2006). *Geologi Lingkungan*. Malang: Bayumedia Publishing.
- of the Republic, L. (January 11, 2021). *Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management*. Retrieved from https://bnpb.go.id/ppid/file/UU_24_2007.pdf
- Safeland. (2011). Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies. Analysis of Landslides Triggered by Anthropogenic Factors in Europe. *Europe*.
- Skrzypczak, I., Kokoszka, W., Pytlowany, T., & Radwański, W. (2020). Landslides and the risk of damage to road infrastructure on the example of a transport node. In *Data Analysis and Modelling* (pp. 53–62). Springer.