LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : JURNAL ILMIAH

Judul karya ilmiah (artikel)	: Geomorphological Spatial Model of Risk Analysis for Natural Disasters in Heritage Railway Tunnel		
Penulis Jurnal Ilmiah	: **A D W Rahmadana, S A P Rosyidi, D M Setiawan and R Nuraini**		
Identitas Jurnal Ilmiah	:	a. Nama Jurnal	: GEOTROPIKA & ICHITRA 2021
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Kategori Publikasi Jurnal Ilmiah : ☑ Prosiding Internasional
☐ Prosiding Nasional

Hasil Penilaian *Peer Review* :

Komponen Yang Dinilai	Nilai Maksimal Prosiding					Nilai Akhir Yang Diperoleh
	Internasional Bereputasi ☐	Internasional ☐	Nasional Terakreditasi ☐	Nasional Tidak Terakreditasi ☐	Nasional Terindeks DOAJ ☐	
Kelengkapan dan Kesesuaian unsur isi buku(10%)	3,00					3
Ruang lingkup dan kedalaman pembahasan (30%)	9,00					8,7
Kecukupan dan kemutakhiran data/ informasi dan metodologi (30%)	9,00					9
Kelengkapan unsur dan kualitas penerbit (30%)	9,00					9
Total = 100%	30,00					29,7
Kontribusi Pengusul (Penulis Pendamping)	Penulis ke-4 dari 4 penulis: (40%*29,7)/3					**3,96**
KOMENTAR PEER REVIEW	1. Tentang kelengkapan unsur isi buku: unsur-unsur dalam makalah telah lengkap dan sesuai dengan kaidah penulisan ilmiah, mulai dari pengungkapan permasalahan, tujuan, metodologi, hasil, pembahasan kesimpulan dan pustaka yang relevan. 2. Tentang ruang lingkup dan kedalaman pembahasan : makalah ini berisi kajian geomorfologi yang diterapkan dalam menilai potensi kebencanaan untuk infrastruktur perkeretaapian menggunakan GIS dan bentang lahan serta penilaian risikonya. Lingkup kajian relevan dengan isu kekinian dalam bidang transportasi dan dibahas secara sistematik dan ilmiah. 3. Tentang kecukupan dan kemutakhiran data/informasi dan metodologi: informasi lengkap dan metodologi yang ditunjukkan valid serta memiliki kebaruan khususnya utk bidang ketekniksipilan dan tidak ada indikasi plagiasi, hasil turnitin rendah < 20% 4. Tentang Kelengkapan unsur dan kualitas penerbit: penyelenggara seminar GEOTROPIKA & ICHITRA 2021 merupakan institusi bereputasi dan IOP merupakan penerbit bereputasi yang terindeks SCOPUS.					

Yogyakarta, Januari 2023
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LEMBAR
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Kelengkapan dan Kesesuaian unsur isi buku(10%)	3,00					3.
Ruang lingkup dan kedalaman pembahasan (30%)	9,00					8.5.
Kecukupan dan kemutakhiran data/ informasi dan metodologi (30%)	9,00					8.5.
Kelengkapan unsur dan kualitas penerbit (30%)	9,00					8.5.
Total = 100%	30,00					28.5.
Kontribusi Pengusul (Penulis Pendamping)						(20%) [illegible]
KOMENTAR PEER REVIEW	1. Tentang kelengkapan unsur isi buku........ Lengkap. 2. Tentang ruang lingkup dan kedalaman pembahasan .... Sangat baik. 3. Tentang kecukupan dan kemutakhiran data/informasi dan metodologi........ Sangat baik. 4. Tentang Kelengkapan unsur dan kualitas penerbit........ Sangat baik, terindeks Scopus.					

3.1 u.

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Geomorphological Spatial Model of Risk Analysis for Natural Disasters in Heritage Railway Tunnel

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Abstract. Flood event in Ijo Tunnel led to disruption to schedules and train routes. The objectives of this research are to determine the susceptibility, vulnerability, capacity, and risk, to analyze the geophysical and geotechnical condition, and to compile the strategy of disaster mitigation of Ijo Tunnel. A spatial approach based on landform analysis was performed to establish the disaster components. Geophysical and geotechnical investigation was conducted to describe the condition of the affected region. A field survey was accomplished to collect data and to study supporting works of literature. The descriptive analysis was completed to determine strategy and recommendation in flood and potential landslide mitigation. The result depicts that Ijo Tunnel holds multi-disaster risk such as floods and landslides. The occurrence of floods is induced by extreme rainfall and inability of drainage channels to retain water. The landslide potential is influenced by morphological factors and composting materials in Ijo Tunnel's region. The existence of spring fracture on the north slope also contributes to increasing the slopes' landslide potential. The flood mitigation measure can be carried out by building a well-prepared drainage system and watershed and surface runoff management. Areas with a high level of landslide susceptibility can be overcome by building permanent retaining walls and pipes on slopes to reduce the soil saturation level.

1. Introduction

Rail transport is a mass transportation mode with more advantages that the other transportation modes. These advantages include: (1) large capacity (bulk); (2) fast; (3) safe; (4) energy-saving and environmental-friendly; and (5) requires relatively small area. Compared to land transportation modes such as buses which have energy consumption of 0.0125 litters of energy per km/Passenger or private cars which have energy consumption of 0.02 litters per KM/Passenger [1], the train energy consumption is considered the most efficient, which is 0.002 litters per km/Passenger. Therefore, trains become the backbone of freight and passenger transportation in Indonesia.

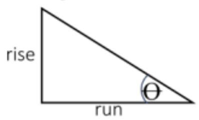
The smoothness of trains in freight and passenger transportation is also affected by natural conditions. One of the disruptions to rail traffic is caused by the disaster aspect [2]. Various natural disasters such as flood, landslide, earthquake, volcanic eruption, and tsunami can affect the rail transportation services negatively [3]. Disaster risk needs to be minimized by identifying the level of vulnerability, susceptibility, and capacity of the railway operator. Such action is needed since the cost of developing railway infrastructure is very expensive [1].

One of the natural disasters that disrupted rail traffic occurred on June 17-18th, 2016 around Ijo Tunnel, Bumiagung Village, Rowokole District, Kebumen Regency. Flood and landslide occurred in Ijo Tunnel have disrupted the railway traffic in the southern part of Central Java. Therefore, several trains (KA) were delayed in departure and arrival.

The effect of the flood and landslide occurred in Ijo Tunnel is material losses. The affected train route certainly needs to be improved regarding its facilities and infrastructure so that similar incidents will not happen again [4]. Therefore, efforts to identify and formulate strategies for handling floods and landslides in the Ijo Tunnel need to be made to maintain the safety of the train travel. Hence, this study has three objectives, those are: (1) determining the level of susceptibility, vulnerability, and capacity in Ijo Tunnel; (2) analyzing the geophysical and geotechnical conditions of Ijo Tunnel; and (3) developing a strategy of flood mitigation strategy in Ijo Tunnel.

2. Method

This research applied a spatial approach based on an analysis of the landform approach in establishing disaster components. Landform units were obtained from the data processing of slope class, lithology, geological structures, and river flow patterns. Slope identification was obtained from each cell of the earth's surface in digital format (raster) which contains information of location point. Raster data is used to build a 3D model into a DEM. The output of the slope raster can be calculated in degrees or percentages with the following triangulation basic equation [5].



$$\text{Degree of slope} = \tan \Theta = \text{rise/run} \tag{1}$$

$$\text{Percent of slope} = \text{rise/run} * 100 \tag{2}$$

Geophysical and geotechnical analysis are the main keys in describing the condition of the area affected by the disaster. Furthermore, the strategies and recommendations in handling disasters in Ijo Tunnel was established descriptively.

2.1. Tools and Materials

This research required certain tools and materials. The tools used included a computer set, ArcGIS 10.1 software, and survey equipment (camera, GPS, compass, and geological hammer). Meanwhile, the research materials used are presented in table 1.

Table 1. Research materials.

Parameter	Research Variable	Data
Susceptibility of landslide disaster	Slope Class	Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency
	Level of incision	Shuttle Radar Topography Mission (SRTM) of 30 m resolution by the United States Geological Survey (USGS)
Subsubsection	Slope Class	Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency
	Landform	Slope Class (Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency)
		Lithology and geological structure (Digital Geological Map shape file (.shp) by Geological Research and Development Center)

		River flow patterns (Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency)
	Rainfalls	Monthly rainfall (Meteorology, Climatology and Geophysics Agency – BMKG)

2.2. Assessment of Multi-hazard

Landslide

The susceptibility of landslides was assessed using slope class and level of incision variables. The landslide susceptibility class was determined by summing up the slope class scores and the level of incision. Classification of slope class, level of incision, and landslide susceptibility is presented in table 2. and table 3.

Table 2. Classification and score of slope class and level of incision.

Skor	Slope	Morphology	Level of Incision
0	0-2 %	Flat	Low (Score 1)
1	2-7 %	Choppy	
2	7-13 %	Wavy	Medium (Score 2)
3	13-20 %	Hills	High (Score 3)
4	20-55 %	Mountains	
5	>55%	Steep Mountains	

Table 3. Classification of landslide susceptibility.

Scores of Slope Class and Incision	Class of Landslide Susceptibility
0-2	Low
3-5	Medium
6-8	High

Flood

The flood susceptibility was identified and assessed using three variables, those are slope class, landform, and rainfall. The susceptibility class was determined by summing up the scores of each variable. Classification of slope classes, landforms, rainfall, and flood susceptibility are presented in table 4. and table 5.

Table 4. Classification and score of slope class, landform, and rainfall.

Skor	Slope	Landform	Monthly Rainfall (mm/month)
0	5-6%	Hills, mountains, scarp	0-100
1	4%	Volcanic fluvio fans, colluvial cones, foot of slopes of volcano, debris flow of the foot of slopes, the foot of volcano	100-200

2	2-3%	Foot plains, alluvial plains, fluviomarin plains, intervolcanic plains, valleys between hills	200-400
3	1%	River valley, floodplain	>400

Table 5. Classification of flood susceptibility.

Scores of Slope Class, Landforms, and Monthly Rainfalls	Class of Flood Susceptibility
0-3	Low
4-6	Medium
7-9	High

Multi-Hazard

Multi-hazard is information on the level of vulnerability of an area to various disaster threats [6]. The multi-hazard level was determined by summing up the flood and landslide susceptibility scores. Classification and classes of multi-disaster are presented in table 6.

Table 6. Multi-hazard class.

Multi-hazard scores	Multi-hazard Class	Score
0-5.7	Low	1
5.8-11.5	Medium	2
11.6-17	High	3

2.3. Assessment of Vulnerability

Disaster vulnerability is a condition of a community or society that leads to an inability to deal with disaster threat. Such vulnerability means an assessment of the magnitude of the element at risk of being affected by a disaster related to facilities, infrastructure, staff, and use of services. There are three assessment parameters used, including the completeness of supporting infrastructure, the quality of the train route, and the density of rail traffic (see table 7).

Table 7. Class of disaster vulnerability.

Class and Score	Completeness of supporting infrastructure	Quality of train route	Density of rail traffic
Low (1)	The existence of buildings such as gabions, embankments, and others to reduce the effect of disasters in almost all vulnerable zones, as well as complete disaster emergency response tools	Good	Not dense
Medium (2)	The existence of buildings such as gabions, embankments, and others to reduce the effect of disasters in parts of all vulnerable zones, yet the disaster emergency response tools is not complete	Quite good	Quite dense
High (3)	No gabions, embankments, and other buildings to reduce the effect of disasters in all vulnerable zones, and the disaster emergency response tools is not complete	Poor	Very dense

2.4. *Assessment of Capacity*

Disaster capacity is the ability of a region and communities to take action to reduce the level of threat and the level of losses due to disasters. Such capacity means the preparedness of the railway operator in this case is PT. Kereta Api Indonesia (Persero) and related agencies in responding to disasters along the train route. There are three assessment parameters used, including Standard Operating Procedures (SOP) for disaster emergency response, studies, and information on disaster risk in the Operational Area (DAOP), as well as communication and coordination of PT. Kereta Api Indonesia (Persero) and related agencies (table 8).

Table 8. Class of disaster capacity.

Class and Score	SOP of disaster and emergency response	Study and information regarding the disaster risk in DAOP	Communication and Coordination
Low (1)	None	Few	Less correlated
Medium (2)	Presents but not in accordance with the standard yet	Quite complete	Correlated but not quite intensive
High (3)	Presents and in accordance with the standard	Complete	Correlated and intensive

2.5. *Assessment of Risk*

Disaster risk is the potential loss caused by a disaster in an area within a certain period. Disaster risk is Mathematically formulated in equation (3). The level of disaster risk will increase as the hazard and vulnerability increase. However, the value of risk can be small if the level of capacity is high. The disaster risk class is divided into three classes, which are low, medium, and high (see table 9).

$$R = (H \times V) / C \tag{3}$$

In which:

R = Risk
H = Hazard
V = Vulnerability
C = Capacity

Table 9. Class of disaster risk.

Class of Risk	Score of Disaster Risk
Low	0.00-3.22
Medium	3.23-6.11
High	6.12-9.00

3. Results and Discussion

3.1. *Multi-Hazard*

Multi-hazard is information regarding the vulnerability level of an area to various natural disaster threats. Multi-hazard refers the vulnerability of Ijo Tunnel area to landslide and earthquake. Multi-hazard mapping is important considering that almost no area on earth has a single vulnerability [7].

Landslide is the mass movement of soil or rock in the potential landslide area. If the movement of the soil mass is excessive, it is called a landslide [8]. Landslide in Ijo Tunnel is triggered by high rainfall so that the water content in the soil increases. Hence, then the resistance of the shear will decrease and there will be mass movement of the soil.

Hardiyatmo [8] claimed that the behavior of annual rain can affect the frequency of landslides. There are two factors that cause such occurrence, including: (1) an increase in groundwater content due to softening of the slope-forming material; and (2) an increase in the groundwater level which reduces the average shear strength of the soil. When it rains, the soil that was originally not saturated with water gradually becomes saturated. Along with the increase in water content in the soil, the shear strength of the soil gradually decreases, especially in fine-grained soils. This is because the pore pressure which was initially negative will become positive.

In further investigation, there are several causes of landslides in Ijo Tunnel, those are: (1) landforms; (2) slope geometry; and (3) the presence of springs. Ijo Tunnel is located in a strongly eroded to light denudational hill form composed of sandy limestone (calcarenite) located at N 060°E/20° (figure 1a.). When the calcarenite rock undergoes weathering, it will form a soil with a sandy clay fraction that has a moderate permeability level. The soil will then become easily saturated with water so that the shear resistance in the soil decreases. Hardiyatmo [8] added that the clay minerals contained in the soil greatly determine the value of the Atterberg boundaries which affect the shear strength empirically.

Soil saturation is also affected by the presence of springs on the northern slopes (figure 1b.). Soil or rock material that has a high-water content will have a high mass weight so that it will tend to move down the slope if it is located on a large slope angle and/or a layered structure that is tilted in the direction of the slope [9]. Thus, the landslide vulnerability in Ijo Tunnel is categorized as high. According to Hardiyatmo [8], springs can also be an indication that the location is the foot or tip of the landslide.

Figure 1. (a) Outcrop of sandy limestone (calcarenite); (b) Spring seepage of North side slope.

In addition to landform, slope geometry also determines the level of landslide susceptibility. The steeper the slope, the greater the gravitational force that pulls the soil mass down the slope. The slope geometry of Ijo Tunnel is as follows: slope direction N 170^{o}E; slope continuity direction N 080^{o}E; and the tilt of slope is 60^{o}. A slope value of ($\angle 60^{o}$) indicates high landslide susceptibility in Ijo Tunnel.

Landslides that occur in Ijo Tunnel are of topples type, which is the movement of collapsed material on rock slopes which is very steep to upright. The discontinuity area on a collapsed slope is relatively vertical. The main factor that causes the topples type landslides is the presence of water that fills the cracks [8]. Cracks in cliffs can be caused by clay mineral content in the soil which has the characteristics of swelling, cutting slopes, and vibration due to rail traffic.

Ijo Tunnel area is a flood-prone area. Flood is an incident or condition in which part, or all of the land is submerged because the volume of water increases [10]. Aspects that determine flood susceptibility include landform and rainfall. The train route in Ijo Tunnel was formed by cutting slope activities on the denudational hilly landform so that the train route occupies the valley part. According to Sartohadi [9], slope cutting to obtain a flat area used as a place for human activities tends to increase the rate and capacity of rainwater infiltration and irrigation. If so, then the surface runoff will be higher and the potential for flood incidence will also be greater. Based on this description, it can be concluded that the flood vulnerability of Ijo Tunnel is categorized as high.

Figure 2. Flood indicator point.

The flood occurred on June 17th, 2016, inundated Ijo Tunnel up to 20 cm (figure 2.). Due to the incident, the train route was eroded, and 13 trains (KA) were delayed. The trains included Pasundan, Progo, Gajahwong, Senja Utama Solo, Kahuripan, Jaka Tingkit, Taksaka Malam, Lodaya, Malabar, Argo Dwipangga, Turangga, Gajayana and Bima trains.

The flood in Ijo Tunnel is an overflow river caused by the inability of river and drainage channels to flow the flood discharge or the existing flood discharge is greater than the existing drainage capacity (figure 3). Therefore, it is necessary to re-evaluate the construction of drainage channels that also considers the return period of rain. Changes in rainfall patterns and intensity as well as changes in land from time to time are possible causes of the mismatch between drainage capacity and the amount of runoff.

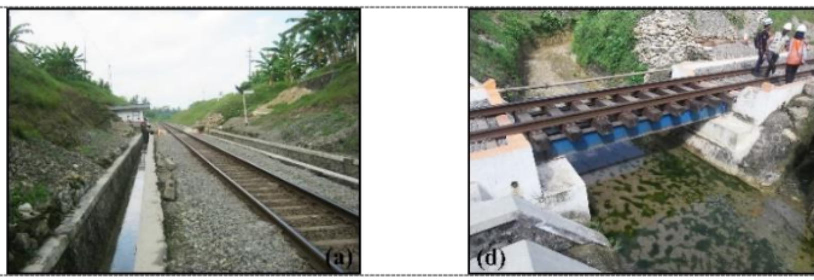


Figure 3. (a) Drainage channel; (b) river channel in Ijo Tunnel.

The multi-hazard in Ijo Tunnel was assessed by summing up the flood susceptibility score and the landslide susceptibility score. Based on the calculations, the multi-hazard of Ijo Tunnel to landslides and floods was high (table 10.). Multi-hazard mapping using a landform approach is a product that facilitates the socialization process of disaster to the community because its boundaries are easy to find in the field [7]. In addition, multi-hazard mapping also makes it easier for PT. Kereta Api Indonesia (Persero) as the organizer of railways to determine disaster-prone areas, update disaster information, and formulate policies and procedures to monitor and maintain the railway facilities and infrastructure to ensure the safety of rail transport users. It should be noted that safety is one of the pillars used as the ba1sis for the operation of the railway to realize the principle of zero fatality and zero accident [11].

Table 10. Assessment of Multi-hazard.

	Parameter	Score	Total Score
Landslide Susceptibility	Slope	5	8
	Level of incision	3	
Flood	Landform	3	9

Susceptibility	Rainfall	3	
	Slope	3	
	Total Multi-hazard		17 (High)

3.2. *Vulnerability*

Vulnerability is a condition of risk elements that lead to an inability to deal with the disaster threat. The higher the level of disaster vulnerability, the easier it is for elements at risk to be affected by disasters. Disaster vulnerability is measured by three assessment components, including the completeness of supporting infrastructure, the quality of the train route, and the density of rail traffic.

Ijo Tunnel is located in a denudational hilly landform with a hilly morphology. The train route is built by cutting the slope so that it is prone to disasters. Therefore, good infrastructure is needed to prevent the occurrence of disasters. The train route in Ijo Tunnel is basically equipped with drainage channels considering its location is a valley where water flows. However, the capacity of the drainage channel is not sufficient to accommodate the water flow so that it is susceptible of flood. In addition, the slopes on the right and left sides of the train route are not entirely built with permanent cliffs so they are vulnerable to landslides (figure 4.). This condition causes Ijo Tunnel's vulnerability to landslides and floods to be high.

Figure 4. Drainage channels along rails and slopes that are not entirely permanent cliffs.

The train route condition around Ijo Tunnel was identified from the type and type of rail, the type and condition of the bearing, the distance of the rail to the edge of the pavement, and the use of the surrounding land. The type of rail used on the train route around Ijo Tunnel is R54 with good condition. The type of rail bearing used is concrete, while the bridge is wooden (figure 5). The condition of the rail bearings is classified as slightly damaged. The distance between the rails and the edge of the pavement is the distance between the rails and the nearest road access. Ijo Tunnel can be accessed by car via a rocky road with rough terrain for 3 km from the main access (arterial road). It is very important to know the road access to Ijo Tunnel to facilitate the process of monitoring rail conditions and the evacuation process during the disaster incident. The use of land around the train route is also important because if there are people living around the train route, areas vulnerable or damaged rails can be easily informed to officers. In addition, the community can also assist officers in the evacuation process when a disaster occurs. The land uses around the Ijo Tunnel are farm, plantations, and forests. By paying attention to the three aspects above, the vulnerability of Ijo Tunnel from the aspect of rail conditions is high.

The determination of disaster vulnerability along the train route can also be done based on the density of rail traffic. The more trains that pass, the higher the potential for vibration. Ijo Tunnel is the main train route across the southern island of Java. This route is traversed by passenger and goods from and to Jakarta, Bandung, Purwokerto, Yogyakarta, Solo, Kediri, to Surabaya. Vibrations caused by rail traffic can cause a decrease in shear strength in some sensitive clays which will increase the potential of landslides [8]. Such conditions in the technical assessment in categorized as high vulnerability.

Based on the descriptions above, the disaster vulnerability around Ijo Tunnel is high. More monitoring and supervision are needed to the risk elements. Periodic checks in accordance with regulations and procedures can minimize the risk of disasters that occur.

Figure 5. (a) Rail condition and (b) Rail bearing.

3. *Capacity*

Capacity is the ability of a region and its community to take action to reduce the level of threat and level of loss due to disasters. Improving the capacity factor is an important aspect since it will accelerate the recovery process due to disasters. Disaster capacity was measured by the presence or absence of disaster SOPs, whether database management related to disasters is established, as well as communication and coordination between agencies in dealing with disasters [12].

Disaster SOPs are systematic stages in disaster mitigation and management efforts. If disaster SOPs are carried out systematically, the disaster mitigation and management process will run quickly and efficiently in terms of the costs and energy required. Ijo Tunnel is included in the working area of DAOP 5 Purwokerto which already has standard operating management in dealing with disasters so that when a disaster occurs, the officers responsible for dealing with disasters are alert. However, SOPs related to disaster emergency response have not yet been formally drafted and ratified to be applied in all DAOPs. This condition is categorized as medium capacity.

According to Central Java Technical Center officers, most of the disaster-prone areas have been recorded and there are procedures for 1×24 hour security at the disaster-prone areas. However, there has been no activity for updating the data for disaster-prone areas [13]. In fact, periodic data updating is very important to monitor disaster-prone areas. This condition is categorized as medium capacity.

During disaster management process, good communication and coordination between agencies engaged in disaster aspects is also required. Based on the statement from the Central Java Technical Center officer, communication and coordination were only carried out internally by DAOP. However, internal coordination is sufficient in dealing with disasters. Based on the assessment parameters (scoring), such conditions are categorized as low capacity. By considering the three aspects of disaster capacity assessment above, the disaster capacity in DAOP 5 is categorized as medium (figure 6).

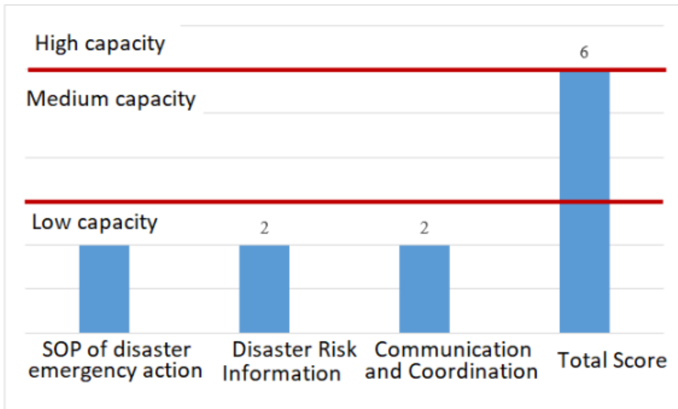


Figure 6. Disaster capacity based on the parameters.

3.4. *Risk of Disaster*

Disaster risk is produced from a systematic calculation of susceptibility, vulnerability, and disaster capacity. Disaster risk in an area was assessed as an integrated step that can be used as a reference in managing disaster aspects as a whole. For example, an area that has a high disaster risk does not necessarily have a low disaster capacity but can be caused by a low susceptibility or vulnerability value. A careful study needs to be done on the efforts to reduce disaster risk in an area so that the decisions made can resolve existing problems.

Disaster risk in Ijo Tunnel area is categorize as medium (figure 7.). This category was obtained from the high value of multi-hazard and disaster vulnerability but the capacity to deal with disasters is categorized as medium (table 11.). Identification of disaster risk provides a basis for decision making to accept how much risk can be faced or borne and design plans and efforts to mitigate it [14].

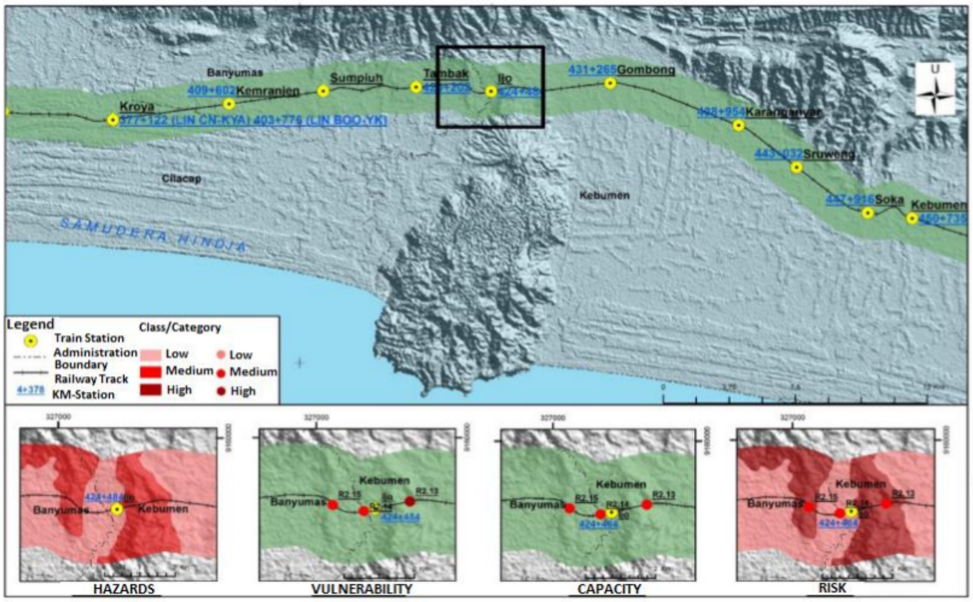


Figure 7. Ijo Tunnel Multi-hazard Risk.

Table 11. Multi-hazard Assessment.

Parameter	Score
Multi-hazard	3
Susceptibility	3
Capacity	3
Risk	3 (Medium)

3.5. *Strategy in Reducing Disaster Risk*

The reduction of disaster risk is a series of strategies and activities performed to anticipate and overcome disaster incidents. The reduction of disaster risk includes three main aspects of its constituents, those are multi-hazard, vulnerability, and capacity. Risk reduction stages are conducted to reduce the effect of disasters [15].

Two things that must be used as the foundation to formulate a disaster risk reduction strategy are by paying attention to the characteristics of the existing landforms and the current field conditions (Figure 7). Landforms are composed of four main aspects, those are [16,17]: (1) morphology; (2) morphogenesis; (3) morpho-chronology; and (4) morpho-arrangement. These four aspects summarize geomorphological processes that cause changes in the configuration of the earth's surface from time to time [18]. If a scientist has the ability to find, identify, and analyze the working geomorphological processes, the factors causing the disasters and their solutions can be formulated properly.

Disaster risk reduction strategies in Ijo Tunnel can be carried out structurally and non-structurally [19]. Structural strategy is carried out by handling in physical form in the form of construction of landslide-retaining buildings and waterways (figure 8.). Meanwhile, non-structural strategies are carried out by increasing the human resource capacity of officers and residents around Ijo Tunnel for disaster management.

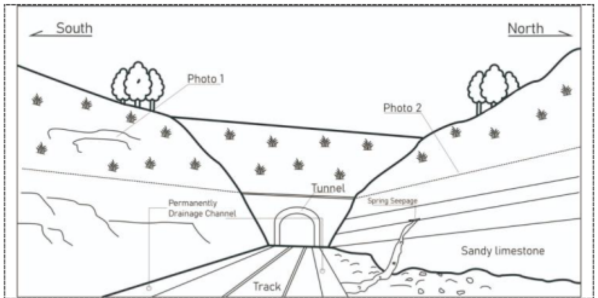


Figure 8. Field Sketch.

Disasters will occur if there is a meeting between multi-hazard and vulnerabilities so that it must be avoided [14]. Stages that can be taken are: (1) strengthening the slope stability to reduce landslide incidents by making permanent cliffs; (2) installing pipes on cliffs to channel excessive water when it rains, especially on cliffs where there are seepage springs; (3) evaluating drainage channels that have been made; (4) implementing the culture of not throwing garbage in rivers which can reduce the capacity of river distribution; and (5) repairing and strengthening of the railway bearing structure which is indicated to be slightly damaged.

Disaster risk can be reduced by increasing capacity. Stages that can be done are: (1) making an SOP of integrated disaster emergency response that can be applied to all DAOPs; (2) periodic updating of disaster information; (3) establishing coordination and cooperation with relevant agencies engaged in the field of disaster; and (4) strengthening knowledge of train operators on disaster risk assessment along train route. The stages above are urgent to take considering that risk management examines all strategic and implementation options both in the context of structural and non-structural handling [14]. Non-structural handling in the form of SOPs and so on needs to be legally legalized in the form of laws and regulations as well as government and institutional regulations.

4 Conclusion

Based on the research results, it can be concluded that Ijo Tunnel has a high level of disaster susceptibility, medium level of disaster vulnerability, medium level of disaster capacity, and medium level of disaster risk. The surrounding condition of Ijo Tunnel is a minor fault area with loose material. Furthermore, there is water seepage that triggers floods and landslides so that volume, construction, and age of buildings around the walls need to be recalculated. Therefore, the disaster management strategy in Ijo Tunnel is carried out structurally through physical and non-structural handling by increasing the capacity.

5. References

[1] Kementerian Perhubungan 2011 *Rencana Induk Perkeretaapian Nasional* (Jakarta: Kementerian Perhubungan, Ditjen Perkeretaapian)

[2] Soemardi K, Prasidi A and Desrianty A 2010 Kajian penyebab laten kecelakaan kereta api, menggunakan kerangka HFACS dengan pendekatan QFD *Proc. Seminar Nasional IV Manajemen & Rekayasa Kualitas 2010* (Itenas, Bandung)

[3] Direktorat Jenderal Perkeretaapian 2014 *Buku Informasi Perkertaapian 2014* (Jakarta: Direktorat Jenderal Perkertaapian, Kementerian Perhubungan Republik Indonesia)

[4] Yusrizal Y, Saleh S M and Fadhly N 2013 Studi revitalisasi jalur kereta api Banda Aceh – Batas Sumatera Utara, *Jurnal Teknik Sipil*. 2(1), 26-38

[5] Esri n.d. Resources https://pro.arcgis.com/en/pro-app/2.7/tool-reference/spatial-analyst/how-slope-works.htm

[6] Maulana E and Wulan T R 2015 Pemetaan multi-rawan kabupaten malang bagian selatan dengan menggunakan pendekatan bentanglahan *Proc. Simposium Nasional Sains Geoinformasi IV/2015* (Yogyakarta)
[7] Wulan T R, Maulana E, Maulia N, Anggara I H, Putra A S, Putra M D, Ibrahim F, Wahyuningsih D S and Siswanti S 2016 Analysis of land capability in alluvial plain and volcanic slope of rembang district using landforms approach *Proc. The 2nd International Conference of Indonesian Society for Remote Sensing* (Yogyakarta)
[8] Hardiyatmo H C 2012 *Tanah Longsor dan Erosi: Kejadian dan Penanganan* (Yogyakarta: Gadjah Mada University Press)
[9] Sartohadi J 2005 *Pemanfaatan Informasi Kerawanan Gerakan Massa Untuk Penilaian Kemampuan Lahan di Sub-DAS Maetan, Daerah Aliran Sungai Luk Ula Jawa Tengah* Majalah Geografi, 19 pp 21-39 (March 2005)
[10] Kodoatie R J and Sugiyanto S 2002 *Banjir: Beberapa Penyebab dan Metode Pengendaliannya dalam Perspektif Lingkungan* (Yogyakarta: Pustaka Pelajar)
[11] PT. Kereta Api Indonesia (Persero) 2016 *Laporan Tahunan 2015: Transformasi dan Inovasi Pelayanan Berkelanjutan Persembahan Untuk Negeri* (Bandung: PT. Kereta Api Indonesia (Persero))
[12] Iridiastadi, H., dan Izazaya, E. 2012. Kajian Taksonomi Kecelakaan Kereta Api Di Indonesia Menggunakan Human Factors Analysis and Classification System (HFACS). Prosiding InSINas 2012. Bandung: Asdep Relevansi Program Riptek, Deputi Bidang Relevansi dan Produktivitas Iptek, Kementerian Riset Dan Teknologi;Hal 51-55.
[13] Nugrahini Y 2012 Analisis kinerja pelaksanaan kewajiban pelayanan publik bidang angkutan kereta api penumpang kelas ekonomi, *Jurnal Perencanaan Wilayah dan Kota*. 23(1) 19-36
[14] Latief H 2011 *Siaga Tsunami di Pesisir Sumatra* in Abdurahman O P 2011 *Hidup di Atas Tiga Lempeng: Gunungapi dan Bencana Geologi* (Bandung: Badan Geologi, Kementerian Energi dan Sumberdaya Mineral)
[15] Novianta M A and Setyaningsih E 2015 Sistem informasi monitoring kereta api berbasis web server menggunakan layanan GPRS, *Jurnal Momentum*. 17(2)
[16] Zuidam and Cancelado, 1985 Terrain Analysis and Classification Using Aerial Photograph; a Geomorphologic Approach. ITC Enchede. The Netherlands
[17] Santosa, 2015 Keistimewaan Yogyakarta Dari Sudut Pandang Geomorfologi. Gadjah Mada University Press. Yogyakarta.
[18] Sartohadi J 2007 Terapan geomorfologi dalam pengelolaan sumberdaya air, *Jurnal Alami*. 12(1) 16-21
[19] Muhtadi A 2011 Kinerja lalu lintas jalan nasional kabupaten sidoarjo, *Neutron Jurnal Teknik Sipil*. 11(2) 17-25

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Geomorphological Spatial Model of Risk Analysis for Natural Disasters in Heritage Railway Tunnel

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Abstract. Flood event in Ijo Tunnel led to disruption to schedules and train routes. The objectives of this research are to determine the susceptibility, vulnerability, capacity, and risk, to analyze the geophysical and geotechnical condition, and to compile the strategy of disaster mitigation of Ijo Tunnel. A spatial approach based on landform analysis was performed to establish the disaster components. Geophysical and geotechnical investigation was conducted to describe the condition of the affected region. A field survey was accomplished to collect data and to study supporting works of literature. The descriptive analysis was completed to determine strategy and recommendation in flood and potential landslide mitigation. The result depicts that Ijo Tunnel holds multi-disaster risk such as floods and landslides. The occurrence of floods is induced by extreme rainfall and inability of drainage channels to retain water. The landslide potential is influenced by morphological factors and composting materials in Ijo Tunnel's region. The existence of spring fracture on the north slope also contributes to increasing the slopes' landslide potential. The flood mitigation measure can be carried out by building a well-prepared drainage system and watershed and surface runoff management. Areas with a high level of landslide susceptibility can be overcome by building permanent retaining walls and pipes on slopes to reduce the soil saturation level.

1. Introduction

Rail transport is a mass transportation mode with more advantages that the other transportation modes. These advantages include: (1) large capacity (bulk); (2) fast; (3) safe; (4) energy-saving and environmental-friendly; and (5) requires relatively small area. Compared to land transportation modes such as buses which have energy consumption of 0.0125 litters of energy per km/Passenger or private cars which have energy consumption of 0.02 litters per KM/Passenger [1], the train energy consumption is considered the most efficient, which is 0.002 litters per km/Passenger. Therefore, trains become the backbone of freight and passenger transportation in Indonesia.

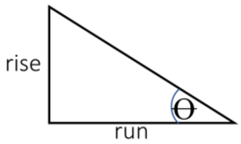
The smoothness of trains in freight and passenger transportation is also affected by natural conditions. One of the disruptions to rail traffic is caused by the disaster aspect [2]. Various natural disasters such as flood, landslide, earthquake, volcanic eruption, and tsunami can affect the rail transportation services negatively [3]. Disaster risk needs to be minimized by identifying the level of vulnerability, susceptibility, and capacity of the railway operator. Such action is needed since the cost of developing railway infrastructure is very expensive [1].

One of the natural disasters that disrupted rail traffic occurred on June 17-18th, 2016 around Ijo Tunnel, Bumiagung Village, Rowokole District, Kebumen Regency. Flood and landslide occurred in Ijo Tunnel have disrupted the railway traffic in the southern part of Central Java. Therefore, several trains (KA) were delayed in departure and arrival.

The effect of the flood and landslide occurred in Ijo Tunnel is material losses. The affected train route certainly needs to be improved regarding its facilities and infrastructure so that similar incidents will not happen again [4]. Therefore, efforts to identify and formulate strategies for handling floods and landslides in the Ijo Tunnel need to be made to maintain the safety of the train travel. Hence, this study has three objectives, those are: (1) determining the level of susceptibility, vulnerability, and capacity in Ijo Tunnel; (2) analyzing the geophysical and geotechnical conditions of Ijo Tunnel; and (3) developing a strategy of flood mitigation strategy in Ijo Tunnel.

2. Method

This research applied a spatial approach based on an analysis of the landform approach in establishing disaster components. Landform units were obtained from the data processing of slope class, lithology, geological structures, and river flow patterns. Slope identification was obtained from each cell of the earth's surface in digital format (raster) which contains information of location point. Raster data is used to build a 3D model into a DEM. The output of the slope raster can be calculated in degrees or percentages with the following triangulation basic equation [5].



$$\text{Degree of slope} = \tan \Theta = \text{rise/run} \tag{1}$$

$$\text{Percent of slope} = \text{rise/run} * 100 \tag{2}$$

Geophysical and geotechnical analysis are the main keys in describing the condition of the area affected by the disaster. Furthermore, the strategies and recommendations in handling disasters in Ijo Tunnel was established descriptively.

2.1. Tools and Materials

This research required certain tools and materials. The tools used included a computer set, ArcGIS 10.1 software, and survey equipment (camera, GPS, compass, and geological hammer). Meanwhile, the research materials used are presented in table 1.

Table 1. Research materials.

Parameter	Research Variable	Data
Susceptibility of landslide disaster	Slope Class	Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency
	Level of incision	Shuttle Radar Topography Mission (SRTM) of 30 m resolution by the United States Geological Survey (USGS)
Subsubsection	Slope Class	Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency
	Landform	Slope Class (Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency)
		Lithology and geological structure (Digital Geological Map shape file (.shp) by Geological Research and Development Center)

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	River flow patterns (Digital Indonesian Topographical Base Map (RBI) in the scale of 1:25,000 by the Geospatial Information Agency)
Rainfalls	Monthly rainfall (Meteorology, Climatology and Geophysics Agency – BMKG)

2.2. Assessment of Multi-hazard

2.2.1. Landslide. The susceptibility of landslides was assessed using slope class and level of incision variables. The landslide susceptibility class was determined by summing up the slope class scores and the level of incision. Classification of slope class, level of incision, and landslide susceptibility is presented in table 2. and table 3.

Table 2. Classification and score of slope class and level of incision.

Skor	Slope	Morphology	Level of Incision
0	0-2 %	Flat	Low (Score 1)
1	2-7 %	Choppy	
2	7-13 %	Wavy	Medium (Score 2)
3	13-20 %	Hills	High (Score 3)
4	20-55 %	Mountains	
5	>55%	Steep Mountains	

Table 3. Classification of landslide susceptibility.

Scores of Slope Class and Incision	Class of Landslide Susceptibility
0-2	Low
3-5	Medium
6-8	High

2.2.2. Flood. The flood susceptibility was identified and assessed using three variables, those are slope class, landform, and rainfall. The susceptibility class was determined by summing up the scores of each variable. Classification of slope classes, landforms, rainfall, and flood susceptibility are presented in table 4. and table 5.

Table 4. Classification and score of slope class, landform, and rainfall.

Skor	Slope	Landform	Monthly Rainfall (mm/month)
0	5-6%	Hills, mountains, scarp	0-100
1	4%	Volcanic fluvio fans, colluvial cones, foot of slopes of volcano, debris flow of the foot of slopes, the foot of volcano	100-200
2	2-3%	Foot plains, alluvial plains,	200-400

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		fluviomarin plains, intervolcanic plains, valleys between hills	
3	1%	River valley, floodplain	>400

Table 5. Classification of flood susceptibility.

Scores of Slope Class, Landforms, and Monthly Rainfalls	Class of Flood Susceptibility
0-3	Low
4-6	Medium
7-9	High

2.2.3. Multi-Hazard. Multi-hazard is information on the level of vulnerability of an area to various disaster threats [6]. The multi-hazard level was determined by summing up the flood and landslide susceptibility scores. Classification and classes of multi-disaster are presented in table 6.

Table 6. Multi-hazard class.

Multi-hazard scores	Multi-hazard Class	Score
0-5.7	Low	1
5.8-11.5	Medium	2
11.6-17	High	3

2.3. Assessment of Vulnerability

Disaster vulnerability is a condition of a community or society that leads to an inability to deal with disaster threat. Such vulnerability means an assessment of the magnitude of the element at risk of being affected by a disaster related to facilities, infrastructure, staff, and use of services. There are three assessment parameters used, including the completeness of supporting infrastructure, the quality of the train route, and the density of rail traffic (see table 7).

Table 7. Class of disaster vulnerability.

Class and Score	Completeness of supporting infrastructure	Quality of train route	Density of rail traffic
Low (1)	The existence of buildings such as gabions, embankments, and others to reduce the effect of disasters in almost all vulnerable zones, as well as complete disaster emergency response tools	Good	Not dense
Medium (2)	The existence of buildings such as gabions, embankments, and others to reduce the effect of disasters in parts of all vulnerable zones, yet the disaster emergency response tools is not complete	Quite good	Quite dense
High (3)	No gabions, embankments, and other buildings to reduce the effect of disasters in all vulnerable zones, and the disaster emergency response tools is not complete	Poor	Very dense

2.4. *Assessment of Capacity*
Disaster capacity is the ability of a region and communities to take action to reduce the level of threat and the level of losses due to disasters. Such capacity means the preparedness of the railway operator in this case is PT. Kereta Api Indonesia (Persero) and related agencies in responding to disasters along the train route. There are three assessment parameters used, including Standard Operating Procedures (SOP) for disaster emergency response, studies, and information on disaster risk in the Operational Area (DAOP), as well as communication and coordination of PT. Kereta Api Indonesia (Persero) and related agencies (table 8).

Table 8. Class of disaster capacity.

Class and Score	SOP of disaster and emergency response	Study and information regarding the disaster risk in DAOP	Communication and Coordination
Low (1)	None	Few	Less correlated
Medium (2)	Presents but not in accordance with the standard yet	Quite complete	Correlated but not quite intensive
High (3)	Presents and in accordance with the standard	Complete	Correlated and intensive

2.5. *Assessment of Risk*
Disaster risk is the potential loss caused by a disaster in an area within a certain period. Disaster risk is Mathematically formulated in equation (3). The level of disaster risk will increase as the hazard and vulnerability increase. However, the value of risk can be small if the level of capacity is high. The disaster risk class is divided into three classes, which are low, medium, and high (see table 9).

$$R = (H \times V) / C \tag{3}$$

In which:

R = Risk
H = Hazard
V = Vulnerability
C = Capacity

Table 9. Class of disaster risk.

Class of Risk	Score of Disaster Risk
Low	0.00-3.22
Medium	3.23-6.11
High	6.12-9.00

3. Results and Discussion

3.1. *Multi-Hazard*
Multi-hazard is information regarding the vulnerability level of an area to various natural disaster threats. Multi-hazard refers the vulnerability of Ijo Tunnel area to landslide and earthquake. Multi-hazard mapping is important considering that almost no area on earth has a single vulnerability [7].

Landslide is the mass movement of soil or rock in the potential landslide area. If the movement of the soil mass is excessive, it is called a landslide [8]. Landslide in Ijo Tunnel is triggered by high rainfall so that the water content in the soil increases. Hence, then the resistance of the shear will decrease and there will be mass movement of the soil.

Hardiyatmo [8] claimed that the behavior of annual rain can affect the frequency of landslides. There are two factors that cause such occurrence, including: (1) an increase in groundwater content due to softening of the slope-forming material; and (2) an increase in the groundwater level which reduces the average shear strength of the soil. When it rains, the soil that was originally not saturated with water gradually becomes saturated. Along with the increase in water content in the soil, the shear strength of the soil gradually decreases, especially in fine-grained soils. This is because the pore pressure which was initially negative will become positive.

In further investigation, there are several causes of landslides in Ijo Tunnel, those are: (1) landforms; (2) slope geometry; and (3) the presence of springs. Ijo Tunnel is located in a strongly eroded to light denudational hill form composed of sandy limestone (calcarenite) located at N 060°E/20° (figure 1a.). When the calcarenite rock undergoes weathering, it will form a soil with a sandy clay fraction that has a moderate permeability level. The soil will then become easily saturated with water so that the shear resistance in the soil decreases. Hardiyatmo [8] added that the clay minerals contained in the soil greatly determine the value of the Atterberg boundaries which affect the shear strength empirically.

Soil saturation is also affected by the presence of springs on the northern slopes (figure 1b.). Soil or rock material that has a high-water content will have a high mass weight so that it will tend to move down the slope if it is located on a large slope angle and/or a layered structure that is tilted in the direction of the slope [9]. Thus, the landslide vulnerability in Ijo Tunnel is categorized as high. According to Hardiyatmo [8], springs can also be an indication that the location is the foot or tip of the landslide.

Figure 1. (a) Outcrop of sandy limestone (calcarenite); (b) Spring seepage of North side slope.

In addition to landform, slope geometry also determines the level of landslide susceptibility. The steeper the slope, the greater the gravitational force that pulls the soil mass down the slope. The slope geometry of Ijo Tunnel is as follows: slope direction N 170ºE; slope continuity direction N 080ºE; and the tilt of slope is 60º. A slope value of ($\angle$60º) indicates high landslide susceptibility in Ijo Tunnel.

Landslides that occur in Ijo Tunnel are of topples type, which is the movement of collapsed material on rock slopes which is very steep to upright. The discontinuity area on a collapsed slope is relatively vertical. The main factor that causes the topples type landslides is the presence of water that fills the cracks [8]. Cracks in cliffs can be caused by clay mineral content in the soil which has the characteristics of swelling, cutting slopes, and vibration due to rail traffic.

Ijo Tunnel area is a flood-prone area. Flood is an incident or condition in which part, or all of the land is submerged because the volume of water increases [10]. Aspects that determine flood susceptibility include landform and rainfall. The train route in Ijo Tunnel was formed by cutting slope activities on the denudational hilly landform so that the train route occupies the valley part. According to Sartohadi [9], slope cutting to obtain a flat area used as a place for human activities tends to increase the rate and capacity of rainwater infiltration and irrigation. If so, then the surface runoff will be higher and the potential for flood incidence will also be greater. Based on this description, it can be concluded that the flood vulnerability of Ijo Tunnel is categorized as high.

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Figure 2. Flood indicator point.

The flood occurred on June 17th, 2016, inundated Ijo Tunnel up to 20 cm (figure 2.). Due to the incident, the train route was eroded, and 13 trains (KA) were delayed. The trains included Pasundan, Progo, Gajahwong, Senja Utama Solo, Kahuripan, Jaka Tingkit, Taksaka Malam, Lodaya, Malabar, Argo Dwipangga, Turangga, Gajayana and Bima trains.

The flood in Ijo Tunnel is an overflow river caused by the inability of river and drainage channels to flow the flood discharge or the existing flood discharge is greater than the existing drainage capacity (figure 3). Therefore, it is necessary to re-evaluate the construction of drainage channels that also considers the return period of rain. Changes in rainfall patterns and intensity as well as changes in land from time to time are possible causes of the mismatch between drainage capacity and the amount of runoff.

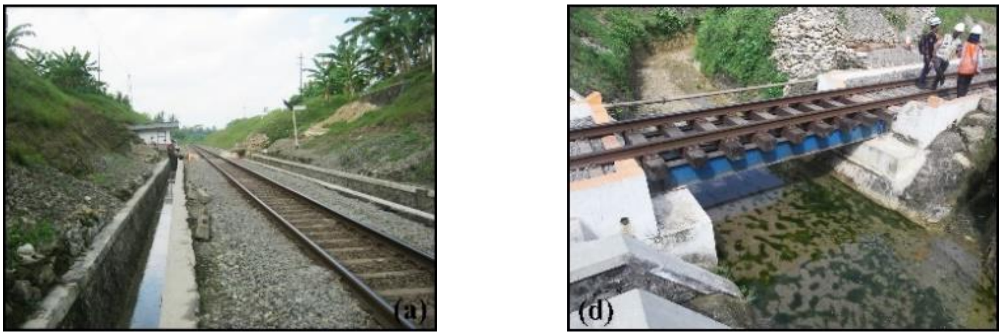

Figure 3. (a) Drainage channel; (d) river channel in Ijo Tunnel.

The multi-hazard in Ijo Tunnel was assessed by summing up the flood susceptibility score and the landslide susceptibility score. Based on the calculations, the multi-hazard of Ijo Tunnel to landslides and floods was high (table 10.). Multi-hazard mapping using a landform approach is a product that facilitates the socialization process of disaster to the community because its boundaries are easy to find in the field [7]. In addition, multi-hazard mapping also makes it easier for PT. Kereta Api Indonesia (Persero) as the organizer of railways to determine disaster-prone areas, update disaster information, and formulate policies and procedures to monitor and maintain the railway facilities and infrastructure to ensure the safety of rail transport users. It should be noted that safety is one of the pillars used as the ba1sis for the operation of the railway to realize the principle of zero fatality and zero accident [11].

Table 10. Assessment of Multi-hazard.

	Parameter	Score	Total Score
Landslide Susceptibility	Slope	5	8
	Level of incision	3	
Flood	Landform	3	9

Susceptibility	Rainfall	3	
	Slope	3	
	Total Multi-hazard		17 (High)

3.2. *Vulnerability*

Vulnerability is a condition of risk elements that lead to an inability to deal with the disaster threat. The higher the level of disaster vulnerability, the easier it is for elements at risk to be affected by disasters. Disaster vulnerability is measured by three assessment components, including the completeness of supporting infrastructure, the quality of the train route, and the density of rail traffic.

Ijo Tunnel is located in a denudational hilly landform with a hilly morphology. The train route is built by cutting the slope so that it is prone to disasters. Therefore, good infrastructure is needed to prevent the occurrence of disasters. The train route in Ijo Tunnel is basically equipped with drainage channels considering its location is a valley where water flows. However, the capacity of the drainage channel is not sufficient to accommodate the water flow so that it is susceptible of flood. In addition, the slopes on the right and left sides of the train route are not entirely built with permanent cliffs so they are vulnerable to landslides (figure 4.). This condition causes Ijo Tunnel's vulnerability to landslides and floods to be high.

Figure 4. Drainage channels along rails and slopes that are not entirely permanent cliffs.

The train route condition around Ijo Tunnel was identified from the type and type of rail, the type and condition of the bearing, the distance of the rail to the edge of the pavement, and the use of the surrounding land. The type of rail used on the train route around Ijo Tunnel is R54 with good condition. The type of rail bearing used is concrete, while the bridge is wooden (figure 5). The condition of the rail bearings is classified as slightly damaged. The distance between the rails and the edge of the pavement is the distance between the rails and the nearest road access. Ijo Tunnel can be accessed by car via a rocky road with rough terrain for 3 km from the main access (arterial road). It is very important to know the road access to Ijo Tunnel to facilitate the process of monitoring rail conditions and the evacuation process during the disaster incident. The use of land around the train route is also important because if there are people living around the train route, areas vulnerable or damaged rails can be easily informed to officers. In addition, the community can also assist officers in the evacuation process when a disaster occurs. The land uses around the Ijo Tunnel are farm, plantations, and forests. By paying attention to the three aspects above, the vulnerability of Ijo Tunnel from the aspect of rail conditions is high.

The determination of disaster vulnerability along the train route can also be done based on the density of rail traffic. The more trains that pass, the higher the potential for vibration. Ijo Tunnel is the main train route across the southern island of Java. This route is traversed by passenger and goods from and to Jakarta, Bandung, Purwokerto, Yogyakarta, Solo, Kediri, to Surabaya. Vibrations caused by rail traffic can cause a decrease in shear strength in some sensitive clays which will increase the potential of landslides [8]. Such conditions in the technical assessment in categorized as high vulnerability.

Based on the descriptions above, the disaster vulnerability around Ijo Tunnel is high. More monitoring and supervision are needed to the risk elements. Periodic checks in accordance with regulations and procedures can minimize the risk of disasters that occur.

Figure 5. (a) Rail condition and (b) Rail bearing.

3.3. *Capacity*

Capacity is the ability of a region and its community to take action to reduce the level of threat and level of loss due to disasters. Improving the capacity factor is an important aspect since it will accelerate the recovery process due to disasters. Disaster capacity was measured by the presence or absence of disaster SOPs, whether database management related to disasters is established, as well as communication and coordination between agencies in dealing with disasters [12].

Disaster SOPs are systematic stages in disaster mitigation and management efforts. If disaster SOPs are carried out systematically, the disaster mitigation and management process will run quickly and efficiently in terms of the costs and energy required. Ijo Tunnel is included in the working area of DAOP 5 Purwokerto which already has standard operating management in dealing with disasters so that when a disaster occurs, the officers responsible for dealing with disasters are alert. However, SOPs related to disaster emergency response have not yet been formally drafted and ratified to be applied in all DAOPs. This condition is categorized as medium capacity.

According to Central Java Technical Center officers, most of the disaster-prone areas have been recorded and there are procedures for 1×24 hour security at the disaster-prone areas. However, there has been no activity for updating the data for disaster-prone areas [13]. In fact, periodic data updating is very important to monitor disaster-prone areas. This condition is categorized as medium capacity.

During disaster management process, good communication and coordination between agencies engaged in disaster aspects is also required. Based on the statement from the Central Java Technical Center officer, communication and coordination were only carried out internally by DAOP. However, internal coordination is sufficient in dealing with disasters. Based on the assessment parameters (scoring), such conditions are categorized as low capacity. By considering the three aspects of disaster capacity assessment above, the disaster capacity in DAOP 5 is categorized as medium (figure 6).

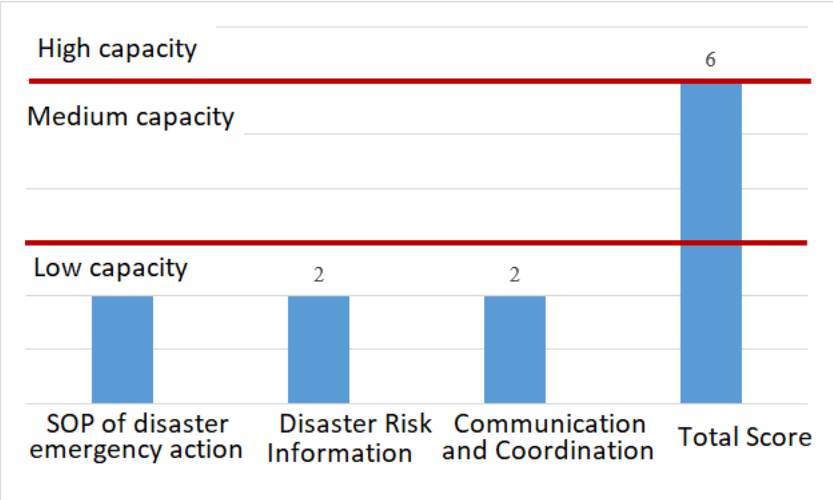

Figure 6. Disaster capacity based on the parameters.

3.4. *Risk of Disaster*

Disaster risk is produced from a systematic calculation of susceptibility, vulnerability, and disaster capacity. Disaster risk in an area was assessed as an integrated step that can be used as a reference in managing disaster aspects as a whole. For example, an area that has a high disaster risk does not necessarily have a low disaster capacity but can be caused by a low susceptibility or vulnerability value. A careful study needs to be done on the efforts to reduce disaster risk in an area so that the decisions made can resolve existing problems.

Disaster risk in Ijo Tunnel area is categorize as medium (figure 7.). This category was obtained from the high value of multi-hazard and disaster vulnerability but the capacity to deal with disasters is categorized as medium (table 11.). Identification of disaster risk provides a basis for decision making to accept how much risk can be faced or borne and design plans and efforts to mitigate it [14].

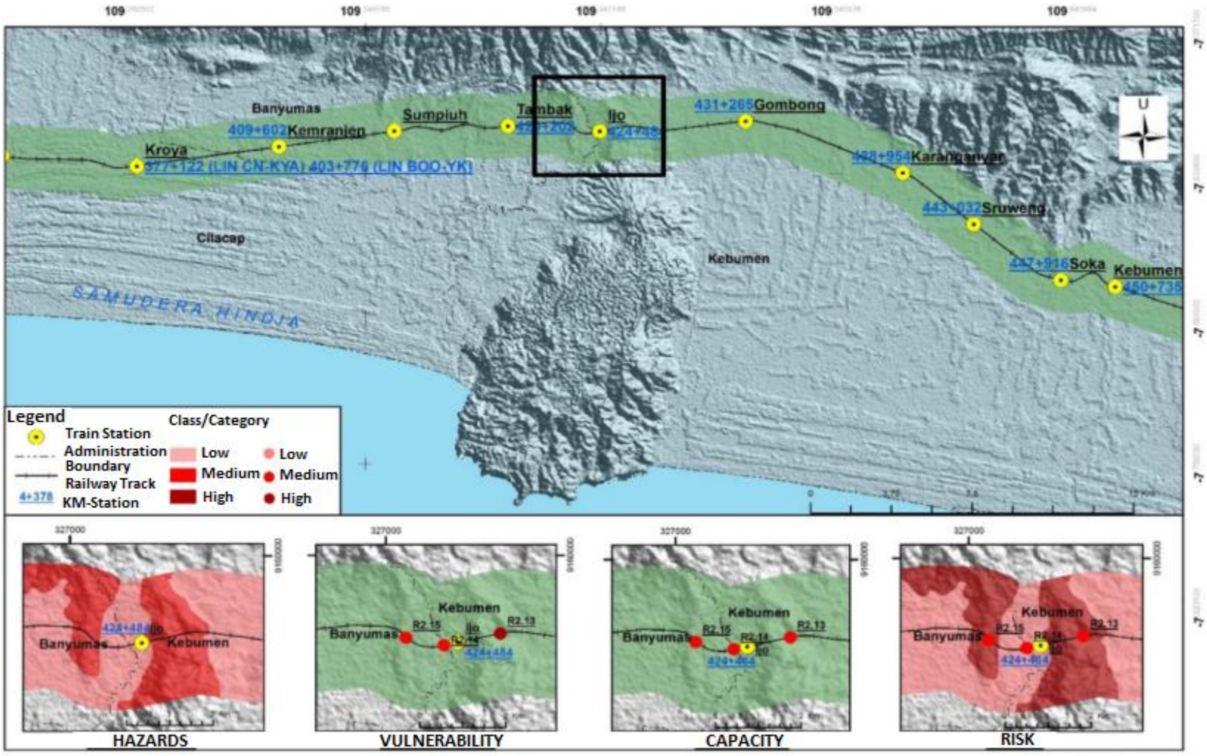

Figure 7. Ijo Tunnel Multi-hazard Risk.

Table 11. Multi-hazard Assessment.

Parameter	Score
Multi-hazard	3
Susceptibility	3
Capacity	3
Risk	3 (Medium)

3.5. *Strategy in Reducing Disaster Risk*

The reduction of disaster risk is a series of strategies and activities performed to anticipate and overcome disaster incidents. The reduction of disaster risk includes three main aspects of its constituents, those are multi-hazard, vulnerability, and capacity. Risk reduction stages are conducted to reduce the effect of disasters [15].

Two things that must be used as the foundation to formulate a disaster risk reduction strategy are by paying attention to the characteristics of the existing landforms and the current field conditions (Figure 7). Landforms are composed of four main aspects, those are [16,17]: (1) morphology; (2) morphogenesis; (3) morpho-chronology; and (4) morpho-arrangement. These four aspects summarize geomorphological processes that cause changes in the configuration of the earth's surface from time to time [18]. If a scientist has the ability to find, identify, and analyze the working geomorphological processes, the factors causing the disasters and their solutions can be formulated properly.

Disaster risk reduction strategies in Ijo Tunnel can be carried out structurally and non-structurally [19]. Structural strategy is carried out by handling in physical form in the form of construction of landslide-retaining buildings and waterways (figure 8.). Meanwhile, non-structural strategies are carried out by increasing the human resource capacity of officers and residents around Ijo Tunnel for disaster management.

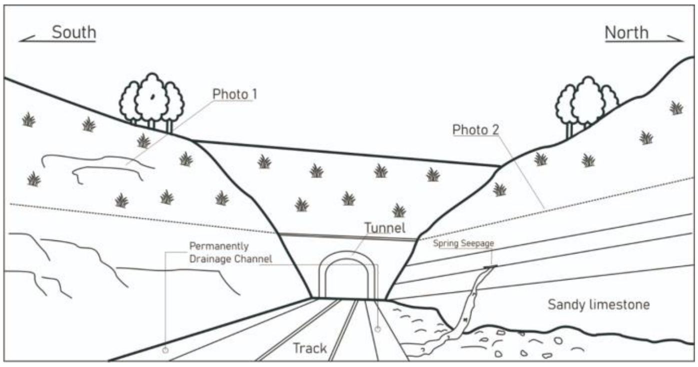

Figure 8. Field Sketch.

Disasters will occur if there is a meeting between multi-hazard and vulnerabilities so that it must be avoided [14]. Stages that can be taken are: (1) strengthening the slope stability to reduce landslide incidents by making permanent cliffs; (2) installing pipes on cliffs to channel excessive water when it rains, especially on cliffs where there are seepage springs; (3) evaluating drainage channels that have been made; (4) implementing the culture of not throwing garbage in rivers which can reduce the capacity of river distribution; and (5) repairing and strengthening of the railway bearing structure which is indicated to be slightly damaged.

Disaster risk can be reduced by increasing capacity. Stages that can be done are: (1) making an SOP of integrated disaster emergency response that can be applied to all DAOPs; (2) periodic updating of disaster information; (3) establishing coordination and cooperation with relevant agencies engaged in the field of disaster; and (4) strengthening knowledge of train operators on disaster risk assessment along train route. The stages above are urgent to take considering that risk management examines all strategic and implementation options both in the context of structural and non-structural handling [14]. Non-structural handling in the form of SOPs and so on needs to be legally legalized in the form of laws and regulations as well as government and institutional regulations.

4. Conclusion

Based on the research results, it can be concluded that Ijo Tunnel has a high level of disaster susceptibility, medium level of disaster vulnerability, medium level of disaster capacity, and medium level of disaster risk. The surrounding condition of Ijo Tunnel is a minor fault area with loose material. Furthermore, there is water seepage that triggers floods and landslides so that volume, construction, and age of buildings around the walls need to be recalculated. Therefore, the disaster management strategy in Ijo Tunnel is carried out structurally through physical and non-structural handling by increasing the capacity.

5. References

[1] Kementerian Perhubungan 2011 *Rencana Induk Perkeretaapian Nasional* (Jakarta: Kementerian Perhubungan, Ditjen Perkeretaapian)

[2] Soemardi K, Prasidi A and Desrianty A 2010 Kajian penyebab laten kecelakaan kereta api, menggunakan kerangka HFACS dengan pendekatan QFD *Proc. Seminar Nasional IV Manajemen & Rekayasa Kualitas 2010* (Itenas, Bandung)

[3] Direktorat Jenderal Perkeretaapian 2014 *Buku Informasi Perkertaapian 2014* (Jakarta: Direktorat Jenderal Perkertaapian, Kementerian Perhubungan Republik Indonesia)

[4] Yusrizal Y, Saleh S M and Fadhly N 2013 Studi revitalisasi jalur kereta api Banda Aceh – Batas Sumatera Utara, *Jurnal Teknik Sipil*. **2(1)** 26-38

[5] Esri n.d. Resources https://pro.arcgis.com/en/pro-app/2.7/tool-reference/spatial-analyst/how-slope-works.htm

[6] Maulana E and Wulan T R 2015 Pemetaan multi-rawan kabupaten malang bagian selatan dengan menggunakan pendekatan bentanglahan *Proc. Simposium Nasional Sains Geoinformasi IV/2015* (Yogyakarta)
[7] Wulan T R, Maulana E, Maulia N, Anggara I H, Putra A S, Putra M D, Ibrahim F, Wahyuningsih D S and Siswanti S 2016 Analysis of land capability in alluvial plain and volcanic slope of rembang district using landforms approach *Proc. The 2nd International Conference of Indonesian Society for Remote Sensing* (Yogyakarta)
[8] Hardiyatmo H C 2012 *Tanah Longsor dan Erosi: Kejadian dan Penanganan* (Yogyakarta: Gadjah Mada University Press)
[9] Sartohadi J 2005 *Pemanfaatan Informasi Kerawanan Gerakan Massa Untuk Penilaian Kemampuan Lahan di Sub-DAS Maetan, Daerah Aliran Sungai Luk Ula Jawa Tengah* Majalah Geografi, **19** pp 21-39 (March 2005)
[10] Kodoatie R J and Sugiyanto S 2002 *Banjir: Beberapa Penyebab dan Metode Pengendaliannya dalam Perspektif Lingkungan* (Yogyakarta: Pustaka Pelajar)
[11] PT. Kereta Api Indonesia (Persero) 2016 *Laporan Tahunan 2015: Transformasi dan Inovasi Pelayanan Berkelanjutan Persembahan Untuk Negeri* (Bandung: PT. Kereta Api Indonesia (Persero))
[12] Iridiastadi H dan Izazaya E 2012 Kajian Taksonomi Kecelakaan Kereta Api Di Indonesia Menggunakan Human Factors Analysis and Classification System (HFACS). Prosiding InSINas 2012. Bandung: Asdep Relevansi Program Riptek, Deputi Bidang Relevansi dan Produktivitas Iptek, Kementerian Riset Dan Teknologi;Hal 51-55.
[13] Nugrahini Y 2012 Analisis kinerja pelaksanaan kewajiban pelayanan publik bidang angkutan kereta api penumpang kelas ekonomi, *Jurnal Perencanaan Wilayah dan Kota*. **23**(1) 19-36
[14] Latief H 2011 *Siaga Tsunami di Pesisir Sumatra* in Abdurahman O P 2011 *Hidup di Atas Tiga Lempeng: Gunungapi dan Bencana Geologi* (Bandung: Badan Geologi, Kementerian Energi dan Sumberdaya Mineral)
[15] Novianta M A and Setyaningsih E 2015 Sistem informasi monitoring kereta api berbasis web server menggunakan layanan GPRS, *Jurnal Momentum*. **17(2)**
[16] Zuidam and Cancelado, 1985 Terrain Analysis and Classification Using Aerial Photograph; a Geomorphologic Approach. ITC Enchede. The Netherlands
[17] Santosa, 2015 Keistimewaan Yogyakarta Dari Sudut Pandang Geomorfologi. Gadjah Mada University Press. Yogyakarta.
[18] Sartohadi J 2007 Terapan geomorfologi dalam pengelolaan sumberdaya air, *Jurnal Alami*. **12(1)** 16-21
[19] Muhtadi A 2011 Kinerja lalu lintas jalan nasional kabupaten sidoarjo, *Neutron Jurnal Teknik Sipil*. **11(2)** 17-25

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