

Categorization of Slope Failure in Southern Malaysia using Total Estimated Hazard (TEHD) Method



Raja Abd Assiss, R. F. F., Zainorabidin, A., Zainun, N. Y.

Abstract: Slope is a measure of steepness or the degree of inclination of a feature relative to the horizontal plane. One of the phenomenon or incidents of a slope was called as slope failure or landslide. Slope failure was a major natural disaster that had affected the country in terms of injuries, deaths, property damage, destruction of services, public inconvenience and economic as well as financial losses. Slope failure cases were very serious geologic hazard disaster that happened in many countries around the world. The aim of this paper is to determine the category of slope failure in the state of Johor based on Landslide Hazard Zonation (LHZ). Data were calculated by using Total Estimated Hazard (TEHD) value method which considered six factors effecting the slope failure, including lithology; slope steepness, topography, land use class, annual rainfall and type of soil. Data on the factors were collected from Malaysia Public Works Department (JKR) inspection form, website, and secondary data resource. After that weight for each factor were identified by referring to Landslide Hazard Evaluation Factor (LHEF) rating scheme. Then determination of LHZ was done according to TEHD values which have five hazard zones; (1) very low; (2) low; (3) medium; (4) high; and (5) very high. The results of this study found that out of total fifty two cases there were three medium hazard (MH), twenty seven high hazard (HH) and twenty two very high hazard (VHH). Comparison between actual data from JKR and total 52 locations of slope failure in Johor showed that 94% accuracy, TEHD equation could calculate potential slope failure hazards in Johor very well.

Keywords : slope failure, TEHD method.

I. INTRODUCTION

According to [1], the slope was known as surface or piece of land that was higher at one end than the other. The shape of

the slope was affected by slope uniformity and runoff production even though slope had a significant impact on sediment yield and rill patterns [2].

The slope failure was a natural disaster that not only caused great loss to the community but also to the country. It is capable of increasing the threat to human life and the destruction of property. Human activities such as tourism, development, forestry and logging increase the incidence of slope failure. Slope failure is a disaster that causes various effects on geomorphological processes and erosion patterns [3]. Malaysian Public Works Department (JKR) was identified more than 100 hillslopes as risky for possible landslides in Malaysia [4].

II. SLOPE STABILITY AND SLOPE FAILURE

The slope was an area of land surface that was part of a mountain or hill which had to be at an angle so that it was more rises at one end than the other. The structure of soil with definite angle was known as slope [5]. That any matters that make the slope more at risk of slope failure or landslides was the steep slope as well as abundant and continuous heavy rainfall that could cause an increase in surface runoff and groundwater flow [5]. There were two types of slope which was natural or man-made, where the slope become vulnerable to slide and failure that then cause tragic disasters [6]. The slope stability was estimating the failure of a soil by checking whether the stress in the soil parallels with the strength of the soil [7]. Slope failure was a one of geological phenomenon that involves large movement of land, falling of rocks or a combination of both [5]. The slope failure had consisted two types of substance which is consolidated and unconsolidated for example soil, rock, artificial filling or the combination of it [8]. The cases of slope failure were increased frequency and it is accompanied with the population sprouting and infrastructure forming such as highway, dam, and new settlement area [9]. Usually, the normal angle of slope that effects the slope failure was between 0.5 to 40 degrees [10].

A. Type of slope failure movement.

A downslope movement of rock or soil or both combinations also known as slope failure where happened on the surface of the schism of the element, either by rotational slide (curved) or translational slide (planar) based on how much of the element frequently moves as a coherent or semi-coherent mass with slightly inner deformation [11].

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According to [12] the type of movement slope failure is delineating the literal inner mechanics of how the slope failure mass is supplant was toppled, fall, slide, spread or flow. Figure 1 shown the part of slope failure.

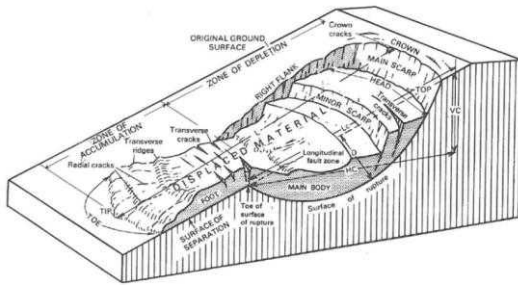


Fig. 1: Part of slope failure (Source: [12])

B. Factor of slope failure

There was two type factor occurrence of slope failure namely as natural factor and man-made factor changes in the environment [6]. The profile of soil could be inherited to make certain soil become weak in the composition or structure of the soil or the soil also could be varied such as rainfall and snowmelt would change in groundwater level or slope failure could occur due to new environmental condition [13]. According to [10], the gravity, weathering, erosion, phenomena of heavy rain, earthquakes, volcanic eruptions and geological factors known as natural factors were inevitable but could be controlled by slope stabilization methods

C. Previous studies

LHEF rating scheme slopes failure modeling techniques used by [14] consist six factors including lithology, slope steepness, topography, land use class, annual rainfall and type of soil as shown in Table 1. Therefore, this study would adopt factors that had been used by [14] to calculate the slope failure using TEHD equation. For each factor had their own weight that will be used in the calculation. High weight values mean these factors could potentially lead to slope failure.

Table 1: LHEF rating scheme

Influence Factor	Weight factor
Lithology	
Jurassic_ Cretaceous	80
Sandstone, siltstone and scarf-Trias	80
Filit, slate and scarf (metasedimen)	100
Igneous	20
Limestone	40
Slope Steepness (°)	
0-15	20
16-25	40
26-35	60
36-45	80
> 45	100
Topography (m)	

<100	60
101-300	80
>300	100
Land Use Class	
Forest	40
Area cleared	100
Swamp	10
Field cattle and grass	60
Municipalities	100
Mining	100
Agriculture	60
Not working	60
Annual Rainfall (mm)	
<2101	20
2101-2197	40
2197-2293	60
2293-2389	80
>2389	100
Type of soil	
Fine Sandy Clay	80
Gravel/Pebble Clay	20
Sandy Clay Loam-Clay	80
Clay	100
Coarse Sandy Clay	60
Clay Loam	80
Coarse Sandy Clay Loam	40
Fine Sandy Clay Loam	60
Sandy Clay Loam	40

TEHD is calculated by adding LHEF ratings obtained for individual inherent parameters. After identifying the type of data involved and the weighting of the data, the calculation of data by using TEHD equation. In this equation, using all the weight of each factor. The equation for this TEHD is given below:

$$TEHD = \frac{(Li + Ss + T + Lu + Ar + Lt)}{6}$$

Where,

- Li = Lithology
- Ss = Slope steepness
- T = Topography
- Lu = Land use
- Ar = Annual rainfall
- Lt = Land type

From the calculated value, the area will be subdivided according to a scale in the assessment of potential slope failure [15]. Little improvement has been made by [15] on a scale in the assessment of potential slope failure suit the suitability of the slope in Malaysia compared to the assessment of potential slope failure by [14] is shown in Table 2.

Table 2: A scale in the assessment of potential slope failure

Potential Zone	[1]	[15]
Very low (VLH)	1.0 - 3.5	0.0 – 31.5
Low (LH)	3.5 – 5.0	31.5 – 45.0
Medium (MH)	5.0 – 6.0	45.0 – 54.0
High (HH)	6.0 – 7.5	54.0 – 67.5
Very high (VHH)	7.5 – 10.0	67.5 – 100.0

Therefore, this study decided to adopt the [15] method to calculate slope failure in Johor and categorized into 5 potential zones.

III. MATERIALS AND METHODS

The research focused on the categories of slope failure in the state of Johor based on the potential scale of the slope failure zone. Methodology framework in Figure 2 explain on the steps used throughout this research in order to complete the main objective of this paper. The collected data would be calculated by using similarity of Total Estimated Hazard (TEHD) values. The calculated data are intended to classify the five potential zones of landslide disaster that are very low, low, medium, high, and very high to create Landslide Hazard Zonation (LHZ) maps.

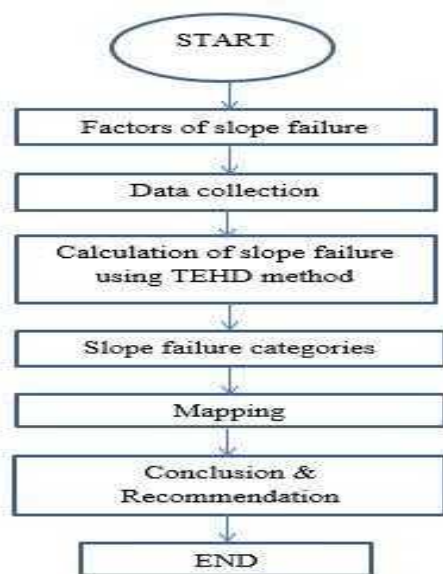


Fig. 2: Methodology Framework

IV. RESULTS AND DISCUSSIONS

Every LHEF factor was changed to weight value based on LHEF scheme rating by [15]. Then the value was calculated by using TEHD equation, total weight of the factor was divided by six (factor). Example calculations as shown in Figure 3.

No.	Region	Location Name	LITHOLOGY	Slope Steepness	Topography (m)	Land Use Class	Annual Rainfall	Type Of Soil	Total TEHD
1	KOTA TINGGI	JALAN KG SG TELOR	100	100	60	60	100	60	80.0
2	KOTA TINGGI	JALAN KG BARU TELUK RAMUNA-DESARU	100	100	60	60	100	40	58.3
3	KOTA TINGGI	JALAN KG BARU TELUK RAMUNA-DESARU	100	100	60	60	100	40	76.7

Fig. 3: Calculated TEHD

After that, the area will be subdivided according to a scale in the assessment of potential slope failure. Table 3 shows that the Classification of hazard zonation was performed by TEHD values according to the LHZ values of [15].

Table 3: Table of Landslide Hazard Zonation (LHZ)

No	Region	Total TEHD	LHZ
1	Kota Tinggi	80.0	Very High Hazard
2	Kota Tinggi	58.3	High Hazard
3	Kota Tinggi	76.7	Very High Hazard
4	Kota Tinggi	73.3	Very High Hazard
5	Kota Tinggi	73.3	Very High Hazard
6	Kota Tinggi	76.7	Very High Hazard
7	Kota Tinggi	73.3	Very High Hazard
8	Kota Tinggi	63.3	High Hazard
9	Kota Tinggi	60.0	High Hazard
10	Kota Tinggi	60.0	High Hazard
11	Kota Tinggi	90.0	Very High Hazard
12	Kota Tinggi	56.7	High Hazard
13	Kota Tinggi	56.7	High Hazard
14	Kota Tinggi	66.7	High Hazard
15	Kota Tinggi	60.0	High Hazard
16	Kota Tinggi	56.7	High Hazard
17	Kota Tinggi	56.7	High Hazard
18	Kota Tinggi	63.3	High Hazard

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19	Mersing	76.7	Very High Hazard
20	Mersing	73.3	Very High Hazard
21	Mersing	60.0	High Hazard
22	Mersing	60.0	High Hazard
23	Mersing	63.3	High Hazard
24	Mersing	63.3	High Hazard
25	Mersing	76.7	Very High Hazard
26	Mersing	76.7	Very High Hazard
27	Mersing	63.3	High Hazard
28	Mersing	76.7	Very High Hazard
29	Mersing	73.3	Very High Hazard
30	Mersing	73.3	Very High Hazard
31	Mersing	66.7	High Hazard
32	Mersing	76.7	Very High Hazard
33	Mersing	60.0	High Hazard
34	Kluang	46.7	Moderate Hazard
35	Kluang	83.3	Very High Hazard
36	Kluang	50.0	Moderate Hazard
37	Kluang	70.0	Very High Hazard
38	Kluang	63.3	High Hazard
39	Segamat	70.0	Very High Hazard
40	Segamat	70.0	Very High Hazard
41	Segamat	70.0	Very High Hazard
42	Segamat	66.7	High Hazard
43	Segamat	73.3	Very High Hazard
44	Muar	56.7	High Hazard
45	Kulai	66.7	High Hazard
46	Kulai	66.7	High Hazard
47	Kulai	66.7	High Hazard
48	Kulai	60.0	High Hazard
49	Kulai	60.0	High Hazard

50	Kulai	60.0	High Hazard
51	Tangkak	50.0	Moderate Hazard
52	Tangkak	76.7	Very High Hazard

Table 4 shows that 22 data were in very high hazard potential zone followed 27 data in a high hazard potential zone and only 3 data in a moderate hazard potential zone. Referring to Table 4, the affected area is the data obtained from the Public Works Department and total TEHD are potential of slope failure. In most cases, the potential percentage of slope failure showed similar results with the actual area of collapse. It can be concluded that the six factors considered are in line with the total affected area of slope failure in the State of Johor. However, the relationship between the potential of slope failure percentage and the actual affected area percentage still requires further studies.

Table 4: Area Affected and Total TEHD of potential slope failure

No	Region	Area Affected (%) (Actual)	Total TEHD
1	Kota Tinggi	65	80.0
2	Kota Tinggi	60	58.3
3	Kota Tinggi	70	76.7
4	Kota Tinggi	65	73.3
5	Kota Tinggi	70	73.3
6	Kota Tinggi	80	76.7
7	Kota Tinggi	75	73.3
8	Kota Tinggi	50	63.3
9	Kota Tinggi	65	60.0
10	Kota Tinggi	60	60.0
11	Kota Tinggi	85	90.0
12	Kota Tinggi	60	56.7
13	Kota Tinggi	50	56.7
14	Kota Tinggi	65	66.7
15	Kota Tinggi	55	60.0
16	Kota Tinggi	55	56.7
17	Kota Tinggi	50	56.7
18	Kota Tinggi	60	63.3
19	Mersing	80	76.7
20	Mersing	70	73.3
21	Mersing	60	60.0
22	Mersing	65	60.0
23	Mersing	60	63.3

No	Region	Area Affected (%) (Actual)	Total TEHD
24	Mersing	50	63.3
25	Mersing	70	76.7
26	Mersing	75	76.7
27	Mersing	60	63.3
28	Mersing	75	76.7
29	Mersing	70	73.3
30	Mersing	70	73.3
31	Mersing	80	66.7
32	Mersing	75	76.7
33	Mersing	50	60.0
34	Kluang	50	46.7
35	Kluang	85	83.3
36	Kluang	50	50.0
37	Kluang	65	70.0
38	Kluang	60	63.3
39	Segamat	80	70.0
40	Segamat	80	70.0
41	Segamat	80	70.0
42	Segamat	80	66.7
43	Segamat	75	73.3
44	Muar	60	56.7
45	Kulai	50	66.7
46	Kulai	80	66.7
47	Kulai	80	66.7
48	Kulai	55	60.0
49	Kulai	70	60.0
50	Kulai	80	60.0
51	Tangkak	80	50.0
52	Tangkak	70	76.7

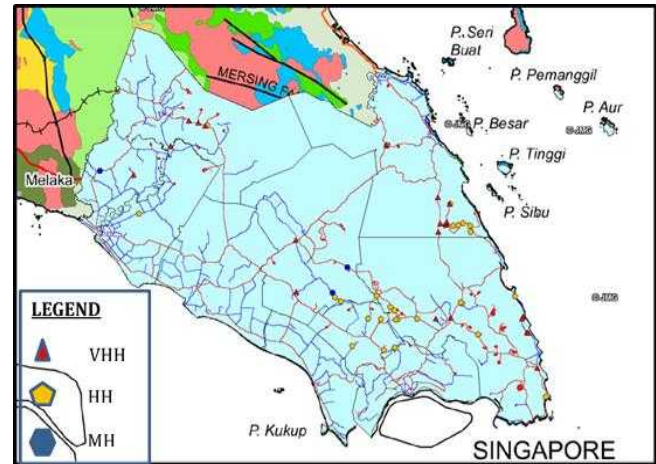


Fig. 4: Map of slope failure by using ArcView GIS

V. CONCLUSIONS

The aim of this research was to determine the category of slope failure in the state of Johor. As can be seen on table 3 Landslide Hazard Zonation (LHZ), the most of the very high hazard (VHH) is for both Mersing and Kota Tinggi area as this district is the east coast of Johor state which is the highest annual rainfall occurred. The steep slope of over 45 ° also affects some of the slope failure occurrences in this area that fall into this potential. In addition, clay-dominated soil types are among the contributors to instability in this area. The results showed that 22 data were in very high hazard potential zone followed 27 data in a high hazard potential zone and only 3 data in a moderate hazard potential zone. Comparison between TEHD and actual data found that TEHD method can determine the potential of slope failure very well with 94% accuracy.

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Table 5 : Percentage by category

Landslide Hazard Zonation	No. of Slope Failure	%
Very Low Hazard (VLH)	0	0.0
Low Hazard (LH)	0	0.0
Moderate Hazard (MH)	3	5.8
High Hazard (HH)	27	51.9
Very High Hazard (VHH)	22	42.3
Total	52	100.0

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Dr Raja Fairol Farouk Bin Raja Abd Assiss was born on July 29, 1979 in Seremban, Negeri Sembilan. Get his early education at SRK KGV, SMK KGV Negeri Sembilan, MRSM Muar and obtained a Bachelor's degree (honors) from University of Technology Malaysia, in civil engineering (2001). He currently

serves as the Senior Engineer in the Public Works Department (PWD), Malaysia. He joined PWD in 2006 and certified his Professional Engineer with Practicing in Civil Engineering from Board Of Engineer, Malaysia in 2015. Previously, he worked at UEM Land, Johor Bahru as a resident engineer in property development (2001 – 2006). His expertise lies in the field of road construction and construction management. He has also been involved in many projects such as housing development while in the private sector and construction of various infrastructure such as highways, schools, government buildings while in the Public Works Department. Before being paid full-time study leave by the government, he served as a special officer to the Director General of Public Works Department (PWD), Malaysia. He is currently pursuing his post graduate studies at UTHM Johor.



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of Civil and Environmental Engineering. He has been very active and well known in both undergraduate and postgraduate teaching and research supervision for more than 22 years. His research and consultancy has focused on his specialist of engineering and construction on challenging peat and soft soil ground conditions. Since obtaining his Certificate of Civil Engineering in 1994 from Polytechnic Port Dickson, where he excelled in his academic studies at the polytechnic, and was awarded a Ministry of Education scholarship to continue his tertiary education under a collaboration program between Malaysia government and World Bank. In 1997, he graduated with a BSc. (Hons) Civil Engineering and obtained his Masters Degree by Research (Geotechnics), majoring in "Geotechnical properties of peat soil in Johor". He furthered his enthusiastic interest in peat soil research and successfully obtained his PhD from the University of East

London, United Kingdom acquiring an expertise in the static and dynamic behaviour of peat soils obtained from both United Kingdom and Malaysia. In the year 2004, he was the First Head of the Research Centre for Soft Soil Malaysia (RECESS) modelled similar to the UK Bothkennar soft clay site. Under his dedicated management, RECESS rapidly established and became well known as a pioneering research centre both at national and international level. One of his prized achievements was when RECESS got their own building completed with advanced geotechnical laboratory and field instrumentation equipment. His area of expertise includes advanced laboratory and in-situ testing, soil properties, ground improvement and soil stabilisation majoring on peat. His research focus areas at the present are on innovative ground improvement methods for peat ground, development of new testing methods of field testing on peat and establishing geotechnical properties of peat. He has supervised and continues to supervise many research students reading for their PhD and Master's level qualifications. Currently his experience and knowledge is utilised, in him being appointed as a committee member to develop Guidelines for Construction on Peat Soil under Construction Research Institute of Malaysia (CREAM).



Dr. Noor Yasmin Zainun is an associate professor in Universiti Tun Hussein Onn Malaysia (UTHM). She joined UTHM in 2003 and graduated her PhD in Civil Engineering from Loughborough University, UK in 2012. Her Expertise lies in the field of construction management. After graduated she was appointed as the department panel chief for 6 years, head of solid waste management project in UTHM, head of research cluster for Sustainable Construction and Management (SCM), fellow researcher Jamilus Research Center (JRC) under sustainable construction, managing editor for *International Journal of Construction*

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