# 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].

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## 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]. 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.

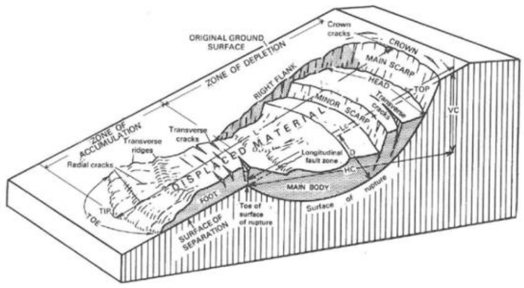



**Fig. 1: Part of slope failure (*Source: [12]*)**

### 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:

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

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.

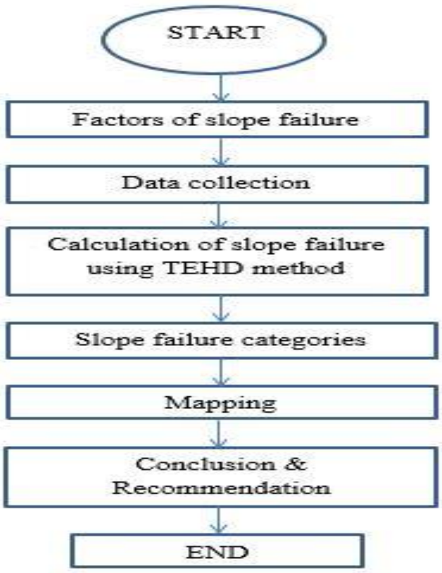
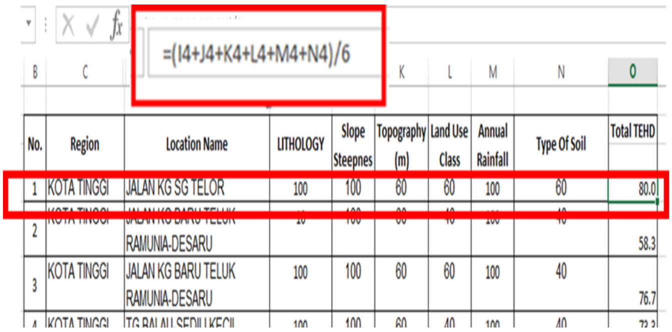



**Fig. 2: Methodology Framework**

## 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.



=(I4+J4+K4+L4+M4+N4)/6

| No. | Region | Location Name | LITHOLOGY | Slope Steepnes | 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 RAMUNIA-DESARU | 10 | 100 | 60 | 40 | 100 | 40 | 58.3 |
| 3 | KOTA TINGGI | JALAN KG BARU TELUK RAMUNIA-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 |

| | | | |
|---|---|---|---|
| 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 |

According to Table 5, it can be seen that the percentage of high and very high categories constituted about 94.2% of the total number of failed slopes in 52 locations. Figures 4 shows that, the data were plotted and mapped in ArcView GIS. Slope failure area marked with different colors and shapes. For very high hazard (VHH) area was marked by triangle shape and red colour, high hazard (HH) was marked by pentagon shape and yellow colour and for moderate hazard (MH) area was marked with hexagon shape and blue colour.

**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** |

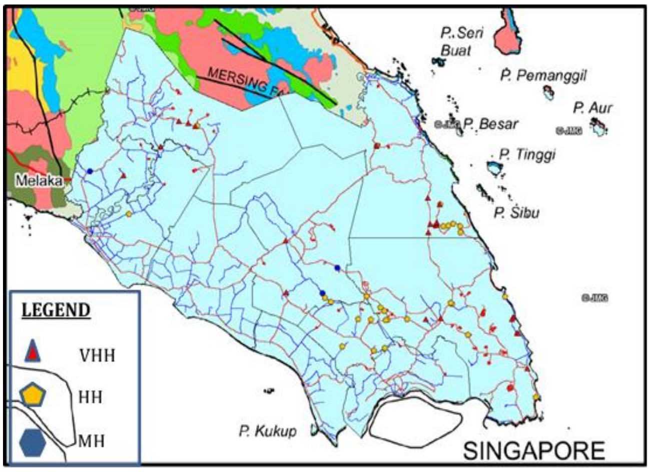



**Fig. 4: Map of slope failure by using ArcView GIS**

## 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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**Ir 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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**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

Technology and Management, academia industry ambassador, Industry Advisor for Department of Civil Engineering in Politeknik Sultan Salahuddin Abdul Aziz Shah and many other committees. She had won various awards on her research innovations and successfully commercial the products. Her computerized model on forecasting low-cost housing demand in urban area in Malaysia won gold medal and Korean Special Invention award in 15th International Invention, Innovation, Industrial Design & Technology Exhibition (I-TEX 2004). She had developed a Low-Cost Housing Demand Predictor (LoCHDeP) system and collaborated with SIRIM Berhad in developing Housing Demand Predictor (HDeP) system. The research was funded by Ministry of Science, Technology and Innovation, Malaysia. In 2013 she venture in solid waste management research and developed Solid Waste Illegal Dumping Waste (SWID) Web and won 5 awards in 2015 including; gold medal and best award at Malaysia Technology Expo (MTE); gold medal at Seoul International Invention Fair (SIIF); gold medal and University Nottingham Malaysia Campus (UNMC) Innovation award at The International Conference And Exposition On Innovations (PECIPTA'15). Other than that, she won 6 gold medal and 1 best theme award in 2019 in research and innovation festival for her smart composter machine. Her involvement in industries bring her to develop food waste grinder machine for Sarjani Agro Shop under Demand-Driven Innovation Project by Public-Private Research Network (PPRN).