HAZARD AND RISK SLOPE INVENTORY USING GEOGRAPHICAL INFORMATION SYSTEM (GIS): CASE STUDY AT FEDERAL ROUTE SIMPANG PULAI FROM SECTION 35 TO 45.

Masiri Kaamin1, Aslila Abd Kadir1 , Nurul Nadzira Abu Zarin2 , Nor Farah Atiqah Ahmad1 , Siti Nooraiin Mohd Razali1, Saifullizan Mohd Bukari2, Mustaffa Anjang Ahmad2

1 Centre For Diploma Studies, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
2 Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia

E-mail: masiri@uthm.edu.my

Abstract. The demand for better and efficient road network has increased tremendously due to the rapid development experienced by the nation in the past few decades. Thus, the tendency to construct roads on the hilly terrain and forced the cuts and fills activities to be carried out. From Public Work Department (PWD) data, the second East West Highway (EWH) found 1335 numbers of non-failed and failed slopes along the highway that are need to be inspected. This case study is focus along the federal road of Simpang Pulai from section 35 to 45 which is part of the second EWH. Therefore, in order to manage the large number of the slopes, it is impossible to access the location and condition of slopes by conducting site inventory without any references. The Slope Smart Proforma A1 and Slope Management and Risk Tracking System (SMART) assessment was used to collect all the slopes data and analyzed the slope in order to verify the condition in terms of hazard and risk. The process of slope mapping was conducted using the Geographic Information System (GIS) application. As a result, the map of slope hazard and risk produced based on rating that has been designed by PWD in SMART. In conclusion, the map produced with data collect through proforma can be useful for the responsible parties to evaluate and inspect the condition of the slope in order to take early preventive measures.

1. Introduction
Condition of hilly terrain will produce a natural slope that are stable and have less risk of failure. However, the economic growth forced the construction of buildings and infrastructures such as roads sometimes had to be done in the hilly terrain [1]. The constructions which conduct in the hills area will produce man-made slopes that require regulation due to its natural state has been disrupted by events of building activities. A total of 21,000 slopes have been identified throughout the country at 16,000 or 76 percent of the slopes are in Peninsular Malaysia, followed by about 3,000 in Sabah and 2,000 in Sarawak [2].

Fifteen federal roads have been identified as high hazard slopes due to its hazardous.. Data obtained by CKC from reported landslides in 2007 and 2008 showed the most affected facility due to landslides in Malaysia were roads and followed by building, houses and others [3]. The construction of East-West Highway at Simpang Pulai, Perak has been completed on 2004 and it was challenging due to its steep terrain of the Main Range [4]. With this construction, it has contributes to the increasing number of steep slopes in Malaysia. Based on PWD Malaysia data, it is stated that 1335 numbers of non-failed and failed slopes along the highway were collected.

In order to manage the large number of the slopes, it is impossible to access the location and condition of slopes by doing site inventory without any references. Thus, by implementing systematic tool such GIS for slope management, it helps in facilitate immediate remedial measures and long term preventive works. By using GIS, slope inventory database would be developed and the condition of slope in term of hazard and risk will be analyzed.
2. Literature Review

2.1 Slope Assessment System (SAS)
Slope assessment and slope management are important requirements to ensure good slope engineering practice. Slope assessment is used to assess the condition of slopes either on small or large scale. Slope assessment is also carried out to understand the likely mechanism which triggers potential occurrence of a landslide. Slope management, on the other hand, is an efficient procedure of variable funds for slope rehabilitation works based on priority ranking of slopes using hazard and risk techniques [5]. To determine the hazard values, a statistical method using discriminant analyses based on slope type (embankment/fill and cut/natural slope) were used. The parameters that normally captured for each slope included the age of the cut slope, batter height, bench width, ratio of crest length to edge length, number of culverts, relationship between slope and topography and etc. [6].

There are four SAS that have been developed by the PWD of Malaysia for predicting landslide at micro level. They are the Slope Maintenance System (SMS), Slope Priority Ranking System (SPRS), Slope Information Management System (SIMS) and Slope Management and Risk Tracking System (SMART) [7]. Results of these SAS can be presented in the form of slope hazard map, which is useful in planning development, slope maintenance and management.

2.2 Geographical Information System (GIS)
Geographic Information System (GIS) is a computer-based system that stores geographically referenced data, links it with non-graphic attributes (data in tables) allowing for a wide range of information processing including manipulation, analysis and modelling. The application of GIS can also provide for map display and production [8]. This system also offered a cost-effective way to analyse and inventory land and environmental resources. There are many attributes that can be displayed and analysed in GIS and one of these attributes is slope [9].

There are two components to GIS data: spatial information (coordinate and projection information for spatial features) and attribute data. Attribute data is information appended in tabular format to spatial features. The spatial data is the where and attribute data can contain information about the what, where, and why. Attribute data provides characteristics about spatial data [10]. GIS integrates two different types of data. Put succinctly, with spatial data enables to draw a map while attribute data makes the map meaningful.

3. Methodology
The database design is a process that shows the arrangement of data collected to produce hazard and risk slope map. The required spatial and attribute data are shown as in Figure 1.

![Figure 1: Flow chart of database design for study area Simpang Pulai from KM35 to KM45](image)

Slope map is the main component in hazards and risks slope maps the slope should represent actual situation on site. For slope map, Smart Data Capture Proforma A1 is a collector document. About 30 data of slope elements in proforma was transferred to attribute data in GIS. For this study, from 30 data in GIS, the most significant data that contribute to the stability of the slopes are Height, Angle, Types of slope and Retaining structure on the slope. Figure 2 show the features that used in hazard and risk slope map. The slope map shown is before the SMART analyses were applied.
The hazard and risk slope map produced after the SMART assessment is applied. In SMART assessment, hazard (IS) and risk (TS) is verified using all data collected in proforma. The weightage used in derived hazard (IS) equation is listed as in Equation 1. The conversion of SI outcome into probability is shown as in Table1. The probability then classified the category of the slope condition in term of hazard based on category designed by PWD. The risk assessment can be calculated by using Equation 2 and the result from this outcome can classify the category of the slope condition.

\[
\text{IS} = 0.027(H) + 0.2(SA) + 0.163(SS) + 0.354(P) + 0.278(CT) + 0.202(ST) - 0.172(MCT) + 0.472(C) + 0.017(\% \text{ RE}) - 1.266(CB) + 0.249(RCP) + 0.281(GS) - 4.293
\]

\[
\text{Table 1: Conversion of SI into probability, P}
\]

| Value of IS | Calculation of probability, P |
|-------------|-------------------------------|
| IS < -2     | P = 0.05                      |
| -2 < IS < 0.5 | P = 0.0037Y^3 + 0.0891Y^2 + 0.3195Y - 0.2531 |
| 0.5 < IS < 4 | P = 0.0105Y^3 - 0.1275Y^2 + 0.5152Y + 0.2952 |
| IS > 4     | P = 1                         |

Source: (PWD, 2004)

The risk values were then obtained using the following equation:

\[
\text{Risk} = \text{Hazard} \times \text{Consequence}
\]
4. Results

The result from the analysis and overlay data process, the slope hazard and risk map can be produced. Figure 3 shows the output map of hazard and risk slope after overlay the features. There are categories listed in the maps in order to identify the condition of the slopes by referring the colors.

![Figure 3: The output map of hazard and risk slope after overlay the features](image)

As a slope inventory tools, GIS is able to display related information according to attribute data contained in the application which is known as query data. Query data is the required data need to be display especially for very high category for both risk and hazard slope. In this study, the slope components on site are the most essential data for inspection purposes. Thus, it is important to highlight some of the slope data. Figure 4 to 9 shows the query data for slope inventory.

![Figure 4: Very High criteria (Very High Hazard combined with Very High Risk)](image)  
![Figure 5: Slope height criteria](image)  
![Figure 6: Slope angle criteria](image)
With these query data, it can be checked that the possibility of the criteria had influenced with others and cause hazard and risk to the slope. Thus, the critical slopes could be identify and the information allows the responsible authority to take precaution measures to these slopes. Results of the combined criteria with very high hazard and risk slope, the data that can be manipulated as follow:

i. Slope height within range of 41 m to 184.5 m.
ii. Slope angle contribute to very high condition with angle of 28º to 75º.
iii. About 40 slopes were classified as very high hazard and risk are cut slope.
iv. 27 slopes are none structure, 11 slopes is gabion retaining wall and 2 is others structure.

Chart map is part of the analysis which overlays a chart onto the map. It is mapping technique in order to display and compare multiple values or values for each layer object. Figure 10 show the pie chart of feature selected overlays with the map. Other than pie chart, analysis can be done in bar/column or stacked.

![Figure 7: Types of slope criteria combined with Hazard](image1)
![Figure 8: Types of slope criteria combined with Risk](image2)
![Figure 9: Types of structure criteria](image3)

Other than querying data, GIS also can hyperlink the data in order to simplify the process on getting the detailed information such as picture, proforma and report. Figure 11 show the hyperlink of Slope 1 which contained of picture and proforma. There are plenty of slopes that required to be inspected and it is difficult to find the proforma document and picture on specific time. Thus, hyperlink function in GIS makes the access of slopes data become systematic.

![Figure 10: The pie chart of feature selected overlays with map.](image4)
5. Conclusions
This study has been carried out at Simpang Pulai from section 35 to 45 and produced the slope inventory which emphasize on slope hazard and risk map along federal road. The hazard and risk map of this study are can be categorized into 5 classes; Very High, High, Medium, Low and Very Low.

The Smart Data Capture Proforma A1 and SMART assessment which has been standardized by PWD was used to analyze the condition of slopes. The classes and weightage used are based on SMART and proforma. Geographical Information System (GIS) helps in displaying the map of hazard and risk slope. Moreover, GIS is able to focus on the criteria that influence the condition of the slopes along the selected section such as slope height, angle, types of slope and structure located at the slopes.

Thus, the hazard, risk and criteria maps produced have enabled slope monitoring and maintenance along the road in the study area. It is facilitate the authority to access the data and analyze the slopes to preventing before failure.

References

[1] Mamat, A.A. (2005). Sistem Pemantauan dan Penyelenggaraan Cerun. Universiti Teknologi Malaysia. Bachelor Degree’s Thesis
[2] Buletin Kerja Raya (2012). 21,000 Cerun Berisiko Dikenalpasti. Kuala Lumpur: Buletin KKR
[3] Slope Engineering Branch (2009). Landslide Statistics in Malaysia for 2007 and 2008. Malaysia: Public Work Department
[4] Lee, C.H. (2009). Design and Construction Of A 20.5 M High Innovative Nehemiah Wall Near Cameron Highland, Pahang. Malaysia: Nehemiah Reinforced Soil Sdn Bhd
[5] Huat, L.T. & Ali, F. (2012). Slope Hazard Assessment in Urbanized Area. Electronic Journal of Geotechnical Engineering, 17(C), pp 341-352.
[6] Harwant S., Bujang B.K.H. and Suhaimi J. (2008). Slope Assessment System: A Review and Evaluation of Current Techniques used for Cut Slopes in the Mountainous Terrain of West Malaysia. Vol. 13, Bund. E. EJGE.
[7] PWD (1996). Final hazard analysis report. In East-West Highway Long Term Preventive Measures ans Stability Study. Public Work Department, Malaysia.
[8] Laura L. (1998). Managing Natural Resources with GIS. 1st ed. California: ESRI
[9] Robert, C. W. J., and Tabitha, L. M. (2004). Modeling Slope in a Geographic Information System. Journal of the Arkansas Academy of Sciences, Vol. 58.

[10] Morais, C.D. (2012). Spatial data and Attribute data. Retrieved on November 28, 2015 from http://www.gislounge.com