INTEGRATION OF GEOGRAPHIC INFORMATION SYSTEM-BASED METHOD IN WEIGHT ASSIGNMENT AND PARAMETER JUSTIFICATION FOR ROCKFALL HAZARD RATING SYSTEM

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DEDICATION

This thesis is dedicated to my father, who support me through my journey in pursuing education and my mother, who endlessly taught me to be patient. I hope that the completion of this master's degree will make them proud. May Allah grant them the highest place in the world hereafter.

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ABSTRACT

The purpose of this study is to do a comparison study of integration of heuristic AHP and GWR methods in predicting rockfall hazard. Rockfall Hazard rating System (RHRS) has been an established method to monitor the rockfall hazard leading to development of other system to study rockfall across different countries. The data used for this study involves classified slope datasets in East-West Federal Highway from Gerik to Temenggor, Perak. The study shows that the hazard map produced from AHP yield better predictive model due to the high percentage match of 85 % with the original score from the field. Heuristic method produces better results for rockfall prediction using only 10 parameters. Regression method are proven to be unsuitable for predictive model if the dataset is small with only several parameters. Addition of parameters in a larger study area may improve the predictive score for GWR. GWR lower score than OLS suggest that the occurrence of rockfall may not be heavily influenced by the surrounding factors, thus a general parameter's coefficient is enough to predict the rockfall hazard.

ABSTRAK

Kajian ini dijalankan bertujuan untuk membuat pembandingan di antara integrasi kaedah AHP dan GWR heuristik dalam meramalkan bahaya batu runtuh. Sistem penilaian bahaya tanah runtuh (RHRS) telah menjadi kaedah yang mapan untuk memantau risiko batu runtuh. Rentetan itu, negara-negara lain telah mebuat kajian untuk menubuhkan sistem ini untuk mengawal dan meramal kawasan yang berpontesi untuk berlaku runtuhan. Data yang digunakan untuk kajian ini melibatkan dataset cerun yang telah diklasifikasikan yang terletak di Lebuhraya Persekutuan Timur-Barat dari Gerik ke Temenggor, Perak. Kajian menunjukkan bahawa peta risiko tanah runtuh yang dihasilkan menggunakan pemberat dari AHP telah menghasilkan model ramalan yang lebih baik berikutan peratusan persamaan yang tinggi sebanyak 85% dengan skor asal dari lapangan. Kaedah heuristik menghasilkan keputusan yang lebih baik untuk ramalan rockfall dengan hanya menggunakan 10 parameter. Kaedah regresi dalam kajian ini terbukti tidak sesuai untuk model ramalan jika set data kecil dengan sebilangan kecil parameter. Penambahan bilangan parameter di kawasan kajian yang lebih besar berpotensi untuk menambahbaik keupayaan model meramalkan cerun yang bahaya. Selain itu, skor teknik GWR yang lebih rendah daripada Teknik OLS menunjukkan bahawa kejadian batu runtuh mungkin tidak banyak dipengaruhi oleh faktor sekitarnya. Oleh itu pemberat parameter umum sudah cukup untuk meramalkan bahaya runtuhan di suatu kawasan.

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LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
GWR		Geographical Weighted Regression
GIS	-	Geographical Information System
SMCE	-	Spatial Multi-Criteria Evaluation
RHRS	-	Rockfall Hazard Rating System
mRHRS	-	Modified Rockfall Hazard Rating System
CRHRS	-	Colorado Rockfall Hazard Rating System
RHRSI	-	Rockfall Hazard Rating System India
PCM	-	Pairwise Comparison Matrix
EBF	-	Evidence Belief Function
OLS	-	Ordinary Least Square
AICc	-	Akaike Information criterion
WLC	-	Weighted Linear Combination
WOE	-	Weight of Evidence
GIS	-	Geographic Information System

LIST OF SYMBOLS

i,	-	Location
γ	-	Rockfall Incidence Rates
β	-	Vector of Regression
x	-	Velocity
ε	-	Random Error Term
0	-	Intercept
f	-	Factor of Normalized Score
w	-	Parameter's Weight
S	-	Sum of Hazard Score
R^2	-	R-squared

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Rockfall is a common bedrock mass movement on steep slopes including free falling, rolling, bouncing, and sliding motion (Davies, 2007). Various natural or man-made factors causes fractures in rocks. In constructing new road network, often the mass of rock is blasted to create pathway. This instability of rock slope is what could lead to the rockfall to become a hazard. Rockfall has been a problem for many countries especially near the road network since rock cutting for road construction causes instability in the rock terrain. Fractures is a feature in rock that represent the plane of weakness and breaks in rock mass. It is one of the factors that control the slope instability. Pierson in 1993 defined Rock Hazard Rating System as a proactive tool that allows transportation agencies to rationally address their rockfall hazard.

Therefore, most of the transportation agency globally had begun to adopt a rock hazard rating system to identify and monitor the condition of the slope along the highway. Rock hazard analysis has been discussed since 1984 from a study by C.O Browner and Duncan Wyllie (Pierson, 1993). Since then, many Rockfall Hazard rating System have been developed. Among them were Oregon-RHRS (Pierson, 1993), RHRON (Franklin & Senior, 1997), and Missouri RHRS (Youssef et al, 2003) (Aqeel, 2018). Most of these methods applied the GIS-based regression statistical analysis and multivariate analysis. Advancement in technology has witnessed the incorporation remote sensing and Rock Activity Index (RAI) method; a point-cloud-derived method for assessing landslide and rockfall hazard. Yet, the simulation was still based on system developed by Pierson (1993). (Dunham et al.,2017). In conclusion, it is necessary to address the spatial analysis algorithm behind the GIS-based predictive modelling.

1.2 Problem Background

There has been a lot of study on GIS-based method on landslide and rockfall susceptibility mapping (Shakoor,2009; Michoud et al., 2012; Shahabi & Hashim,2014; Saroglou, 2019). The current Rockfall Hazard Rating System has applied subjective and quantitative method to categorize slope hazard. The heterogeneity of risk scales adopted across rock hazard system raise an issue on how the hazard is defined as it could lead to an overestimation or underestimation of rockfall risk along the road. Moreover, the common RHRS are likely to underestimate the risk due to the steps in the algorithm which just simply sum up the scores of all the categories. Effort to monitor this risk hazard has mostly been done through landslide method such as geotechnical approach, direct method like mapping and indirect method including univariate, bivariate or multivariate regression analysis (Marquinez et.al., 2003, Zhu & Huang,2006).

1.3 Research Aim

Research aims to do a comparison study of integration of heuristic AHP and GWR methods in acquiring weightage for each parameter for rockfall hazard prediction. This research's objective is also to observe the parameter used to assess the rockfall risk in the study area based on literature studies and statistical method. Thus, this study has proposed an integration of geospatial analysis by implementing two different GIS-based methods in the weighting component of Rockfall Hazard Rating System in order to generate better predictive model for rock slope hazard mapping.

1.4 Research Question

The research questions for this study are as below:

1. Is the original rock hazard rating system suitable for the road condition and weather in Malaysia?
2. Which modified version should be adjusted to suit the condition of Malaysian road?
3. Is there any parameter that should be removed from the current analysis to improve the performance?
4. Can jenk natural break or other classification method provide better distinction of the hazard class?
5. Which GIS-based method has the highest accuracy to produce the best rockfall predictive model?
6. Which rock hazard rating system is the best and should integrated with better performing GIS-based method?

1.5 Research Objectives

The objectives of the research are:

a) To identify the GIS based statistical method to be used in the algorithm for Rockfall Hazard Rating System
b) To compare the different risk scale system and scoring system in the algorithm of Rockfall Hazard Rating System
c) To review the existing rock hazard rating system analysis and integrate with geospatial analysis by comparing different GIS-based methods for rockfall susceptibility mapping
d) To assess the improvement of the new modified Rockfall Hazard Rating System statistically in predictive modelling of rockfall by using categorized rock slope dataset. To assess and compare the performance of the predictive model using AHP and regression technique.

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