

Relationship of Environmental Factors Toward Accident Cases using GIS Application in Kedah

Nur Fatma Fadilah Yaacob
*Faculty of Architecture, Planning and
Surveying*
Universiti Teknologi MARA
Perlis, Malaysia
cikfatma@yahoo.com

Noradila Rusli
*Faculty of Built Environment and
Surveying*
Universiti Teknologi Malaysia
Johor Bharu, Malaysia
noradila@utm.my

Sharifah Norashikin Bohari
*Faculty of Architecture, Planning and
Surveying*
Universiti Teknologi MARA
Perlis, Malaysia
ashikin10@perlis.uitm.edu.my

Abstract—Malaysia has been ranked as one of the top three countries in the world with deadliest roads. The aim of this study is to determine the relationship between environmental factors and the occurrence of accident cases. The road accident data were obtained from Ibu Pejabat Kontinjen (IPK) Alor Setar and the weather data were obtained from the Malaysian Meteorological Department (MMD) from the year 2013 to 2015. These data were processed through ArcGIS software 10.5. Subsequently, to determine the relationship between accident cases and environmental factors, the regression method was carried out. The result show rainfall has effects toward road accidents at the low level of rainfall. Besides that, there are two levels of temperature that lead to accidents occurring in Kedah such as cool day and warm day. The number of accident cases increased when the temperature value in cool day category increased and the number of road accident cases occurred decreased when the temperature value increased in warm day category. Meanwhile, the number of accident cases increased when the wind speed is maximum or above 20 m/s. In conclusion, the advancements in Geographical Information System (GIS) can be put to effective use in road accidents for further analysis such as spatial-temporal analysis, hotspots area analysis, shortest path analysis and emergency response analysis.

Keywords—*environmental factor, road accident, regression, GIS application*

I. INTRODUCTION

Lack of road safety in the world is the leading cause of mortality in low-income and middle-income countries [1], which causes between 20 and 50 million injuries every year. Besides that, road accident is the leading cause of death among the 15-29 year-olds, where half of the people killed on the road are pedestrians, cyclists and motorcyclists. It is predicted that road accident is likely to be the seventh (7th) leading cause of death by 2030, of which road accidents were ranked ninth in deaths in the year 2009.

Many factors can be contributors to road accidents. These factors are usually related to traffic characteristics, road users, vehicles, roadway infrastructure and environment [1][2]. Environmental factors consist of unfavourable weather conditions such as heavy rainfall, massive wind, temperature and earth surface condition [3]. Weather conditions have been affecting the capabilities of drivers, stability of vehicles and pavement's friction, which then give impacts on traffic through visibility, precipitation, wind speed and temperature [2].

Rainfall affects the visibility of the driver and makes the road surface slippery due to water reducing the tyre-road friction [4][5][6]. This is because reduced friction on the

road surface and braking distances are longer. The disturbance of visibility occurs due to the reflection on wet surfaces. Besides that, the first day after a dry period causes the number of road accidents to increase [7][8][9] and it will affect the severity level.

Temperature has effects on driver's performance, road infrastructure and vehicle performance [13]. High temperature leads to decrease of accident cases in fatigue level and aggressive behaviour. Even though most vehicles are equipped with air-conditioning system, temperature still contributes to the occurrence of road accidents. Nevertheless, extreme temperature causes lower number of road accident cases [14]. This is because people remain indoor in this level of temperature.

The advancements in GIS can be put to effective use in road accident analysis. Even though GIS has been used for over thirty years, it has only been recently used in the field of transportation [15]. Thus, this study is to investigate the relation of environmental factors toward accident cases using the GIS application.

II. DATA COLLECTION

A. Study Area

The study area chosen for this study is Kedah. It is the 8th largest state in Malaysia with a land area that is estimated to be around 9,500 km² and the size of population was 2.12 million in the year 2016. Kedah consists of 12 districts which are Kubang Pasu, Padang Terap, Kota Setar, Pokok Sena, Pendang, Yan, Kuala Muda, Sik, Baling, Kulim, Bandar Baharu and Langkawi. However, this study does not focus on the Langkawi district due to lack of data.

B. Road Accident Data

The road accident data were collected from Ibu Pejabat Polis Kontinjen (IPK) Kedah. The data obtained were from the year 2013 to 2015. The total number of accident cases for 3 years of investigation are 44,767 cases (see Fig. 1).

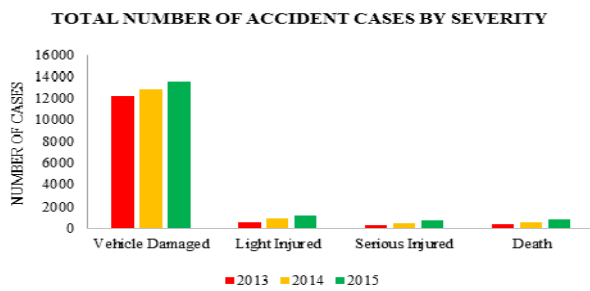


Fig. 1. Total Number of Accident Cases by Severity

C. Weather Data

This analysis used the daily mean of temperature, rainfall and wind distribution. All these data were obtained from the Malaysian Meteorological Department (MMD) for a duration of 3 years of observation. There are 4 weather observation stations in Kedah such as in Alor Setar, MARDI Bukit Tangga, Hospital Kulim and Pusat Pertanian Bukit Seketol (see Fig. 2).

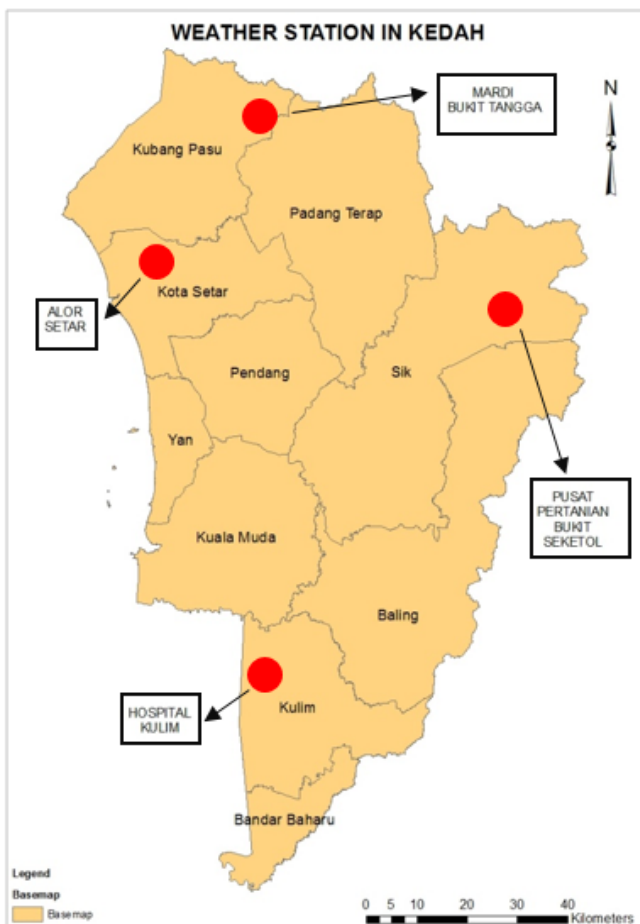


Fig. 2. Weather Station Observation

D. Software Used

This study used ArcGIS software 10.5 as the main software for processing data, Global Mapper used TanDEM-X image, and Ultra Edit was used to clean and filter data (see Fig. 3).



Fig. 3. Type of Software Used

III. METHODOLOGY

There are several processes to investigate the effects of environmental factors toward accident cases such as the creation of accident database, rainfall interpolation process, wind interpolation process, temperature derivation process and lastly data analysis using the regression method (see Fig. 4).

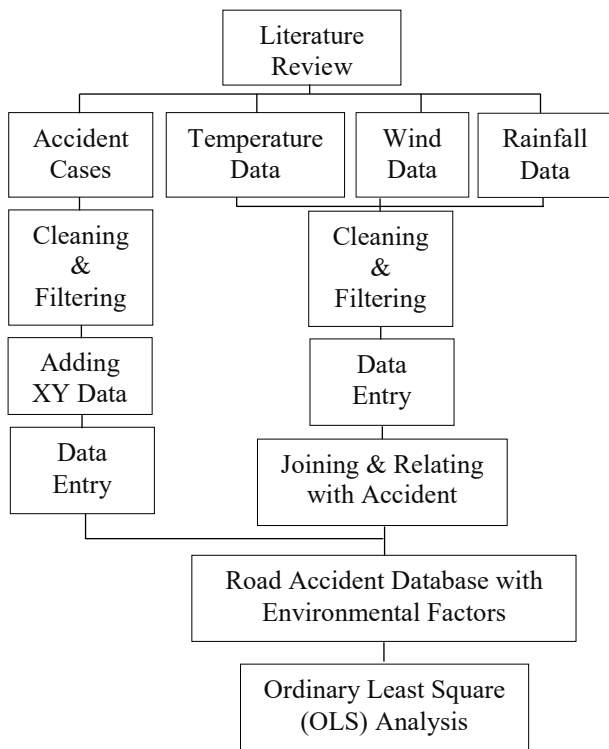


Fig. 4. Methodology Workflow

The accident database was created to store all attributes of accident data such as location of accident, coordinate of a location, type of accident, time and date of accident occurred. Besides that, the environmental factor data were also stored in this database using join and relate process. The steps of processing accident database included the creation of accident geodatabase, data cleaning and filtering, coordinate conversion, adding XY data, and data entry of attribute information. XY data refer to plot the actual location of accident cases occurred in ArcGIS software. Data entry of road accident cases, temperature, wind and rainfall is done to make sure all information about these data completed such as date of accident occur and its causes.

The rainfall and wind data from four weather stations were processed from the year 2013 to the year 2015 using ArcGIS software. The database was created using extracted data in excels. Cleaning and filtering data was done on selected rainfall and wind data based on the date of accident cases occurred. After that, the amounts of rainfall and wind were keyed in and the data were combined with the road accident data. Then, symbology classification was carried out for direction of wind.

Temperature derivation procedure is the same with rainfall interpolation procedure method. The temperature data were cleaned and filtered based on the date of accident

cases occurred. The daily mean of temperature was keyed in and the data were joined with the road accident database.

The regression method was carried out to analyze the relationship of environmental factors and road characteristics factors toward accident cases using ordinary least square (OLS) method. According to ArcGIS Desktop Help 10.5, ordinary least square (OLS) use to generate predictions or to model a dependent variable in term of its relationships to a set of explanatory. The output of OLS is in feature class and optional tables with coefficient information and diagnostics. Fig. 5 show element of an OLS regression equation. Element of OLS was described below.

- Dependent variable (y): This variables represents the process that want to predict. It also known as observed values.
- Independent/Explanatory variables (X): Variables that will used to model or to predict the dependent variable values.
- Regression coefficients (β): Coefficients are computed by the regression tool. It was represent the strength and the type of relationship the explanatory variable has to the dependent variable. When the relationship is positive, the sign for the associated coefficient is also positive; while coefficients for negative relationships have negative signs.
- P-values: It shows probability value of the model. Small p-values show small probabilities values and large p-values show higher probability.
- R²/R-squared: Multiple R-squared and adjusted R-squared are both statistics derived from the regression equation to quantify model performance. The value of R-squared ranges from 0 to 100 percent. The adjusted R-squared value is always a bit lower than the multiple R-squared values because it reflects model complexity.

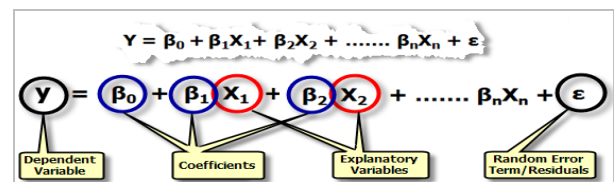


Fig. 5. Element of an OLS Regression Analysis

IV. RESULTS AND DISCUSSION

Rainfall level is classified into four (4) level in this study (see TABLE I). It consist of sunny day, low level, medium level and high level. TABLE I show the categories for each level.

TABLE I. CLASSIFICATION OF RAINFALL LEVEL

Level	Classification
Sunny Day	No rain/ (0 mm)
Low	Maximum at or above 5 mm
Medium	Maximum at or above 20 mm
High	Maximum at or above 40 mm

Fig. 6 show the number of accident cases based on rainfall level. Accident cases occurred in sunny day highly on year 2015, 2014 and 2013 in decrease sequent. The highest accident cases occurred during lower volume rainfall was in year 2014 followed by year 2013 and 2015. Besides that, medium volume rainfall leads to the high of accident cases on year 2013, 2014 and 2015 in decrease sequent. Lastly, most accident cases occurred during high volume rainfall was year 2013, 2014 and 2015 in increased sequent.

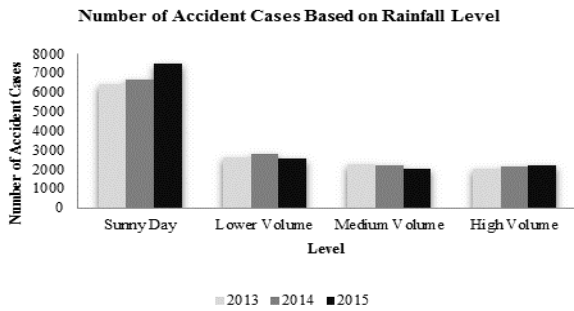


Fig. 6. Number of Accident Cases Based Rainfall Level

This study also investigated the temperature derivation toward accident cases based on classification of temperature regulation by the Meteorology Department. There are five (5) classifications of temperature level such as cool day, warm day, hot day, very hot day and extremely hot day (see TABLE II).

TABLE II. CLASSIFICATION OF TEMPERATURE LEVEL

Level	Classification
Cool	Below 28°C
Warm	Maximum at or above 35°C
Hot	Maximum at or above 36°C
Very Hot	Maximum at or above 37°C
Extremely Hot	Maximum at or above 38°C

The result revealed that only two (2) levels of temperature lead to accidents that occurred in Kedah which are cool day and warm day. Mostly, road accidents occurred on chilly days. This is because people like to do outdoor activities on cold days [14]. Besides that, the daily mean temperature of Kedah from 2013 to 2015 was between 23°C and 31°C. Fig. 7 show the number of accident cases based on temperature level.

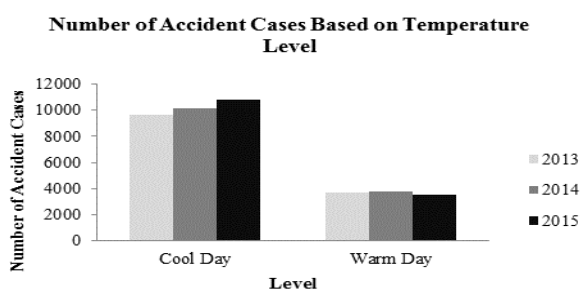


Fig. 7. Number of Accident Cases Based on Temperature Level

There is also a relationship between wind interpolations toward accident cases. There were three (3) classifications of speed such as low speed, medium speed and high speed that indicated 1.0 m/s, 2.0 m/s and 3.0 m/s respectively. This classification was based on the actual observation of the daily wind data from the Meteorology Department. Fig. 8 show number of accident cases based on wind speed.

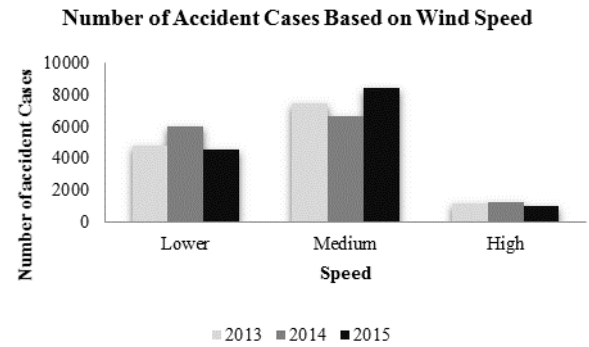


Fig. 8. Number of Accident Cases Based on Wind Speed

Generally, accident cases occurred when the wind was at a medium speed. Increase in wind speed indirectly has decreased the number of accidents that occurred [16] [2] [7]. One of the reasons why the number of accident cases decrease during high speed of wind is people take a proper caution when driving in this situation. Besides that, the geographical location of the main roads in Kedah is mostly not situated in coastal regions. Driving in coastal region sometimes deviates the vehicle from its path and will lead to road accidents [17].

The most influence factor contributed to accident cases based on this parameters was used ordinary least square (OLS) method using ArcGIS software. Table III shows the percent of environmental factors influenced to road accident by year. From this result, we can see that the highest value of influencing of environmental factor toward accident cases contributed to year 2013, followed by year 2014 and year 2015. It can therefore be assumed that the highest number of road accident occurred on that year indicates the more influenced of environmental factors towards road accidents.

TABLE III. THE R² RESULT OF ENVIRONMENT FACTORS

Year	Adjusted R ² Value	Percent (%)
2013	0.24	24%
2014	0.23	23%
2015	0.23	23%

The variance inflation factor (VIF) result obtained from OLS analysis are set out in Fig. 9. Function of VIF is measures redundancy among explanatory variables (ArcGIS Desktop Help 10). The largest value of VIF showed the most factor influence the result. Mean the highest value VIF of the variable showed it be the main in the story. But if the value VIF has two variables more than 7.5 it should be removes

from the regression because both of the variables are telling the same story (ArcGIS Desktop Help 10).

The most factor influenced road accident cases based on environmental factors among three (3) years showed in Table IV and Fig.9. It found that temperature is monopoly factor to lead accident cases along 3 year, followed by wind and rainfall. The temperature impact different during summer and low winter but the both will decrease the driving performance. This is lead to decrease and fatigue and aggressive behavior. Even though, mostly vehicle are equipped with air-conditioning system but still temperature has a contributed to road accident occurred. The following conclusions can be drawn from this result that authority should restrict the law enforcement of road safety that give awareness to driver that always used the suitable limit of car speed for each road.

TABLE IV. THE R^2 RESULT OF ENVIRONMENT FACTORS

Parameter/Year	2013	2014	2015	Average
Rainfall	1.08	1.04	1.04	1.05
Temperature	1.22	1.15	1.19	1.19
Wind	1.13	1.12	1.16	1.14

Variance Inflation Factor (VIF) of Environmental Factors

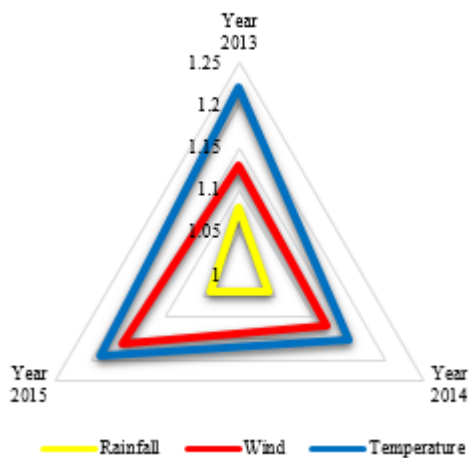


Fig. 9. VIF of Environmental Factor Through 3 Years

CONCLUSION

The results of the study conducted for the assessment to determine the relationship between environmental factors and the occurrence of accident cases are presented in this article. The regression analysis was used to investigate the influence of environment on road accident cases. GIS was used to visualize the results. The results revealed that more accidents occurred during lower volume of rainfall. An increasing number of accidents happened when the temperature value is near 28°C and the number decreased when the temperature value is near 30°C. Accidents in Kedah were found to have occurred when the wind was at a medium speed. The most environment factor influence to road accident cases is temperature parameter. Based on the

results achieved, it can be concluded that the environmental factors had effects on road accident cases.

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