Application of GIS to Traffic Accident Analysis: Case Study of Naypyitaw-Mandalay Expressway (Myanmar)

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Abstract

Accident data collection and reporting system are very important in road safety management. A systematic accident data recording system is necessary to analyze and visualize hazardous locations. Road traffic accidents are recognized as one of the primary causes of social and economic losses, both in developed and developing countries. This study aims to identify the hazardous road locations on the Naypyitaw-Mandalay Expressway in Myanmar. In the current situation, there is a National Road Safety Strategy in Myanmar but it is partly funded and cannot be implemented successfully. Moreover accident data have been reported in documentary format by the highway polices. Traffic accidents data used in this study are collected from the Ministry of Construction and Highway Police Station in Naypyitaw. Hazardous locations on the expressway are identified by using accident rate and quality control methods and the results are presented by using GIS. This study will be useful for the responsible authorities to find out the hazardous locations on other roads with the use of accident analysis methods.

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1. Introduction

Nowadays, the most negative results in developing transportation systems are road accidents which result in personal injuries, loss of lives and property damage. Road traffic safety is the most critical matter in both developed and developing countries. A convenient transportation system is important in Myanmar for the movement of people and goods. According to the WHO Global Status Report on Road Safety 2015, road traffic accidents are predicted to rise to become the 7th leading cause of death by 2030. About 1.25 million people die and between 20 and 50 million people suffer from non-fatal injuries every year due to traffic accidents. Around 90% of road traffic deaths occur in low- and middle-income countries (World Health Organization [WHO], 2015a). In Myanmar, the numbers of deaths related to road accident have increased since 2013, and road accidents result in the death of 11 people per day on average in 2015 (World Health Organization [WHO], 2015b). For the implementation of accident reduction, it is very important for identification of hazardous locations.

The Yangon-Mandalay Expressway is the first and only one expressway in Myanmar. There are many requirements in road furniture and pavement condition is also under the expressway standard. But speed limit is 100 kilometer per hour and more accidents occurred in this road compared with others. Hence, it is essential to know the prior section for the improvement with the limited budget. The primary objective of this study is to identify the hazardous locations and visualize accident data on Naypyitaw–Mandalay Expressway in Myanmar by using accident analysis methods and Geographical Information System (GIS). GIS is a very important and comprehensive management tool for traffic safety. The advancements in GIS and Global Positioning System (GPS) mean that it can be put to effectively use in accident analysis. GIS is a technology for managing, analyzing, exploring spatial data and related information in a less time consuming manner (Apparao, Mallikarjunareddy & Raju, 2013; Erdogan, Yilmaz, Baybura & Gullu, 2008; Hirasawa & Asano, 2003; Jayan & Ganeshkumar, 2010; Saleh, 2014). Therefore GIS will provide a platform to maintain, visualize and explore relationships between accident record databases and hence further analysis.

This research uses the statistical test methods for identifying of hazardous locations on the expressway by using GIS (Iamtrakul & Raungratanaamporn, 2015, pp. 39-52). No research has been done for this kind of analysis by using GIS in Myanmar. This research will be useful for the responsible authorities for the implementation of a road safety action plan.

2. Literature Review

Spatial data and its analysis is one of the most important tools for traffic accident analysis. The location of the highest accident occurrence can be defined as a point or area where there is a particularly frequent recurrence of an event and these locations are determined statistically. There have been various visual methods and reports about the use of GIS on accident analysis, which include intersection analysis, segment analysis, cluster analysis, density analysis, pattern analysis, and spatial accident analysis modeling techniques (Eck & David, 1995; Erdogan et al., 2008). Since 1990's, GIS has been used in the field of Transportation (Erdogan et al., 2008) and it has the ability to organize the various types of data and maps that can be easily stored, shared and manipulated.

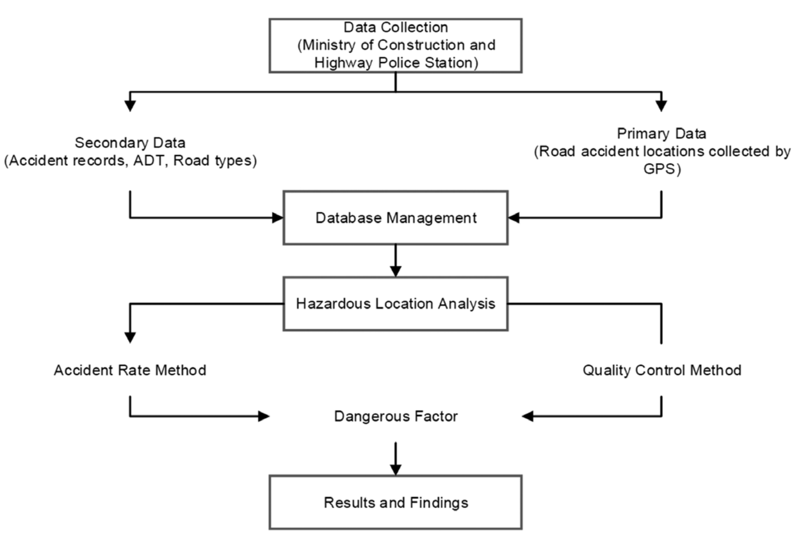
Accident analysis statistical methods (accident frequency, accident rate, severity index, quality control and combined method) were used to identify hazardous road locations on the highways in Thailand (Kowtanapanich, 2007; Ratanavaraha & Amprayn, 2003), India (Apparao et al., 2013), and Turkey (Yakar, 2015). Different parameters for each one kilometer road section were calculated and each of these values was compared with a critical value. The road section having higher parameter values than the critical ones for all these parameters, was considered as a hazardous location. Moreover GIS was used to design accident database and produce ranking of hazardous locations based on either total accidents occurring or accident rates.

Kim and Levine (1996) described spatial analysis of traffic accidents in Honolulu, Hawaii using GIS. These spatial analysis methods based on point, segments, and zones analyses had been developed. Jayan and Ganeshkumar (2010) studied to identify hazardous locations and safety deficient areas by using GIS to create a geo-database and density map. The accident database in their study included the attribute data such as date, location, type of vehicle involved, number of persons injured or killed for the years 2006, 2007 and 2008. Both simple and kernel density estimation (KDE) methods were applied to identify the hazardous locations and accident patterns. Erdogan et al. (2008) studied to analyze hazardous locations and detect safety deficient areas on the highway in Afyonkarahisar, Turkey. Repeatability methods were used to identify the hot spots areas and compared the results by using kernel density estimation methods. As a result of both analyses, hazardous locations were found to almost overlap thus indicating the same locations. There are many techniques to identify hazardous location occurrence areas. Different techniques produce different hot spots in terms of shape, size and location. In this study, statistical test methods; accident rate method and quality control method are used to identify the hazardous location which is highly dependent on accident numbers, and the results are shown with mapping format using Arc GIS.

3. Study Area

Naypyitaw–Mandalay Expressway is studied in this research and it is the major highway in Myanmar. Naypyitaw is the Capital city and also known as the administrative city of Myanmar. It is also a junction point connecting to the developed cities. Mandalay is the second largest city and also an economic hub of upper Myanmar. Moreover Mandalay is the last royal capital of Myanmar and center of Myanmar Culture, and it includes a number of tourist attractions. This expressway is connected to these two major cities and it has a length of 164.25 miles (265 km). According to the data from Ministry of Construction and Highway Police Station in Naypyiaw, this highway has the highest accident rates in the country. There were totally 398 accidents for both directions of highway within 3 years from 2013 to 2015. The study area, Naypyitaw–Mandalay Expressway, lies between 19°39’40.8”N to 21°53’55.6”N Latitude and 96°03’25.1”E to 96°05’10.0”E Longitude.

Figure 1. Research Methodology.



4. Methodology

The methodology of this research consists of 4 steps including data collection, database management, hazardous location analysis and results and findings as shown in the following Figure 1.

4.1 Data Collection

The data used in this study consists of two sources, primary data and secondary data. Primary data consists of geographic coordinates of accident location and road network, and secondary data include average daily traffic, time of occurrence, and length of highway for the study. Accident data are collected from Ministry of Construction and Highway Police Station in Naypyitaw, Myanmar and primary data are collected with the help of Global Positioning System (GPS). Microsoft Excel is used for building the accident database in a format for implementation in Arc GIS 10.1 software, processing of the maps and performing the analysis.

4.1.1 Monthly Traffic Accident Records

The numbers of monthly traffic accident occurrences on the expressway for Naypyitaw-Mandalay (NPT-MDY) and Mandalay-Naypyitaw (MDY-NPT) directions from 2013 to 2015 are shown in the following Figure 2.

4.2 Database Management

The Accident database table involves attributes such as accident location, number of accident occurrence, average number of daily traffic on the expressway and dangerous factor values from the analysis. The accident database used in GIS has been prepared with DBF4 (dBASE4) format by using Microsoft Excel 2003. The accident locations on the map are identified as point features and road network are identified as line features in Arc GIS 10.1. The following Figure 3 shows the point of every accident collisions on upstream and downstream of the expressway within the 3 years between 2013 and 2015. There are 267 accident locations on upstream and 131 locations on downstream of the expressway, and each location are described by mile/furlongs on both lane directions.

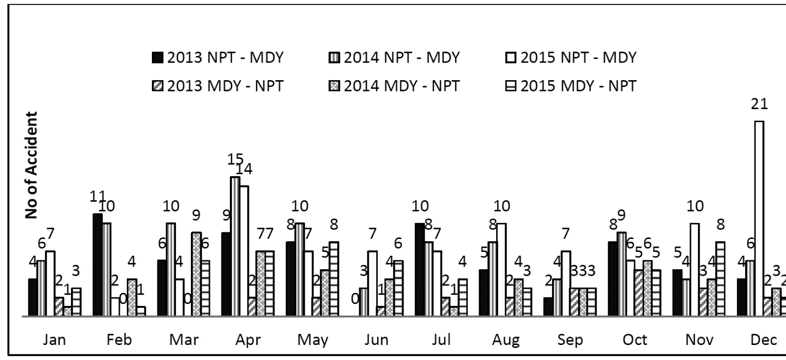


Figure 2. Monthly Traffic Accident Record on Naypyitaw-Mandalay Expressway from 2013 - 2015 (NPT–MDY and MDY–NPT direction).

4.3 Hazardous Locations Analysis

The hazardous locations are considered as a place where the road traffic accidents have unusual high concentration of occurrence. Accident rate method and quality control method are used for identifying the hazardous locations on the expressway and the results are shown by using Arc GIS 10.1 in this study. These methods are statistical tests and based on the recorded accidents data with respect to number of accidents, traffic volumes and million vehicle-miles. For the purpose of determining hazardous location along a roadway, the road must be divided into the segments. In this study the road segment is divided into 0.5 mile each segments in both directions. Therefore 329 segments are considered for analyzing hazardous locations in each direction.

Accident Rate Method is the commonly used method for analyzing hazardous locations and ranking them in descending order through the use of the number of accidents to determine and prioritize accident prone spots which were estimated by counting the reportable accidents occurred in each road segment (Ratanavaraha & Watthanaklang, 2013). The total number of accident occurrence on a segment is related to the number of vehicles using the facility, therefore the accident rate is often calculated to allow for comparisons of different facilities (Preston, Barry & Stein, 2008; Transportation, 2014). Accident rate for each segment is defined as the number of accident per million vehicle miles. It can be calculated by the following Equation 1:

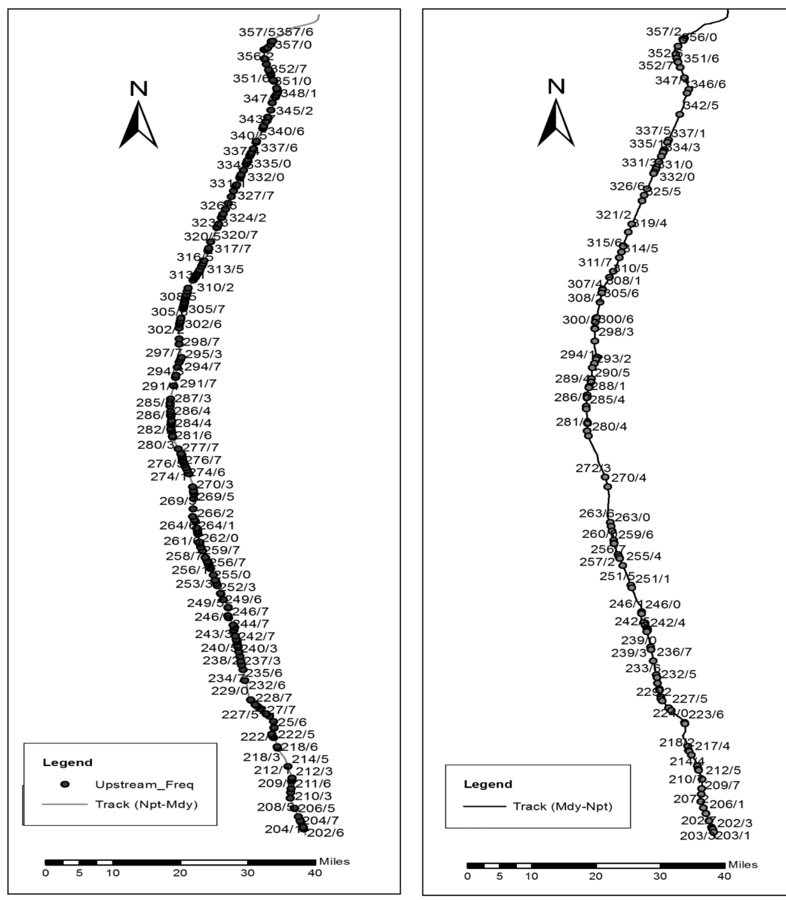


Figure 3. Accident Locations on the Naypyitaw-Mandalay Expressway from 2013-2015 (On both directions).

$$R = \frac{(A*1{,}000{,}000)}{(365*T*V*L)} \qquad \text{(Equation 1)}$$

Where,

R = accident rate for each segment (in accident per million vehicle-miles)

A = total number of accidents per each segment that occur during the study period

T = analysis time period (year)

V = average daily traffic (ADT) during the study period

L = length of segments (mile)

Quality Control Method, is the way of measuring accident risk spots on the roadway segments, the critical accident rate for each segment can be computed by using the following Equation 2 (Preston et al., 2008):

$$R_c = R_a + K\left[\frac{R_a}{\left(\frac{365*T*V*L}{1{,}000{,}000}\right)}\right]^{0.5} + \frac{0.5}{\left[\frac{365*T*V*L}{1{,}000{,}000}\right]} \qquad \text{(Equation 2)}$$

Where,

R_c = critical accident rate for each segment (number of accident per million vehicle-miles)

R_a = average accident rate for all segments

R_a = sum of accident rate (R) of each segment/ total number of segments in a particular state route

T = analysis time period (year)

V = average daily traffic (ADT) during the study period

L = length of segments (mile)

K = statistical rate factor with specified significance level (K = 1.645, for 95% confidence level)

Dangerous Factor (DF) is important to determine the hazardous locations on the roadway. All roadway segments will be ranked based on their Dangerous Factor (DF), if the value of the DF is greater than 1, these segments are considered as hazardous location (Garber & Hoel, 2015; Ratanavaraha & Amprayn, 2003; Ratanavaraha & Watthanaklang, 2013). Dangerous factor for road segments can be computed by using the following Equation 3 (Ratanavaraha & Watthanaklang, 2013):

$$DF = \frac{R}{R_c} \qquad \text{(Equation 3)}$$

Where,

R = accident rate method

R_c = quality control method

4.4 Results and Findings

The previous topic explained how to analyze and classify the hazardous locations on the expressway by using equation 1, 2 and 3. In accident analysis methods, a total of 329 segments in each lane are considered to identify hazardous locations. The dangerous factor (DF) is the key ingredient to location classifications (Ratanavaraha & Amprayn, 2003; Ratanavaraha & Watthanaklang, 2013). If their DF value is greater than 1, these roadway segments are classified as hazardous locations and the segments with DF less than 1 are classified as non-hazardous locations. Table 1 shows the analysis results of DF values to classify hazardous locations for all segments.

The finding based on analysis results of hazardous location on the expressway, in which 307 roadway segments on NPT-MDY direction and 315 segments on MDY-NPT direction are found as DF values less than 1, therefore these segments have been considered as non-hazardous locations. Moreover 22 segments on NPT-MDY direction and 14 segments on MDY-NPT direction are found as hazardous locations since their DF values greater than 1. Consequently, a segment with higher DF value is considered more hazardous than the one with a lower DF. The dangerous road segment locations and their accident numbers, average daily traffic (ADT) and dangerous factor (DF) values occurred in each segments on both lanes of the expressways are shown in Table 2. For the purpose of identifying the analysis result in Arc GIS, the databases have been prepared for each direction with their attributes. The hazardous roadway segments on upstream and downstream of the expressway are illustrated in Figure 4, and these hazardous locations are depicted as red color in arc map for both directions. General investigation based on hazardous road segments and accident records, the accident prone locations are occurred near entrance and exist of bridges, curve areas, upgrade, downgrade, lane-reduction transition (four- to two- lane road), roundabout and U-turn areas.

5. Conclusion and Recommendation

This research presents a methodology to identify hazardous locations on the expressway. Accident rate and quality control method are used as a statistical test method, which is very effective in identifying hazardous locations on the highway. According to the results, the inspection identified the most hazardous locations with 22 segments in Naypyitaw to Mandalay and 14 segments in Mandalay to Naypyitaw. Albeit only accident analysis method might be adequate to analyze hazardous locations, GIS application was also used to identify the significant of hazardous locations on the highway as a result in graphical map format. Geographic Information System is a very important and comprehensive management tool to display different type of spatial accident distribution on digital road network and many different data files such as map, text file and graphic can be interconnected to each other. GIS system helps the user to identify hazardous locations, obtain the accident location's ranking, quick access for obtaining information, data storage, output and integrity in a short period of time.

According to the analysis results and accident records, most of the hazardous locations are founded near exit and entrance of bridges, curve areas, upgrade, downgrade, near roundabout, and slippery road surface areas on both direction of the highway. Based on the findings of hazardous location analysis, the authors would like to propose to improve the roadway facilities, such as installation of warning signs to warn drivers to get a caution, speed detector, drainage repairs and fencing to prevent people, animals and vehicles entering from local road on both side of the whole expressway. Deficient slippery areas should be provided with surface treatment such as chip seal, or overlaying a new layer of asphalt. Moreover shoulder rumble strip should be installed, which is renowned as a safety device for alerting drivers and to prevent run-off-road accidents (Ratanavaraha & Jomnonkwao, 2015).

Since the main problem of traffic accident analysis is the data collection, it is very important to improve the method of collecting data and the methodology of processing these data. The accuracy and comprehensiveness of the traffic accident report is very important for inputting data and spatial analysis for improving traffic safety analysis. It is recommended that the accident reports and accident database systems should be accurate, detailed,

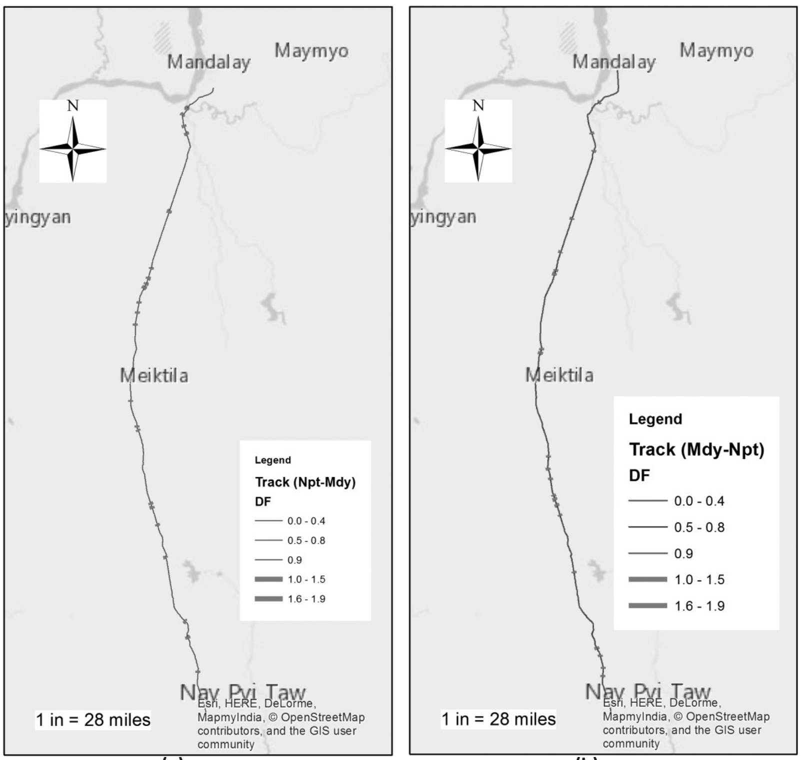
Table 1. Results of hazardous location analysis using Accident Rate and Quality Control Methods on both lanes.

Naypyitaw - Mandalay Direction				Mandalay - Naypyitaw Direction			
No of Accident	ADT	DF	No of Segment	No of Accident	ADT	DF	No of Segment
5 to 7	1729 - 2519	1.9	2	4	1962	1.9	1
4 to 5	1729 - 2083	1.6	3	3	1962	1.4	3
4	2083	1.3	1	2	1476	1.2	9
3	1729	1.2	7	3	2408	1.1	1
4	2519	1.1	2	2	1962	0.9	11
3	2083	1	7	2	2408	0.8	1
2	1729	0.8	19	1	1476	0.6	32
2	2083	0.7	25	1	1962	0.5	36
2	2519	0.5	2	1	2408	0.4	5
1	1729	0.4	44	0	1476 - 2408	0	230
1	2519 - 2083	0.3	51				
0	1729 - 2083	0	166				

Table 2. Hazardous locations and their accident numbers, average daily traffic (ADT) and dangerous factor (DF) values on upstream and downstream of the expressway.

Naypyitaw – Mandalay (Upstream)					Mandalay – Naypyitaw (Downstream)				
No	Location (Mile/ Furlong)	No of Accident	ADT	DF	No	Location (Mile/ Furlong)	No of Accident	ADT	DF
1	316/1 - 316/4	5	1729	1.9	1	246/3 - 246/0	4	1962	1.9
2	352/5 - 353/0	7	2519	1.9	2	257/7 - 257/4	3	1962	1.4
3	275/1 - 275/4	5	2083	1.6	3	243/3 - 243/0	3	1962	1.4
4	282/5 - 283/0	5	2083	1.6	4	214/7 - 214/4	3	1962	1.4
5	311/1 - 311/4	4	1729	1.6	5	351/7 - 351/4	2	1476	1.2
6	276/1 - 276/4	4	2083	1.3	6	335/3 -335/0	2	1476	1.2
7	301/5 - 302/0	3	1729	1.2	7	332/3 - 332/0	2	1476	1.2
8	304/5 - 305/0	3	1729	1.2	8	331/3 -331/0	2	1476	1.2
9	307/1 - 307/4	3	1729	1.2	9	316/7 - 316/4	2	1476	1.2
10	312/1 - 312/4	3	1729	1.2	10	308/3 - 308/0	2	1476	1.2
11	313/5 - 314/0	3	1729	1.2	11	301/7 - 301/4	2	1476	1.2
12	330/5 - 331/0	3	1729	1.2	12	300/7 - 300/4	2	1476	1.2
13	350/5 - 351/0	3	1729	1.2	13	289/7 - 289/4	2	1476	1.2
14	355/5 -356/0	4	2519	1.1	14	352/7 - 352/4	3	2408	1.1
15	357/5 - 358/0	4	2519	1.1					
16	212/1 - 212/4	3	2083	1					
17	221/1 - 221/4	3	2083	1					
18	225/5 - 226/0	3	2083	1					
19	242/5 - 243/0	3	2083	1					
20	251/1 - 251/4	3	2083	1					
21	255/5 - 256/0	3	2083	1					
22	256/5 - 257/0	3	2083	1					

formatted and updated yearly. Instead of a documentary reporting system, GPS and GIS should be integrated into a new coded reporting system, in order to help for improving the hazardous areas. Moreover the important of accident reports must be explained to the highway polices and if necessary training for the police should be held as soon as possible.



(a) (b)

Figure 4. Hazardous Locations on (a) upstream and (b) downstream of the Expressway (Dangerous Factor ≥ 1).

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References

Apparao, G., Mallikarjunareddy, P. & Raju, S. G. (2013). Identification of accident black spots for national highway using GIS. *International Journal of Scientific and Technology Research, 2*(2), 154-157.

Eck, J. E. & David, W. (1995). Crime places and crime theory. *Crime and Place, 4*, 1-33.

Erdogan, S., Yilmaz, I., Baybura, T. & Gullu, M. (2008). Geographical information systems aided traffic accident analysis system case study: City of afyonkarahisar. *Accident Analysis and Prevention Journal, 40*, 174-181.

Garber, N. J. & Hoel, L. A. (2015). *Traffic and highway engineering (Vol. 5th Edition)*. United States of America.

Hirasawa, M. & Asano, M. (2003). Development of traffic accident analysis system using GIS. Proceedings of the Eastern Asia Society for *Transportation Studies, 4*, 1193-1199.

Iamtrakul, P. & Raungratanaamporn, I. (2015). Sustainable campus town development in suburban area of Bangkok, Thailand. *International Journal of Building, Urban, Interior and Landscape Technology, 6*, 39-52.

Jayan, K. D. & Ganeshkumar, B. (2010). Identification of accident hot spots: A GIS based inplementation for kannur district, Kerala. *International Journal of Geomatics and Geosciences, 1*(1), 51-59.

Kim, K. & Levine, N. (1996). Using GIS to improve highway safety. *Computer environment and Urban Systems Journal, 20(4/5)*, 289-302.

Kowtanapanich, W. (2007). Black spot identification method in Thailand. *Thai Academic Journa*l, 126-134.

Preston, H., Barry, M. & Stein, W. (2008). *Traffic safety fundamental handbook*. MinnesotaDepartmentofTransportation: Office of Traffic, Safety and Technology.

Ratanavaraha, V. & Amprayn, C. (2003). Causative highway accident factors of the expressway system in Thailand. *Journal of the Eastern Asia Society for Transportation Studies, 5*, 2422-2429.

Ratanavaraha, V. & Jomnonkwao, S. (2015). The efficiency testing of Shoulder Rumble Strips (SRS) on noise for alerting drivers in Thailand: A comparison among three types of SRS. *Advance in Transportation Studies an International Journal, Section B36*, 109-118.
Ratanavaraha, V. & Watthanaklang, D. (2013). Road safety audit: Identification of bus hazardous location in Thailand. *Indian Journal of Science and Technology, 6*(8), 5126-5133.
Saleh, S. (2014). Geographical Information System [GIS]-based analysis of road traffic accident blackspots in Federal Capital Territory [F.C.T]. *Journal of Traffic and Logistics Engineering, 2*(2), 108-112.
Transportation, O. D. O. (2014). *Analysis procedure manual* (Vol. Version 2). Salem, Oregon.
World Health Organization [WHO]. (2015a). *Global status report on road safety 2015*. Switzerland: WHO Press.
World Health Organization [WHO]. (2015b). *Road safety in Myanmar*. Retrieved from http://www.searo.who.int/myanmar/areas/roadsafety_datacollection/en/
Yakar, F. (2015). Identification of accident-prone road sections by using relative frequency method. *Traffic and Transportation, 27*(6), 539-547.