APPLICATION OF GIS TO TRAFFIC ACCIDENT ANALYSIS: CASE STUDY OF NAYPYITAW-MANDALAY EXPRESSWAY IN MYANMAR

Kyaw Zin Htut

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Transportation

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การประยุกต์ใช้ระบบจีไอเอสสำหรับการวิเคราะห์อุบัติเหตุทางถนน กรณีศึกษาของทางด่วนสายเนปิดอว์-มัณฑะเลย์ ของสาธารณรัฐแห่งสหภาพเมียนมาร์

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

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โจว ซิน ทูป : การประยุกต์ใช้ระบบจีไอเอสสำหรับการวิเคราะห์อุบัติเหตุทางถนน กรณีศึกษาของทางด่วนสายเนปิดอว์-มัณฑะเลย์ ของสาธารณรัฐแห่งสหภาพเมียนมาร์ (APPLICATION OF GIS TO TRAFFIC ACCIDENT ANALYSIS: CASE STUDY OF NAYPYITAW-MANDALAY EXPRESSWAY IN MYANMAR) อาจารย์ที่ปรึกษา : รองศาสตราจารย์ ดร.วัฒนวงศ์ รัตนวราห, 70 หน้า

อุบัติเหตุทางถนนในสาธารณรัฐแห่งสหภาพเมียนมาร์ส่งผลให้อัตราผู้เสียชีวิตมีจำนวนมากขึ้นในปี พ.ศ. 2556 ข้อมูลจากองค์กรอนามัยโลก แสดงให้เห็นว่าถนนในสาธารณรัฐแห่งสหภาพเมียนมาร์มีความอันตรายเป็นลำดับที่สองในเอเชียตะวันออกเฉียงใต้ รองจากประเทศไทย อุบัติเหตุทางถนนถือเป็นปัญหาหลักด้านสุขภาพและคาดว่าจะเพิ่มขึ้นหากยังไม่มีการจัดการภายในประเทศที่ดีพอ ดังนั้นจึงมีความจำเป็นต้องมีการศึกษาเรื่องอุบัติเหตุทางถนนทั้งในสาธารณรัฐแห่งสหภาพเมียนมาร์และประเทศอื่นๆ

งานวิจัยนี้ได้ทำการวิเคราะห์อุบัติเหตุทางถนนที่เกิดขึ้นระหว่างปี พ.ศ. 2556 ถึง 2558 บนทางด่วนสายเนปิดอว์-มัณฑะเลย์ โดยมีวัตถุประสงค์เพื่อที่จะศึกษาเกี่ยวกับการประยุกต์ใช้วิธีการที่หลากหลายในการระบุช่วงอันตรายบนทางด่วน ในส่วนแรกของงานวิจัยได้ทำการวิเคราะห์อุบัติเหตุเพื่อระบุช่วงอันตรายของทางด่วน โดยแบ่งทางด่วนออกเป็นช่วงละ 0.5 ไมล์ ซึ่งจะทำให้ได้ทั้งหมด 329 ช่วงเพื่อใช้ในการวิเคราะห์ช่วงอันตราย ผลจากการวิเคราะห์แสดงให้เห็นว่ามี 22 ช่วงในส่วนต้นของถนน (Upstream) และ 14 ช่วงในส่วนปลายของถนน (Downstream) เป็นช่วงทางด่วนที่อันตราย

ส่วนที่สองของงานวิจัยเป็นการประเมินกลุ่มของอุบัติเหตุ และระบุความสอดคล้องกับความรุนแรงของการบาดเจ็บ งานวิจัยในส่วนนี้มีการประยุกต์ใช้การคาดการณ์ความหนาแน่นของเคอร์เนลในการวิเคราะห์ ผลจากการวิเคราะห์แสดงให้เห็นว่ามี 5 กลุ่มที่อันตรายมากที่สุดอยู่ในส่วนต้นของทางด่วนสายเนปิดอว์-มัณฑะเลย์ (Upstream) และ 2 กลุ่มในส่วนปลายของถนน (Downstream) จะมีความอันตรายมากที่สุด

ส่วนที่สามใช้สถิติ Getis-Ord Gi* อธิบายความอันตรายของพื้นที่และระบุความรุนแรงของอาการบาดเจ็บของพื้นที่เหล่านั้นบนถนน ผลจากการวิเคราะห์พบว่า ส่วนที่มีการบาดเจ็บ และเป็นอุบัติเหตุเล็กน้อยที่เกิดขึ้นจะกระจายตัวอยู่ในส่วนต้นของทางด่วน (Upstream) ในขณะที่ส่วนปลายของทางด่วน (Downstream) การเกิดการบาดเจ็บและอุบัติเหตุเล็กน้อยจะอยู่ในส่วนท้ายของถนนโดนสรุปแล้วการวิเคราะห์ด้วยเทคนิคที่หลากหลายแสดงให้เห็นถึงส่วนต้นของทางด่วนสายเนปิดอว์-มัณฑะเลย์ (Upstream) จะมีตำแหน่งที่อันตรายมากกว่าส่วนปลาย (Downstream)

ของทางด่วนดังนั้นข้อมูลของอุบัติเหตุและเทคนิคด้าน GIS มีประสิทธิ์ภาพที่จะสามารถนำมาประยุกต์สำหรับระบุช่วงอันตรายของตำแหน่งทางด่วนสายเนปิดอว์-มัณฑะเลย์ได้

สาขาวิชา วิศวกรรมขนส่ง ลายมือชื่อนักศึกษา____________

ปีการศึกษา 2559 ลายมือชื่ออาจารย์ที่ปรึกษา ____________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ____________

KYAW ZIN HTUT : APPLICATION OF GIS TO TRAFFIC ACCIDENT ANALYSIS: CASE STUDY OF NAYPYITAW-MANDALAY EXPRESSWAY IN MYANMAR. THESIS ADVISOR : ASSOC. PROF. VATANAVONGS RATANAVARAHA, Ph.D., 70 PP.

TRAFFIC ACCIDENTS/GEOGRAPHIC INFORMATION SYSTEM (GIS)/ ACCIDENT ANALYSIS METHODS/KERNEL DENSITY ESTIMATION/ GETIS-ORD GI* STATISTIC

Myanmar's road accidents related to deaths have increased since 2013. According to WHO figures, Myanmar's road and highway were the second-deadliest in Southeast Asia after Thailand's. Road traffic accident is a major problem of public health and is expected that it will increase if countries do not treat the road safety properly. Therefore, road traffic accident is an increasingly important phenomenon that needs to be studied either in Myanmar or in any other country.

This research analyzed the road traffic accidents that occurred during the 2013-2015 period in Naypyitaw-Mandalay expressway. The primary objective of this research is to discuss the applicability of different methods and definitions for hazardous road locations identification and their respective results. In the first section of the related chapter, accident analysis methods are used to identify the hazardous locations on the expressway. For the consideration of these methods, the road length is divided into 0.5 mile in each segment on both directions and 329 segments are analyzed hazardous locations. According to the analysis results, 22 segments on upstream and 14 segments on downstream of the expressway are found as hazardous locations.

The second research evaluated the clusters of traffic accidents and identified them according to their severity. Kernel density estimation is a spatial analysis technique, used in this study to identify the clusters of road accidents on both direction of the expressway. As a result show that, there are five most dangerous sections on Naypyitaw-Mandalay (upstream), while there are two most dangerous sections on the Mandalay-Naypyitaw expressway (downstream) respectively.

The third section used Getis-Ord Gi∗ statistics to explore dangerous areas and to identify the severity of those areas on the expressway. According to the results of this section, injury and light accident are occurred scattering along upstream of the expressway, while the downstream occurred injury and light accidents are clustering happened at the end of the expressway.

In conclusion, result of different technique showed that the upstream (Naypyitaw-Mandalay) of the expressway have more several dangerous locations than the downstream (Mandalay-Naypyitaw) of the expressway. Therefore, accident spatial data and GIS technique are efficient approach for identification of hazardous road location on the Naypyitaw-Mandalay expressway.

School of Transportation Engineering — Student's Signature ________________

Academic Year 2016 — Advisor's Signature ________________

Co-Advisor's Signature ______________

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SYMBOLS AND ABBREVIATIONS

WHO	=	World Health Organization
GIS	=	Geographic Information System
GPS	=	Global Positioning System
DF	=	Dangerous Factor
KDE	=	Kernel Density Estimation
NPT-MDY	=	Naypyitaw-Mandalay
ADT	=	Average Daily Traffic
Gi*	=	Getis-Ord Gi statistics

CHAPTER I

INTRODUCTION

1.1 General

Traffic accidents have been recognized as one of the major causes of human and economic losses, both in developed and developing countries. According to the World Health Organization Global Status Report on Road Safety 2015, road traffic accidents are predicted to become the 7th leading cause of death by 2030. About 1.25 million people died and approximately (20-50 million) people injured every year due to traffic accidents. Around 90% of road traffic deaths occur in low- and middle-income countries (Organization, 2015a). In Myanmar, the numbers of deaths related to road accident has increased since 2013. According to WHO figures, road and highway in Myanmar are the second-deadliest in Southeast Asia after Thailand, with 20.3 deaths per 100,000 people, or more than 10,000 nationwide in 2015 (Organization, 2015b). For the implementation of accident reduction, it is very important to analyze the hazardous road locations.

Road accident analysis concerns the management aspect of a road traffic system, just like those of traffic flow management, highway safety management, and road infrastructure maintenance. This management combines to ensure the well function of the road networks. Road accident analysis is therefore undertaken for a better understanding on why are road-related accidents. The identification of high probability accident areas is an important issue of traffic safety programs, because precautions and infrastructure assessments can be prioritized at these locations to make more efficient source allocations. Such areas are called “black spots” in highway safety literature and generally have some clearly defined methods to detect.

This research proposes the use of Geographic Information Systems (GIS) technology on traffic accident analysis and particularly it will highlight how GIS can be applicable on accident analysis with different tools in the ArcGIS software. Since 1990’s, GIS has been used in the field of transportation (Erdogan, S. Yilmaz, I. Baybura, & T. Gullu, 2008) and it has the ability to organize the various types of data and maps that can be easily stored, shared and manipulated.

1.2 Study area

The road network of a country is playing an important role in economic and social policy. Myanmar is still a developing country; highway transportation is very important for transporting of people and goods from one place to another. The study area, Naypyitaw-Mandalay expressway (one section of Yangon-Mandalay expressway) is the first and only one expressway in Myanmar.

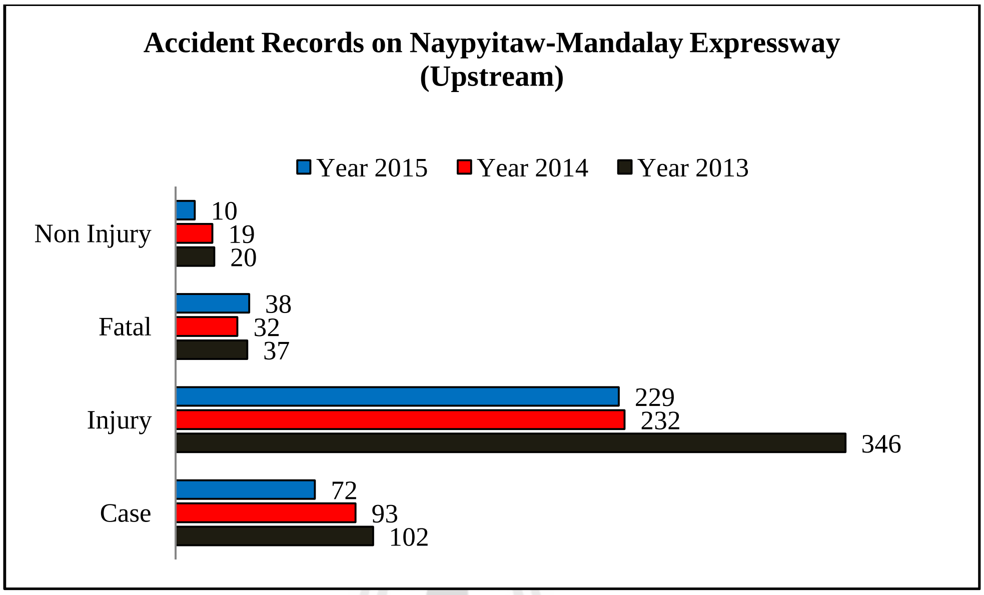
Naypyitaw is the Capital and administrative city of Myanmar. It is also a junction point connecting to the developed cities. Mandalay is the second largest city and economic hub of upper Myanmar. Naypyitaw-Mandalay expressway is connected to these two major cities and has a length of 164.25 miles (265km). According to the accident data collected from Ministry of Construction and Highway Police Station in Naypyitaw, this highway has the highest accident rate in the country. There were totally 398 accidents on upstream and downstream of the expressway within 3 years from 2013 to 2015.The study area, Naypyitaw–Mandalay Expressway, lies between

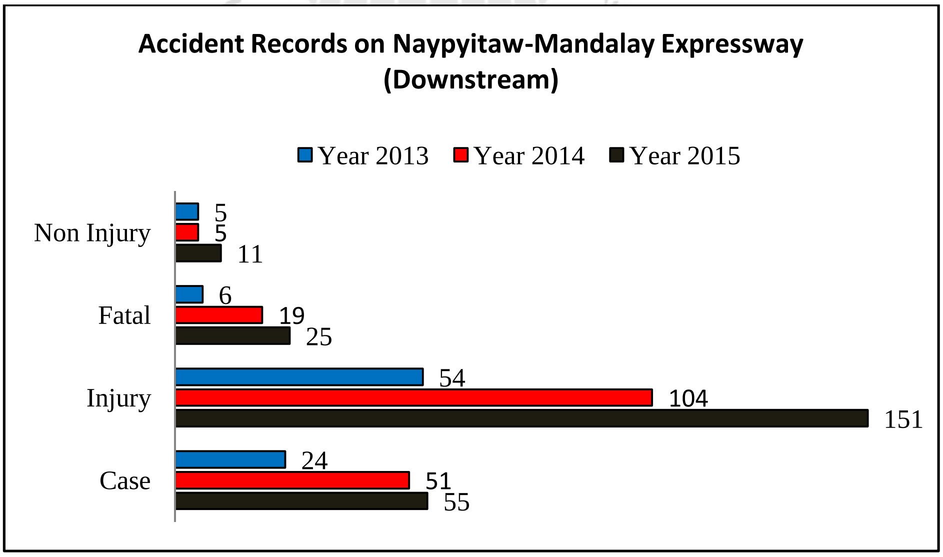
19°39’40.8”N to 21°53’55.6”N Latitude and 96°03’25.1”E to 96°05’10.0”E Longitude.

1.3 Problem statement

Statistics from the Ministry of Transport and Communications in Naypyitaw reveal that, in 2013 to 2015, there were 44, 585 accidents in the whole country while 398 accidents on Naypyitaw-Mandalay expressway, albeit the accident severity value on the expressway have 3.2 higher than the whole country is 1.95. There were totally 157 people died, 1,116 people injured and 70 relating to damage for both directions of highway within three years from 2013 to 2015. Figure 1.1 and 1.2 are accident records of 2013, 2014 and 2015 that were identify the number of accident, number of severity and property damage on both direction of the expressway within three years. With the poor provision of the road furniture and the exceeding speed limit, loads of car accidents have occurred frequently on this expressway. That is why new methodologies for analyzing road traffic accident safety should be developed to create faster solutions in the vulnerable locations.

Nowadays, GIS has become one of the most used programs in various project and research areas such as engineering, surveying, economics, business, geology, etc. It is considered to have a potential in transportation engineering applications because ArcGIS can give us the option to create new tools by programming with different languages in addition to the commands that are already present in the ArcGIS software package itself. A development of a safety analysis application can give us the option of performing a safety study within a short time period and with a higher accuracy. Moreover, GIS can relate crash data to maps so it could be much easier for


Accident Records on Naypyitaw-Mandalay Expressway
(Upstream)
Year 2015
Year 2014
Year 2013
Non Injury
10
19
20
Fatal
38
32
37
Injury
229
232
346
Case
72
93
102


Accident Records on Naypyitaw-Mandalay Expressway
(Downstream)
Year 2013
Year 2014
Year 2015
Non Injury
5
5
11
Fatal
6
19
25
Injury
54
104
151
Case
24
51
55

1.4 Research background – GIS and road accident analysis

Geographic or spatial data usage plays an important role on many fields of daily life. Usage of spatial data required selection and manipulation of them correctly. GIS has an important role, it is a tool which provides collection, storage, manipulation, query, analysis and visualization of the spatial data (Lloyd, 2010).

Geographic location gives information about accidents more than their coordinates. Accident occurrence at the same place or nearby places could be the indicator of causes of accidents. For this reason, traffic accidents should be analyzed with their coordinates. With the help of spatial analysis tools, high crash occurrence areas could be clearly identified. In order to understand causes of accidents, improve traffic safety, and hazardous location analyses have an important role. Hazardous location can be explained as the highly incident occurrence areas.

One of the most important problems is that traffic official face is where and how to implement precautionary measures and provisions so that they can have the most significant impact for traffic safety (Khan, Qin, & Noyce, 2008). GIS is a very important and comprehensive management tool for traffic safety. In the traffic safety analysis, GIS can visualize the locations of accidents and store the attributes of accidents (i.e. time of accident, number of injuries/ fatalities, characteristics of roads that accidents occur, land use characteristic, etc).

Recently, many studies related with traffic safety analysis have been performed with the help of GIS. The type of analysis applicable for accident analysis, include intersection analysis, segment analysis, cluster analysis, density analysis, pattern analysis, proximity analysis, spatial query analysis and spatial accident analysis modeling techniques. Different types of spatial analysis methods based on point, segments and zones analysis had been developed.

1.5 Scope and objective of the study

The application of geographic information system in road traffic accident analysis is not widely available in Myanmar. How can GIS help in road accident analysis? It is known that geographic data (i.e. road location where an accident has occurred) is a major component of road accident data. The distinctive power of GIS is the ability to match the geographic or location specific data with the relevant attributes (such as severity or number of injury in the accident). The matching of these types of data forms the basis for mapping the results.

The advantages in GIS and GPS can be put to effective use in accident analysis. GIS is a technology for managing, analysing, exploring spatial data and related information in a less time period (Apparao, Mallikarjunareddy, & Raju, 2013; Erdogan et al., 2008). It provides a platform for data analysis and visualization to explore relationships between data and it can easily provide graphical or non-graphical outputs. Spatial data and its analysis is one of the most information for traffic accident analysis. GIS aids spatial data and spatial analysis to provide a lot of information to analysis about hazardous locations, hot spots and black spots area.

This research focuses to demonstrate new means of displaying road traffic accident data on Naypyitaw-Mandalay expressway through accident analysis methods and the use of GIS technology. The proposed approach will be contributed toward an increased efficiency in road accident analysis and management of a safety action plan in the future. The objective of this thesis is summarized below.

1. To identify the hazardous road locations and visualize the accident data by using accident analysis method.
2. To examine the spatial clustering of accident locations along the expressway by using spatial analysis tools in ArcGIS program.
3. To explore dangerous areas on the expressway and to identify the severity of those areas by applying Getis-Ord Gi* analysis in the ArcGIS.

1.6 Thesis organization

The rest of this thesis is organized by five chapters. The introductory chapter gives a brief description of the study area, research background, problem statement, the scope and objectives of the research. This chapter provides a preliminary understanding on road accident data and the possibility of applying geographic information system on its analysis.

Chapter two describes the application of geographic information system (GIS) in traffic safety and accident analysis methods used to identify the hazardous locations. Accident rate and quality control methods are applied for calculating the dangerous factor (DF) and ranking of hazardous location.

Chapter three presents the used of kernel density estimations methods in Arc GIS for identifying the spatial clustering of road traffic accidents on the expressway. It is a description of the tools developed in the current study and their uses.

Chapter four proposes a procedure which evaluates hotspots of traffic accident on the expressway by using Getis-Ord Gi* statistic in GIS program. This technique shows the potential causes of accidents by their severity. This study is extremely beneficial to the relevant highway traffic organizations to consider safety improvements, either strategies or practices, on Naypyitaw-Mandalay expressway.

A general conclusion will be summarizes in chapter five. Benefits and recommendation of the research will be interpreted and it is the final suggestion on the present road accident analysis on Naypyitaw-Mandalay expressway, Myanmar will be highlighted.

1.7 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.

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.

Khan, G., Qin, X., & Noyce, D. A. (2008). **Spatial Analysis of Weather Crash Patterns.** *Journal of Transportation Engineering, 134*(5), 191-202.

Lloyd, C. D. (2010). ***Spatial Data Analysis: An Introduction for GIS Users*.** Oxford University Press.

Organization, W. H. (2015a). *Global Status Report on Road Safety*

Organization, W. H. (2015b). **Road Safety in Myanmar.** Retrieved from website http://www.searo.who.int/myanmar/areas/roadsafety_datacollection/en/

CAHPTER II

APPLICATION OF GIS TO TRAFFIC ANNIDENT ANALYSIS: CASE STUDY OF NAYPYITAW-MANDALAY EXPRESSWAY (MYANMAR)

2.1 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.

2.2 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 (Organization, 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 (Organization, 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. 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.

2.3 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.

2.4 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 (265km). 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.

2.5 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 2.1).

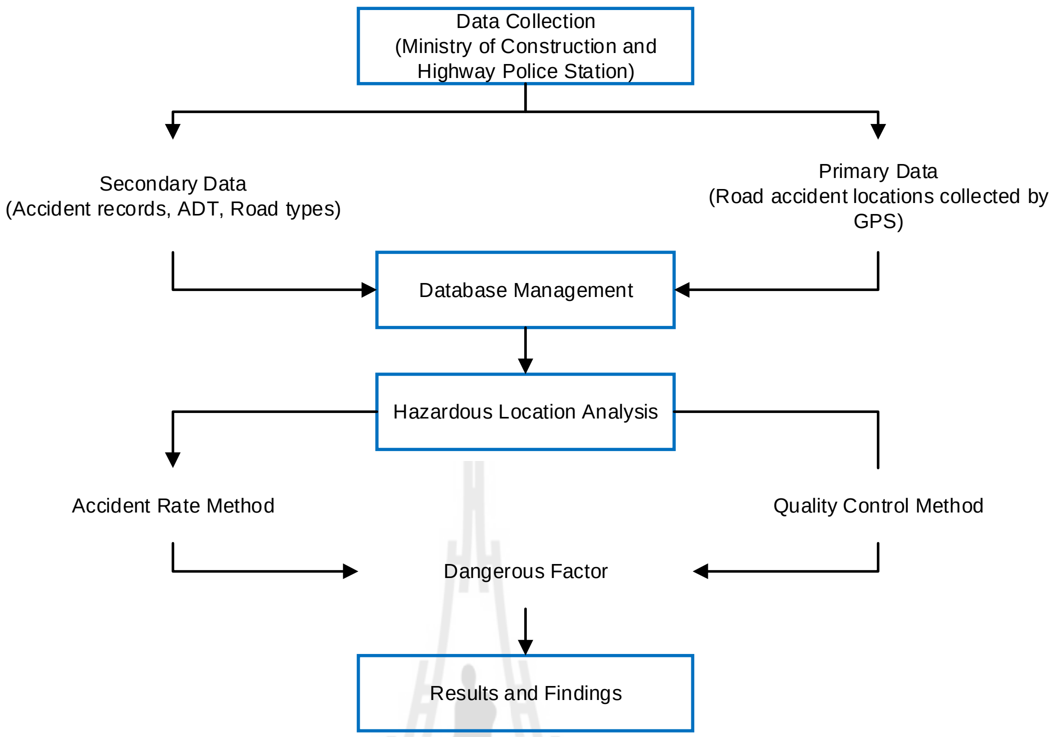
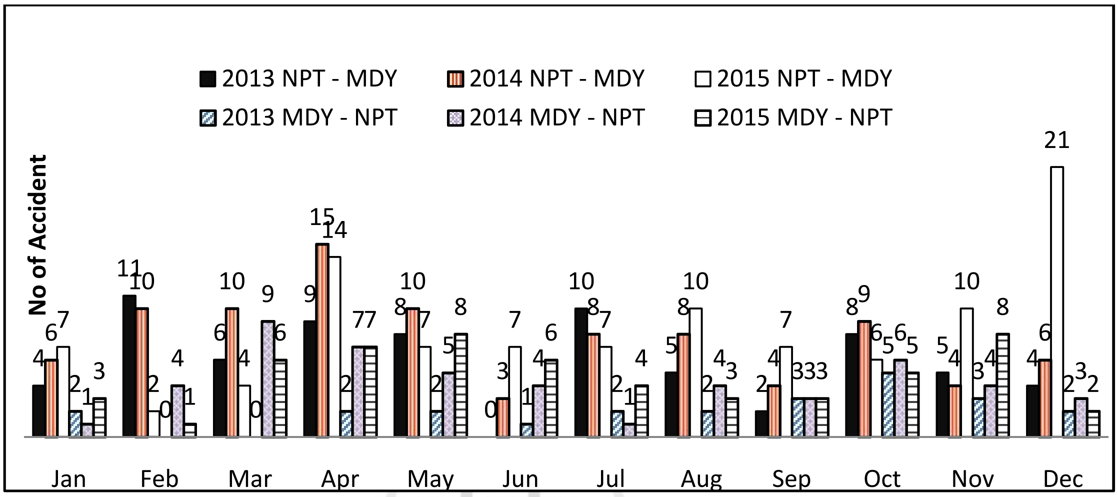


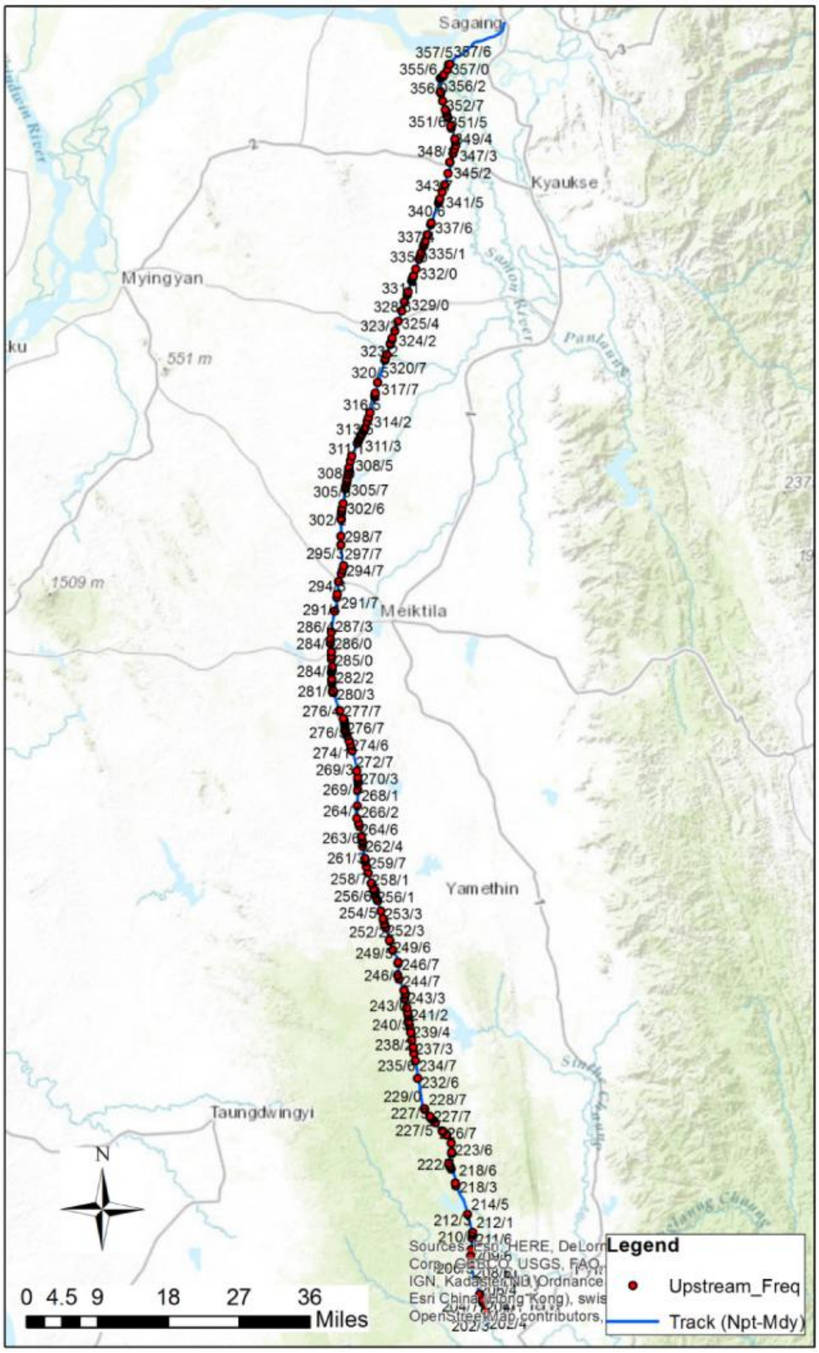
Figure 2.1 Research methodology.

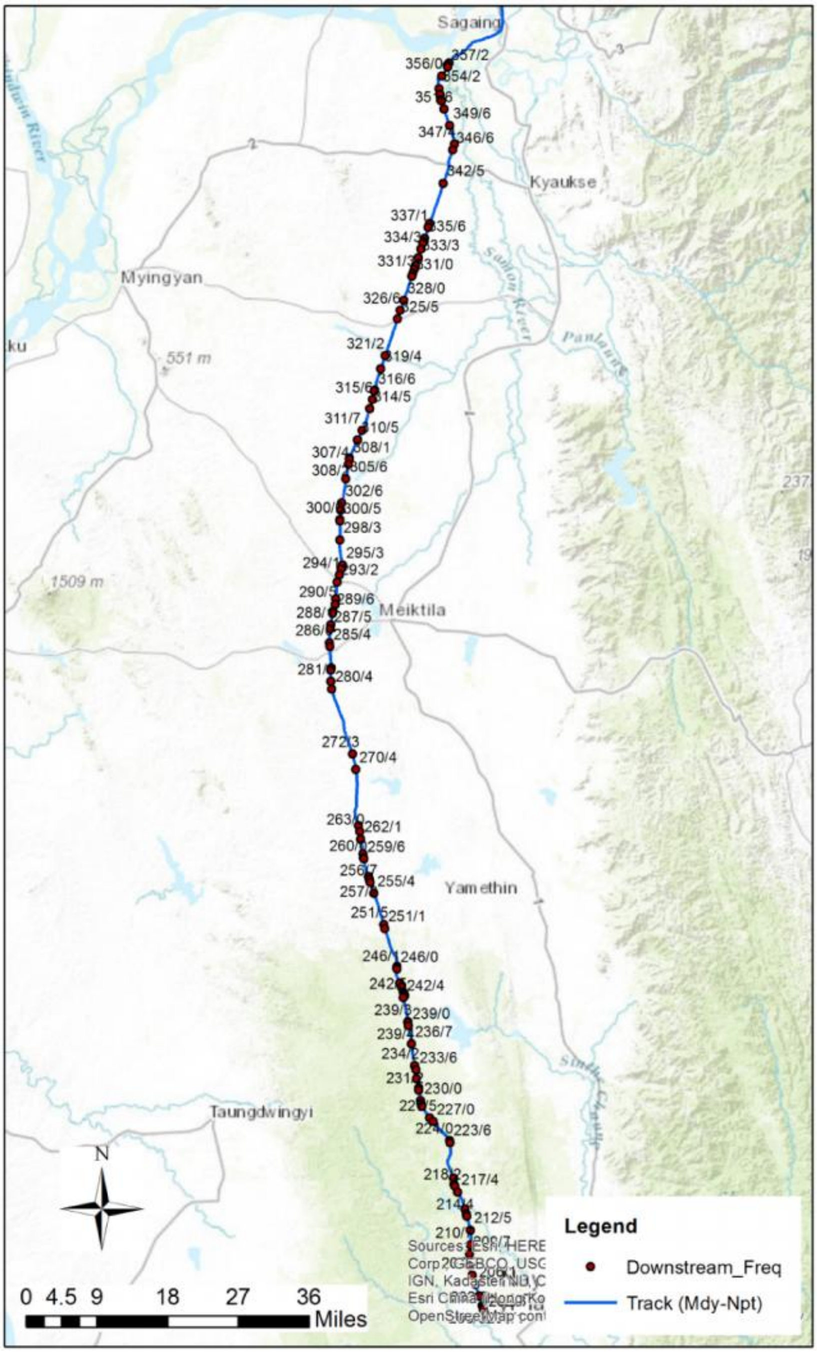
2.5.1 Data collection

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.



2013 NPT - MDY
2014 NPT - MDY
2015 NPT - MDY
2013 MDY - NPT
2014 MDY - NPT
2015 MDY - NPT
No of Accident
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Sagaing
Kyaukse
Myingyan
Meiktila
Yamethin
Taungdwingyi
Legend
Upstream_Freq
Track (Npt-Mdy)
0 4.5 9 18 27 36
Miles
N



Sagaing
Kyaukse
Myingyan
551 m
1509 m
Meiktila
Yamethin
Taungdwingyi
357/2
356/0
354/2
349/6
347/
346/6
342/5
337/1
335/6
334/3
333/3
331/0
328/0
326/6
325/5
321/2
319/4
316/6
315/6
314/5
311/7
310/5
307/4
308/1
305/6
302/6
300/5
298/3
295/3
294/1
293/2
290/5
289/6
288/
287/5
286/
285/4
281/
280/4
272/3
270/4
263/0
262/1
260/
259/6
256/7
255/4
257/
251/5
251/1
246/1
246/0
242/4
239/0
236/7
233/6
230/0
227/0
223/6
218/
217/4
212/5
N
0 4.5 9 18 27 36
Miles
Legend
Downstream_Freq
Track (Mdy-Npt)

2.5.3 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 estimatedby 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 2.1,

$$R = \frac{(A \times 1000000)}{(365 \times T \times V \times L)} \qquad (2.1)$$

Where, R is the accident rate for each segment (in accident per million vehicle-miles), A is total number of accidents per each segment that occur during the study period, T is analysis time period (year), V is average daily traffic (ADT) during the study period, L is 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 2.2 (Preston et al., 2008),

$$R_C = R_a + K\left[\frac{R_a}{\left(\frac{365 \times T \times V \times L}{1000000}\right)}\right]^{0.5} + \frac{0.5}{\left[\frac{365 \times T \times V \times L}{1000000}\right]} \tag{2.2}$$

Where, R_c is the critical accident rate for each segment (number of accident per million vehicle-miles), R_a is the average accident rate for all segments, R_a is the sum of accident rate (R) of each segment/ total number of segments in a particular state route, T is analysis time period (year), V is average daily traffic (ADT) during the study period, L is length of segments (mile), K is the 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 2.3 (Ratanavaraha & Watthanaklang, 2013).

$$DF = \frac{R}{R_C} \qquad (2.3)$$

Where, R is accident rate method, and R_c is the quality control method.

2.5.4 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 2.1 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.

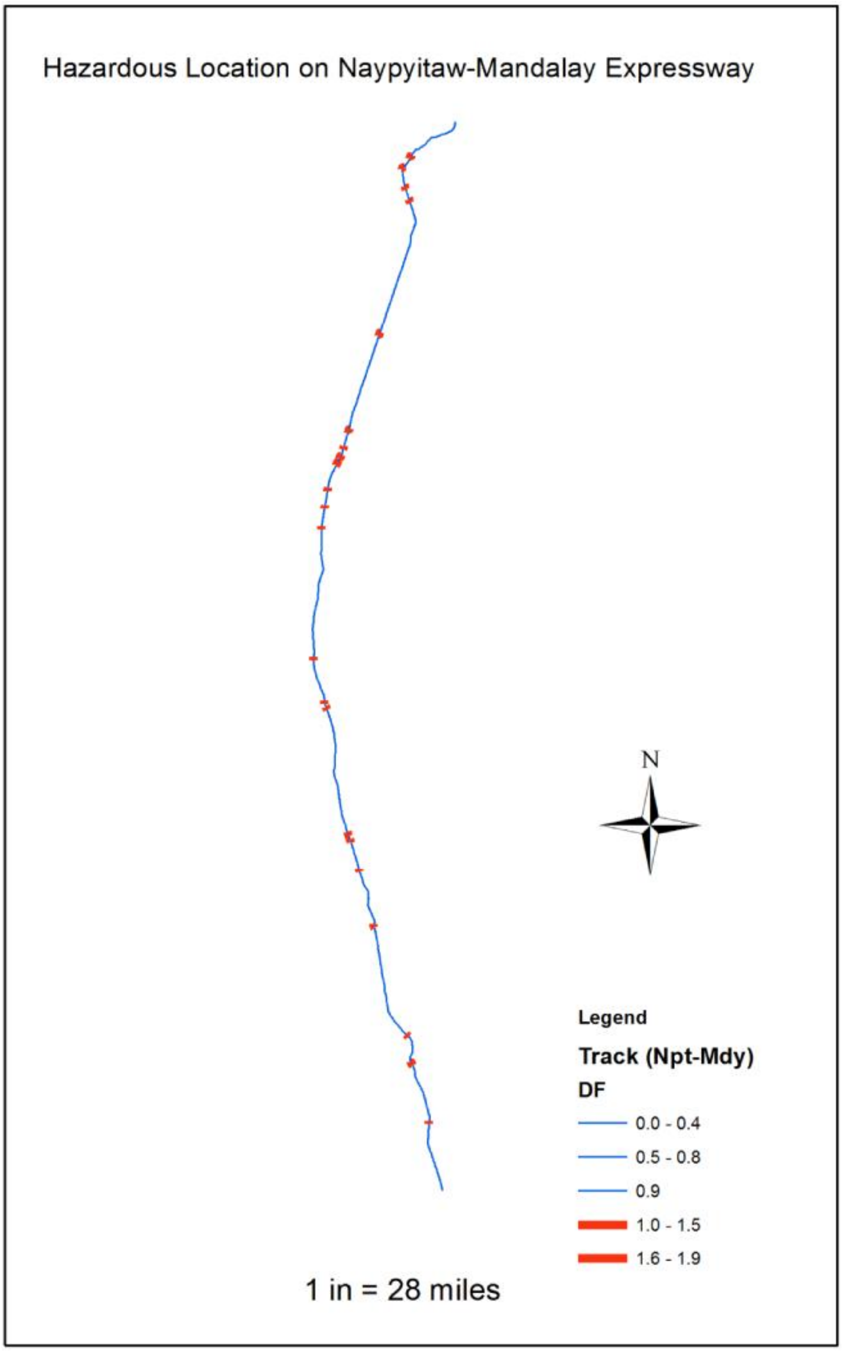
Table 2.1 Dangerous factor (DF) values for all segments based on Accident Rate and Quality Control Methods.

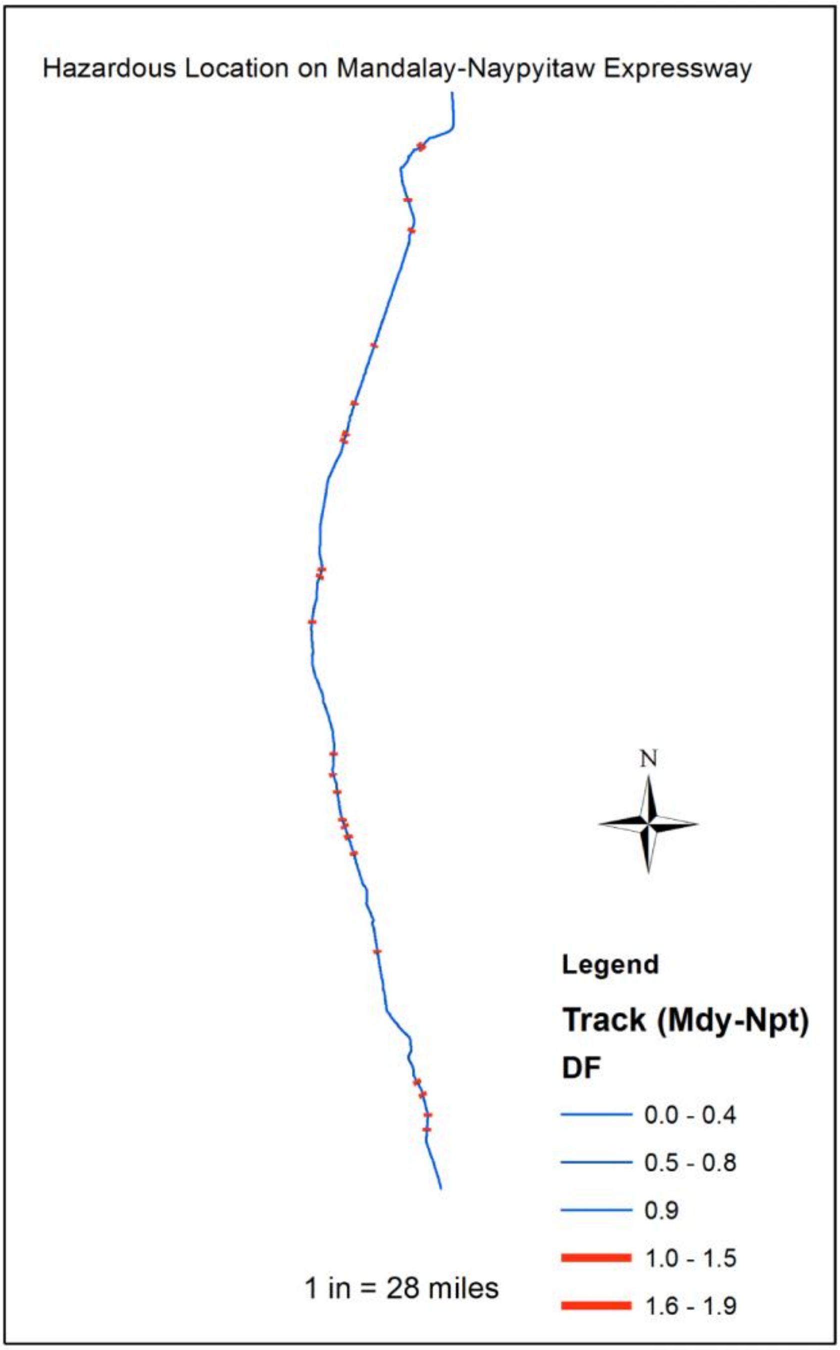
Naypyitaw-Mandalay Direction (Upstream)				Mandalay-Naypyitaw Direction (Downstream)			
No of Accident	**ADT**	**DF**	**No of Segment**	**No of Accident**	**ADT**	**DF**	**No of Segment**
5 to 7	1729 - 2519	1.9	2	4	1962	1.9	1
4 to 5	1729 - 2083	1.6	3	3	1962	1.4	3
4	2083	1.3	1	2	1476	1.2	9
3	1729	1.2	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				

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 2.2. 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 2.5 and 2.6, 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.

Table 2.2 Finding of hazardous locations based on dangerous factor (DF) on upstream and downstream of Naypyitaw-Mandalay expressway.

Naypyitaw-Mandalay Direction (Upstream)					Mandalay- Naypyitaw Direction (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					


Hazardous Location on Naypyitaw-Mandalay Expressway
N
Legend
Track (Npt-Mdy)
DF
0.0 - 0.4
0.5 - 0.8
0.9
1.0 - 1.5
1.6 - 1.9
1 in = 28 miles


Hazardous Location on Mandalay-Naypyitaw Expressway
N
Legend
Track (Mdy-Npt)
DF
0.0 - 0.4
0.5 - 0.8
0.9
1.0 - 1.5
1.6 - 1.9
1 in = 28 miles

2.6 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, 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.

2.7 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.

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 Journal*, 126-134.

Organization, W. H. (2015a). *Global Status Report on Road Safety*.

Organization, W. H. (2015b). **Road Safety in Myanmar**. Retrieved from http://www.searo.who.int/myanmar/areas/roadsafety_datacollection/en/

Preston, H., Barry, M., & Stein, W. (2008). ***Traffic Safety Fundamental Handbook***. Minnesota Department of Transportation: Office of Traffic, Safety and Technology.

Ratanavaraha, & 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 B 36*, 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.

Yakar, F. (2015). **Identification of Accident-Prone Road Sections by Using Relative Frequency Method.** *Traffic and Transportation, 27*(No. 6), 539-547.

CHAPTER III

IDENTIFYING THE SPATIAL CLUSTERING OF ROAD TRAFFIC ACCIDENTS ON NAYPYITAW-MANDALAY EXPRESSWAY

3.1 Abstract

This paper proposes a technique which evaluates clusters of traffic accidents and identifies them according to their severity. In Myanmar, statistics show that the number of traffic accidents have been increased since 2013. Naypyitaw-Mandalay expressway is one of the most frequent to occurrences of the road accidents distributing along the highway. Kernel density estimation is a spatial analysis technic used in this study to identify the clusters of road accidents on both lanes of the highway. Consequently, those clustering hotspots are also verified and ranked their severity based on the clustering locations. As a result, it was found that there are five most dangerous sections on the Naypyitaw-Mandalay, while there are two most dangerous sections on the Mandalay-Naypyitaw expressway. These most dangerous parts were identified on the maps in this paper. The explored locations of the most dangerous parts on these expressways are extremely important and beneficial to the relevant highway traffic organizations to consider safety improvements, either strategies or practices, on these expressways.

3.2 Introduction

Traffic accidents have been recognized as one of the major causes of human and economic losses, both in developed and developing countries. According to the WHO Global Status Report on Road Safety 2015, road traffic accidents are predicted to become the 7^{th} leading cause of death by 2030. About 1.25 million people died and approximately 20-50 million-people injured every year due to traffic accidents. Around 90% of road traffic deaths occur in low- and middle-income countries (Organization, 2015a). In Myanmar road statistics, the numbers of deaths related to road accident have increased since 2013, it was shown that there were averagely 11 people died from road accidents in 2015 (Organization, 2015b). The study area, Naypyitaw-Mandalay expressway (one section of Yangon-Mandalay expressway) is the first and only one expressway in Myanmar, (Figure 3.1). With the poor provision of the road furniture and the exceeding speed limit, loads of car accidents have occurred frequently on this expressway. For this reason, it is necessary to determine hazardous locations (accident prone locations) to propose the traffic safety enhancement in the vulnerable locations.

This study aims to identify the clustering accidents along the highway by using spatial analysis tools in ArcGIS. Geographic Information System (GIS) is a tool widely used to analyze the statistical data associated with locations. Road accidents have been continuously analyzed based on the total number of accidents in each road segment by using GIS (Erdogan, Yilmaz, Baybura, & Gullu, 2008; Longley, Goodchild M. F, Maguire D. J, & W, 2005). One of the most important problems is to implement precautionary measures for traffic safety (Khan, Qin, & Noyce, 2008). GIS is a very important and comprehensive analysis tool for traffic safety.

Since the 1990’s, GIS has been used in the field of transportation with the ability to organize various types of data and maps that can be easily stored, shared and manipulated. In addition, GIS can provide a platform to maintain, visualize and explore relationships between accident record databases and hence further analysis.

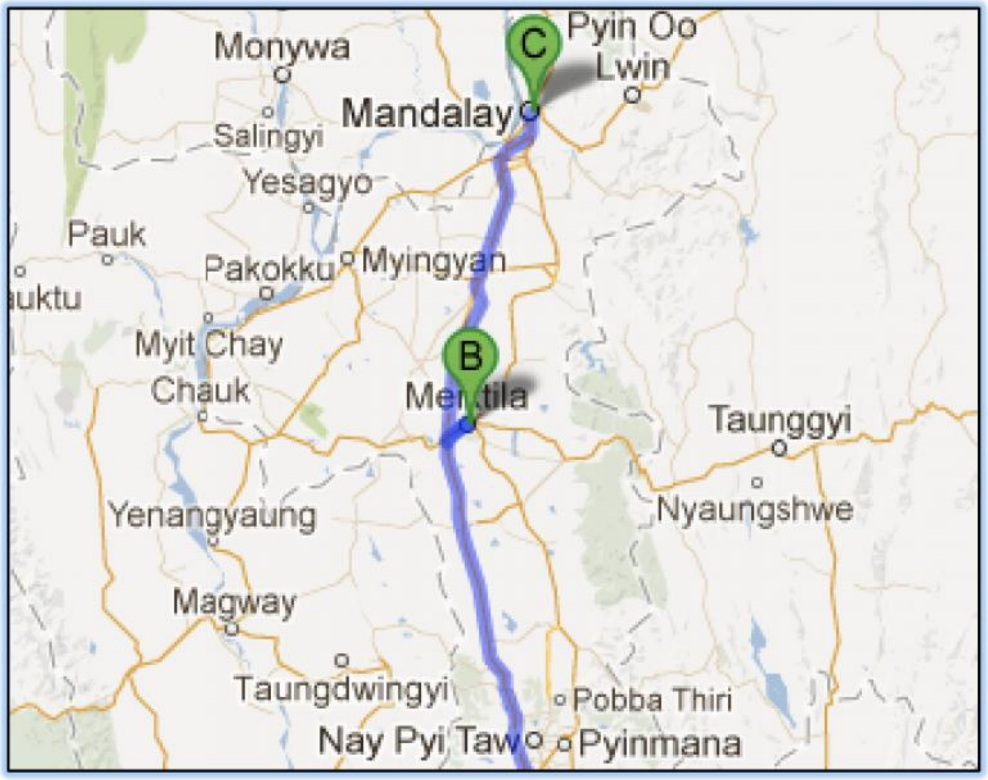


Figure 3.1 Naypyitaw-Mandalay expressway.

3.3 Literature review

GIS is a technology for managing, analyzing, exploring spatial data and related information in a less time consuming manner (Apparao, Mallikarjunareddy, & Raju, 2013; Erdogan et al., 2008; Hirasawa & Asano, 2003; Jayan & Ganeshkumar, 2010; Saleh, 2014). GIS aided spatial data and spatial analysis have been employed to present hazardous locations, hot spots, warm spots etc (Erdogan et al., 2008). Spatial data is the important information for traffic accident analysis.

The accurate result of traffic safety analysis relies on the accurate traffic accident reports (Erdogan et al., 2008).

There are several ways to identify the locations of accidental occurrences. Kernel density is one of the most common methods for identifying hotspots for crime and crash, due to a smooth and continuous surface map of risk targets within the study area (Plug, Xia, & Caulfield, 2011). Kernel density estimates the density of events around these points, scaled by the distance from the point to each event. The basic procedure of kernel density is to estimate a magnitude per unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point or polyline (Silverman, 1986). The kernel density divides the entire study area into predetermined number of cells and draws a circular neighborhood around each accident point. Radius of circular neighborhood affects the result of density map. The density of events is highest when the radius from the point is zero and the density decreases when the radius increases.

The main advantage of the KDE method as opposed to classical statistical clustering methods is that the uncertainty about the exact position of traffic accident expressed by the bandwidth of the kernel – this means something like spreading the risk of an accident (Anderson, 2009). Both simple and kernel density were applied to identify the hazardous locations and accident patterns. The accident hot spot areas and detected safety deficient areas have been identified by using Kernel density estimation and repeatability methods on the highway in the city of Afyonkarahisar, Turkey (Erdogan et al., 2008). The clustering analysis has been studied with respect to accident types, occurrence time, and then calculated Moran's I Index to identify spatial autocorrelation (Prasannakumar, Vijith, Charutha, & Geetha, 2011).

Clustering analyses were performed by using KDE and Getis-Ord GI* statistics to determine accident hot and cold spots.

Three different methods were studied to identify hazardous road location (HRL) in the City of Vila Real, Portugal, namely NNH (Nearest Neighborhood) clustering algorithm, KDE and Point Density methods (Moreira, 2012). As a result of their study, HRL were varied according to the applied methods and routines. In addition, all the methods identified HRL of different sizes and shapes, mostly located on intersections of the highest road functional hierarchy levels. According to Hauer (Hauer, 1996), it was found that some researchers ranked locations by accident rate, some used accident frequency while others use a combination of the two. However, the most widely used technique to determine whether a location has a safety problem is based on the road accident history and determination of the "hot spot". Also, the whole accident prevention and mitigation process is often referred to hot spots improvement (Kowtanapanich Wichuda, Tanaboriboon Yordphol, & Witaya, 2006).

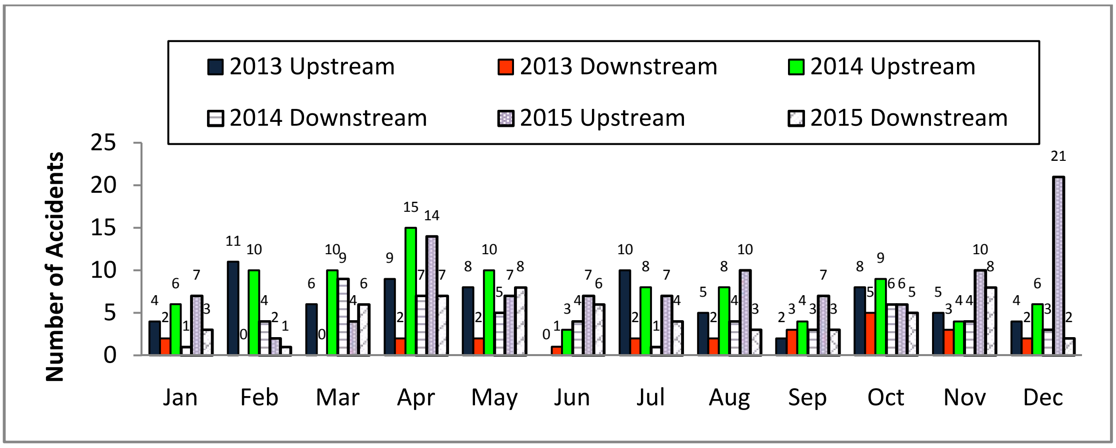
As mentioned in the literature, there are many techniques to identify high rate accidental areas, in which different techniques produce different hot spots in terms of shape, size and location. In this study, kernel density estimation method is used in the spatial analyst extension for identifying of the hazardous locations and accident patterns on the Naypyitaw-Mandalay expressway. In the current situation in Myanmar, there is a National Road Safety Strategy, which is partly funded but has never been implemented successfully. Moreover there is no research have been done by using GIS on the road safety analysis. This research is extremely beneficial to the relevant highway traffic organizations to consider the safety improvements, either strategies or practices, on Naypyitaw-Mandalay expressway.

3.4 Methodology

Highway transportation is very important in Myanmar. Naypyitaw is the Capital and administrative city of Myanmar. It is also a junction point connecting to the developed cities. Mandalay is the second largest city and economic hub of upper Myanmar. Naypyitaw-Mandalay expressway is connected to these two major cities and has a length of 164.25 miles (265km). According to the traffic accident data collected from Ministry of Construction and Highway Police Station in Naypyitaw, this highway has the highest accident rates in the country. There were totally 398 accidents on upstream and downstream of the expressway within 3 years from 2013 to 2015. For this study, the road-shape file and coordinates of accident points were collected by using a GPS device. 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. All data were inputted into the MS Excel and transformed to point features in GIS platform.

As flat topography and straight route, drivers are able to accelerate their vehicles on the expressway. Therefore, losses and injuries always happen in various severity levels. Traffic accidents can be reduced by the application of proper traffic precautionary measures (Hauer, 1996). There are various spatial tools developed to assist the understanding of changing geographies of point patterns, in which the most promising of these tools is kernel density estimation (Chainey & Ratcliffe, 2005; Sabel, Kingham, Nicholson, & Bartie, 2005).

In this study we used the kernel density dialog box with default radius for the purpose of identifying the clusters of accident hotspots on both lanes along the expressway. Kernel density estimation (KDE) is one of the most widely used


2013 Upstream
2013 Downstream
2014 Upstream
2014 Downstream
2015 Upstream
2015 Downstream
Number of Accidents
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Two parameters affecting outcome of the KDE are bandwidth (search radius) and cell size. Arguably, the most important criterion for determining the most appropriate density surface is the bandwidth (Bailey & Gatrell, 1995; Fotheringham, Brunsdon, & Charlton, 2000; Silverman, 1986). The choice of bandwidth will affect the outcome of the hotspots, for example the larger the bandwidth the larger the hotspots will be (Anderson, 2009). This analysis use population field as “None” and defaults for cell size and search radius for analyzing accident hotspots. These are automatically calculated by Arc Map providing a reasonable density surface. A default unit is selected based on the linear unit of the projection of the output spatial reference. The output unit can be changed with appropriate unit to convert the density output. In this study we use the SQUARE_MILE, since the unit is mile.

After analyzing the hotspots by kernel density, the “Classified renderer” was used with a single-band raster layer. The Classified method displayed thematically by grouping cell values into classes. This type of thematic classification can be used with continuous phenomena, such as slope, distance, or suitability, where we can classify the ranges into number of classes and assign colors for those classes. Natural breaks (Jenks) classification method was used in this analysis, since the class breaks were determined statistically by finding adjacent feature pairs.

3.4.1 Illustration of hotspot locations

Maps are indispensable products of numerical data to illustrate or analyze various subjects. According to the type of map reader, or subject, different maps are produced for different purposes. In this study, the results of hotspot locations have been seen that there is not just one event at any locations and shown in red speckles for both lanes of the expressway on the map. According to the analysis results, five clusters of hotspots on the upstream (Naypyitaw-Mandalay) and two clusters of hotspots on the downstream (Mandalay-Naypyitaw) of the expressway were identified in Figure 3.3 and Figure 3.4 respectively.

Based on the statistical data from the traffic records in 2013-2015, hotspots or accidental locations on the Mandalay-Naypyitaw expressway were identified spatially as points on the route tracks. Each point on the tracks shows a single location of an accident occurred in 2013-2015. With the Natural Breaks (Jenks), the clustering points of hotspots were classified explicitly associated with the natural clustering values of the data. Therefore, the density of accidental occurrences on the expressway was classified into five major groups, very high density, high density, medium density, low density, and none. The results of hotspot clustering approach for both lanes of expressway are based on the traffic accident data for 3 years as shown in Figure 3.3 and Figure 3.4.

Considering the Figure 3.3 and Figure 3.4, the most dangerous locations on Naypyitaw-Mandalay and Mandalay-Naypyitaw expressway are identified virtually. It is also found that there are five dangerous sections scattering on Naypyitaw-Mandalay expressway, while the Mandalay-Naypyitaw expressway consists of a long way of most dangerous and a tiny spot of most dangerous part. It can be concluded that the kernel density analysis can be applied to identify all accidental locations on these expressways.

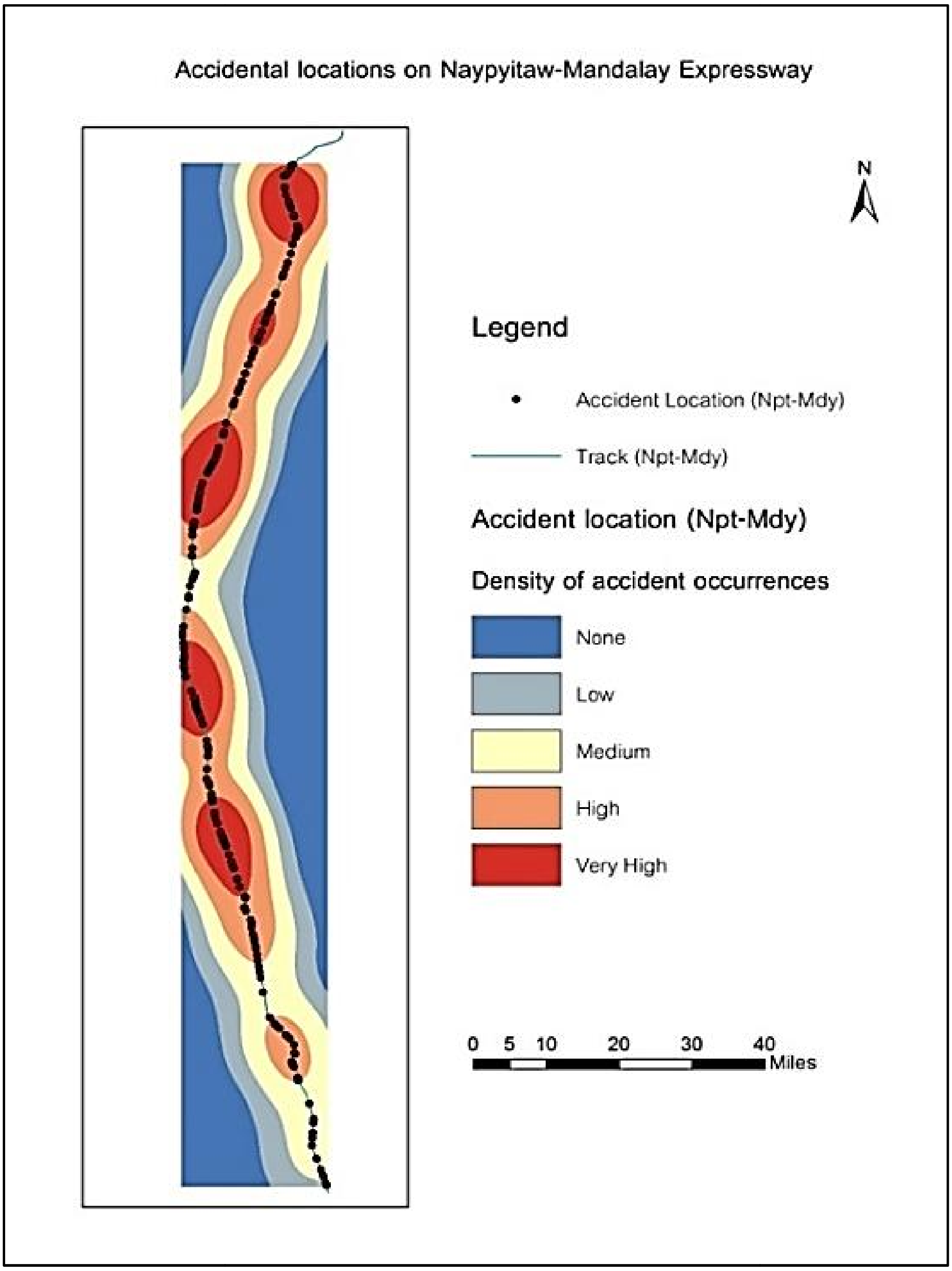


Figure 3.3 Kernel density maps of accidents on upstream (Naypyitaw-Mandalay expressway) in 2013-2015.

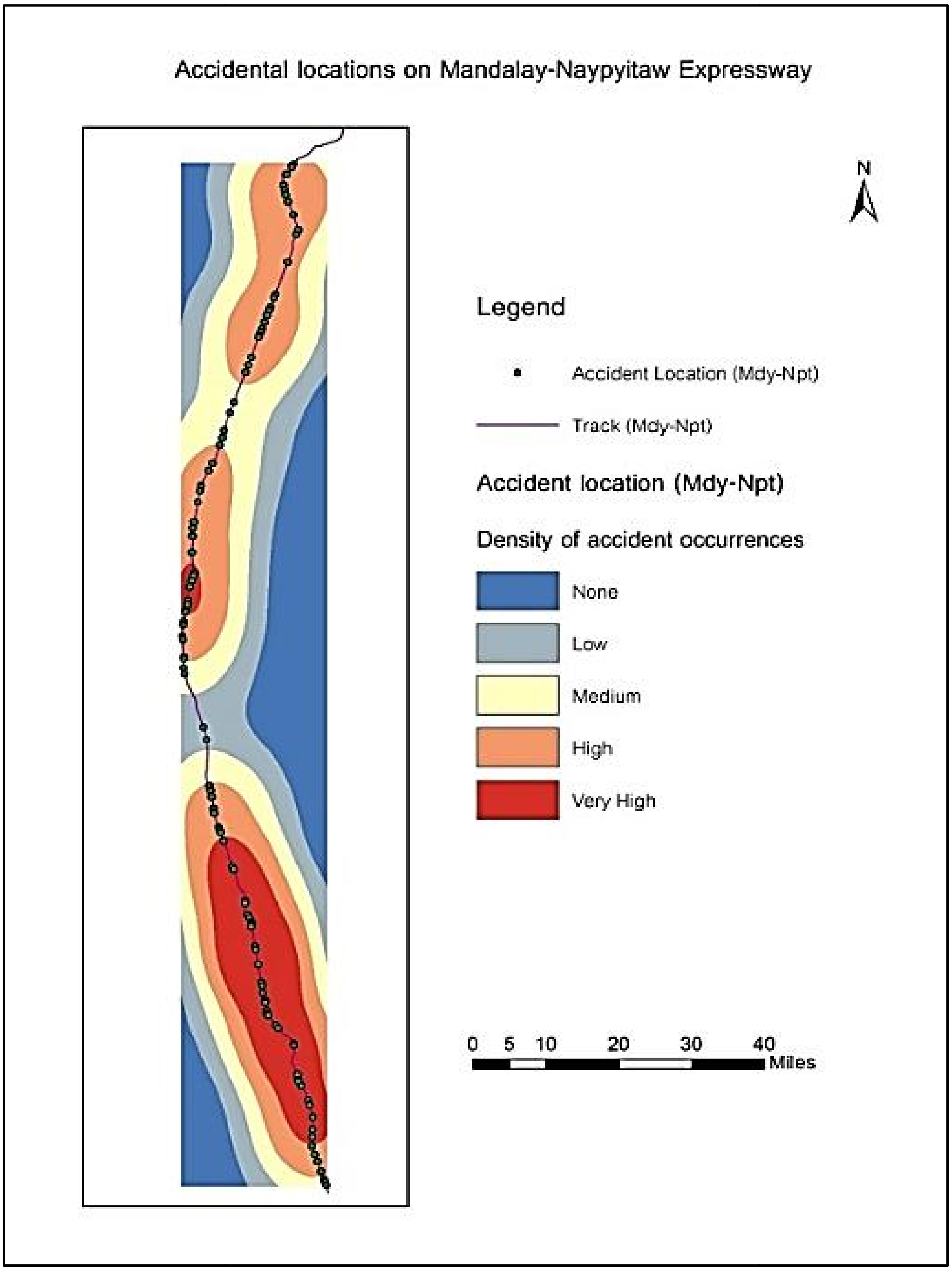


Figure 3.4 Kernel density maps of accidents on downstream (Mandalay-Naypyitaw expressway) in 2013-2015.

3.5 Conclusions

Traffic accidents are threatening people over the world. All relevant organizations and authorities have attempted to reduce the number of accidents and mitigate the severity of those accidents in several ways. In order to reduce these serious situations, the first afford is to identify the locations of the accidental occurrences. Alternatively, it can be achieved by using the statistical records from the authorities. For this reason, an accurate statistical record is very significant in this process. With the implementation of GPS equipment, the accident hotspots could be collected preciously and systematically which the obtained data are applicably analyzed in the GIS platform. It is able to reduce the time of data collection and analysis dramatically.

Regarding the analyzed results of this study, it can be concluded that the dangerous parts of the upstream of this expressway consist of 5 parts, while the downstream of this expressway consist of 2 parts. It is noticeable that the Naypyitaw-Mandalay expressway contains more several dangerous parts than the Mandalay-Naypyitaw expressway. Regarding the analyzed result of this study, the relevant organizations and authorities can use the explored results of this study in enhancing the safety of this expressway with their responsible and authorized ways in term of both strategies and practices. Eventually, it is crucial to also explore the causes of those accidents in the future study.

3.6 References

Anderson, T. K. (2009). **Kernel density estimation and K-means clustering to profile road accident hotspots**. *Accid Anal Prev, 41*(3), 359-364.

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.

Bailey, T. C., & Gatrell, A. C. (1995). ***Interactive spatial data analysis*: Longman Scientific & Technical.**

Chainey, S., & Ratcliffe, J. (2005). ***GIS and Crime Mapping*: John Wiley and Sons**, UK.

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.

Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2000). ***Quantitative Geography: Perspectives on Spatial Data Analysis*:** SAGE Publications.

Hauer, E. (1996). **Identification of Sites with Promise.** *Transportation Research Record: Journal of the Transportation Research Board, No. 1542,* 54-60.

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.

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.

Khan, G., Qin, X., & Noyce, D. A. (2008). **Spatial Analysis of Weather Crash Patterns**. *Journal of Transportation Engineering, 134*(5), 191-202.

Kowtanapanich Wichuda, Tanaboriboon Yordphol, & Witaya, C. (2006). **Applying Public Participation Approach to Black Spot Identification Process - A Case Study in Thailand.** *IATSS Research, 30(1)*, 73-85.

Longley, P. A., Goodchild M. F, Maguire D. J, & W, R. D. (2005). *Geographic Information Systems and Science* (2nd Edition ed.).

Moreira, I. F. (2012). **Identification of Hazardous Road Locations in Urban Areas Through Spatial Analysis: Application to Vila Real.** *26th Annual Congress, METU, Ankara*.

Organization, W. H. (2015a). ***Global Status Report on Road Safety***

Organization, W. H. (2015b). **Road Safety in Myanmar.** Retrieved from http://www.searo.who.int/myanmar/areas/roadsafety_datacollection/en/

Plug, C., Xia, J. C., & Caulfield, C. (2011). **Spatial and temporal visualisation techniques for crash analysis**. *Accid Anal Prev, 43*(6), 1937-1946.

Prasannakumar, V., Vijith, H., Charutha, R., & Geetha, N. (2011). **Spatio-Temporal Clustering of Road Accidents: GIS Based Analysis and Assessment**. *Procedia - Social and Behavioral Sciences, 21*, 317-325.

Sabel, C. E., Kingham, S., Nicholson, A., & Bartie, P. (2005). ***Road Traffic Accident Simulation Modelling - A Kernel Estimation Approach*****.** Paper presented at the The 17th Annual Colloquium of the Spatial Information Research Centre, University of Otago, Dunedin, New Zealand.

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.

Silverman, B. W. (1986). ***Density Estimation for Statistical and Data Analysis*** (1st ed.). Monograph on Statistics and Applied Probability, London: Chapman and Hall.

CHAPTER IV

IDENTIFY THE SEVERITY LEVEL OF DANGEROUS LOCATIONS ON NAYPYITAW-MANDALAY EXPRESSWAY

4.1 Abstract

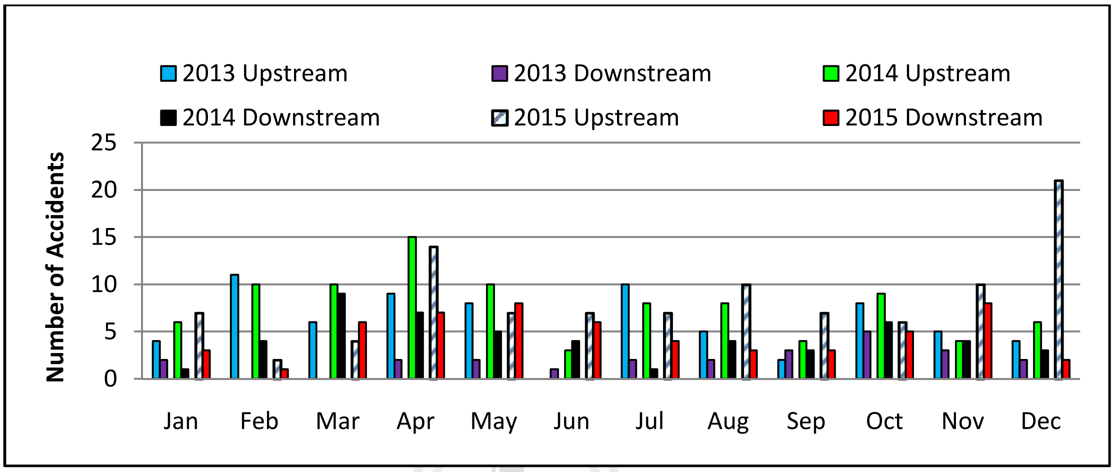
This paper proposes a technique to evaluate hazardous locations and severity levels of traffic accidents on Naypyitaw-Mandalay expressway by using the available statistical data from 2013-2015. Naypyitaw-Mandalay expressway is one of the most frequent occurrences of road accidents in Myanmar. Due to the straight line and suddenly sharp curve with the accessibility of communities along the expressway, car accidents always happen in various severity levels, such as losses and injuries. Getis-Ord Gi∗ statistics, known as hotspots analysis, is used to explore dangerous areas and identify the severity of those dangerous areas on Naypyitaw-Mandalay expressway significantly. As a result shows that injury and light accidents occur in several parts along the Naypyitaw-Mandalay expressway, while the injury and light accidents cluster at the end of the backward Mandalay-Naypyitaw expressway. These dangerous locations were identified on the maps illustrating the severity levels of road accidents on both forward and backward Naypyitaw-Mandalay expressway. This study is extremely beneficial to the relevant highway traffic organizations to consider

the safety improvement, in particular those specific parts, and to reduce the number of accidents and severity levels in those dangerous areas, either strategies or practices.

4.2 Introduction

Nowadays, traffic accidents have become a serious social problem and require concerted efforts for effective and sustainable prevention. A report from the World Health Organization (WHO) and World Bank shows that, around 1.25 million people died and approximately 20-50 million-people injured due to traffic accidents. Around 90% of road traffic deaths occur in low-and-middle countries (*World Health Organization. Global Status Report on Road Safety 2015*). Therefore, road traffic accident is a vital phenomenon that needs to be studied either in Myanmar or in any other countries. The numbers of deaths related to road accident in Myanmar have increased since 2013. According to WHO figures, Myanmar's road and highway were the second-deadliest in Southeast Asia after Thailand's, with 20.3 deaths per 100,000 people, or more than 10,000 nationwide in 2015(*Road Safety in Myanmar* 2015).

Naypyitaw-Mandalay expressway (one section of Yangon-Mandalay expressway) is the first and only one expressway in Myanmar. Statistical data from the Ministry of Transport and Communications in Naypyitaw show that, there were 44,585 accidents from 2013 to 2015 in the whole country while 398 accidents on Naypyitaw-Mandalay expressway, albeit the accident severity value on the expressway has 3.2 higher than the whole country which is 1.95. With the poor provision of the road furniture and exceeding the speed limit, loads of car accidents have occurred frequently on this expressway. Therefore, losses and injuries always happen in several severity levels with the highest accident rates in the country. Especially in April and December, the numbers of vehicles on the expressway have



2013 Upstream
2013 Downstream
2014 Upstream
2014 Downstream
2015 Upstream
2015 Downstream
Number of Accidents
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Highway 304, Thailand (Kassawat, Sarapirome, & Ratanavaraha, 2015), kernel density analysis and spatial-autocorrelation analyses (e.g., Getis-Ord Gi* analysis) in GIS platforms were commonly used to identify the cluster patterns for crime and crash data and various purposes of road safety improvements (Black, 1998; Choudhary, 2015; Flahaut, Mouchart, Martin, & Thomas, 2003; Kingham, 2011; O'Sullivan & Unwin, 2003; Pulugurtha, Krishnakumar, & Nambisan, 2007; Schneider, Ryznar R.M, & A.J, 2004; Steenberghen, 2010).

Spatial clustering of accidents locations on Naypyitaw-Mandalay expressway have been studied by using kernel density estimation method (Htut, Piyatadsananon, & Ratanavaraha, 2016). It was found that there were five dangerous clustering sections on the upstream (Naypyitaw-Mandalay) and two dangerous sections on the downstream (Mandalay-Naypyitaw) of the expressway. Regarding the spatial clustering of accidents from the previous study, it is necessary to determine the severity levels of those hazardous locations significantly. This study aims to explore the hotspots location on forward and backward Naypyitaw-Mandalay expressway with the severity levels of those dangerous areas on the expressway by using the Getis-Ord Gi* analysis in ArcGIS Software. According to the Getis–Ord Gi∗ statistic, known also as hotspot and cold spots analysis where feature with significant high and low values has to be surrounded by features having simultaneously significant high and low values. It is utilized to detect traffic accident hotspots significantly on various roads and highways by researchers (Erdogan, 2009; Getis & Ord, 1992, 1996; Mitchell, 2005; Truong & Somenahalli, 2011).

4.3 Material and methods

4.3.1 Study area and traffic accident dataset

Naypyitaw is the Capital and administrative city of Myanmar. It is also a junction point connected by roads to other countries, such as..??... Mandalay is the second largest city and economic hub of upper Myanmar. The study area, Naypyitaw-Mandalay expressway links these two major cities with 164.25 miles (265km) long. This 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 4.2). According to the statistical records of road accidents this highway is the highest number of accidents over other areas across the country. Occasionally, traffic accidents can be reduced by the application of proper traffic precautionary measures (Hauer, 1996). The success of these precautionary measures depends on the analysis of traffic accident records. So it is important to collect the accurate, precise and reliable data with the traffic accident reports (Erdogan et al., 2008). A series of accident data used in this study were collected from Ministry of Construction, Ministry of Transport and Communications, and Highway Police Station in Naypyitaw. There were totally 398 accidental locations (267 on upstream and 131 on downstream), which resulted in 157 fatalities, 1,116 injuries and 70 economic damages on upstream and downstream of the expressway within three years from 2013 to 2015. All collected data were inputted into the MS Excel database and transformed to point features analyzed in GIS platform. The road-shape file and coordinates of accident point locations in this study were collected by using a GPS device.

Imphal
Manipur
Aizawl
Mizoram
MYANMAR
(BURMA)
hittagong
Mandalay
Mengzhe
Nay Pyi
Taw
Chiang
Mai
Yangon
0 45 90 180 270 360
Miles
N

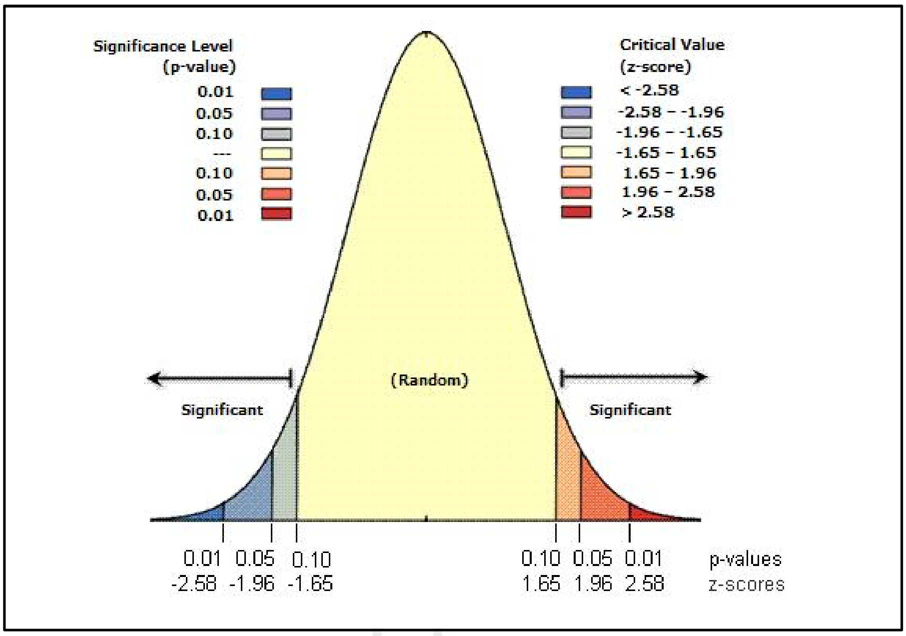
for the study of local patterns in spatial data, were extended and re-written in 1995 to redefine Gi as a standard random variable and to allow for non-binary classifications of the distance *d* (Getis & Ord, 1996). In this analysis, the Gi∗(*d*) statistic is used as the following Equation 4.1, 4.2 and 4.3 (Khan et al., 2008):

$$G_i^* = \frac{\sum_{j=1}^{N} w_{ij}(d)x_j - \bar{x}\sum_{j=1}^{N} w_{ij}(d)}{S\sqrt{\frac{\left[N\sum_{j=1}^{N} w_{ij}^2(d) - \left(\sum_{j=1}^{N} w_{ij}(d)\right)^2\right]}{N-1}}} \qquad (4.1)$$

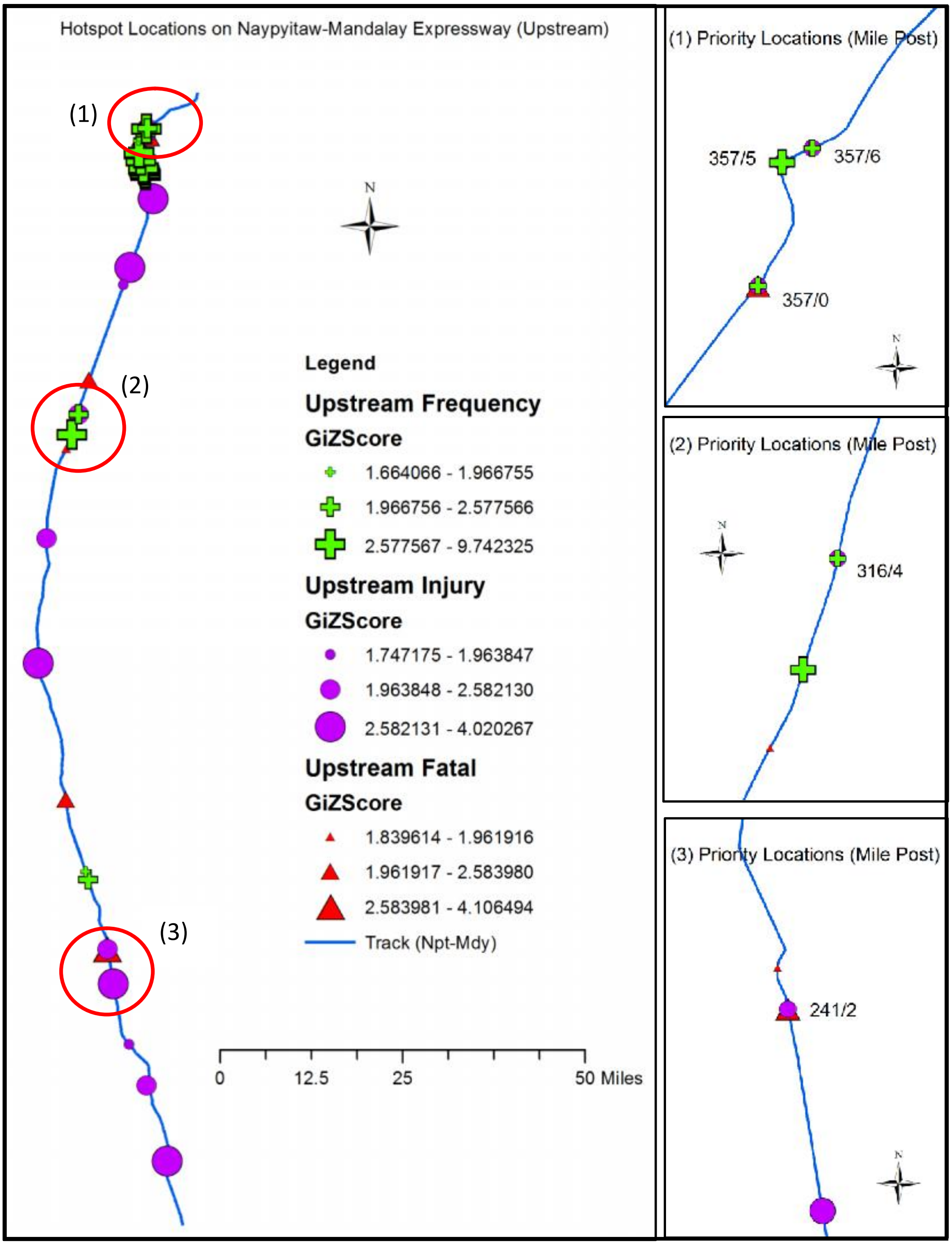
$$\bar{x} = \frac{\sum_{j=1}^{N} x_j}{N} \qquad (4.2)$$

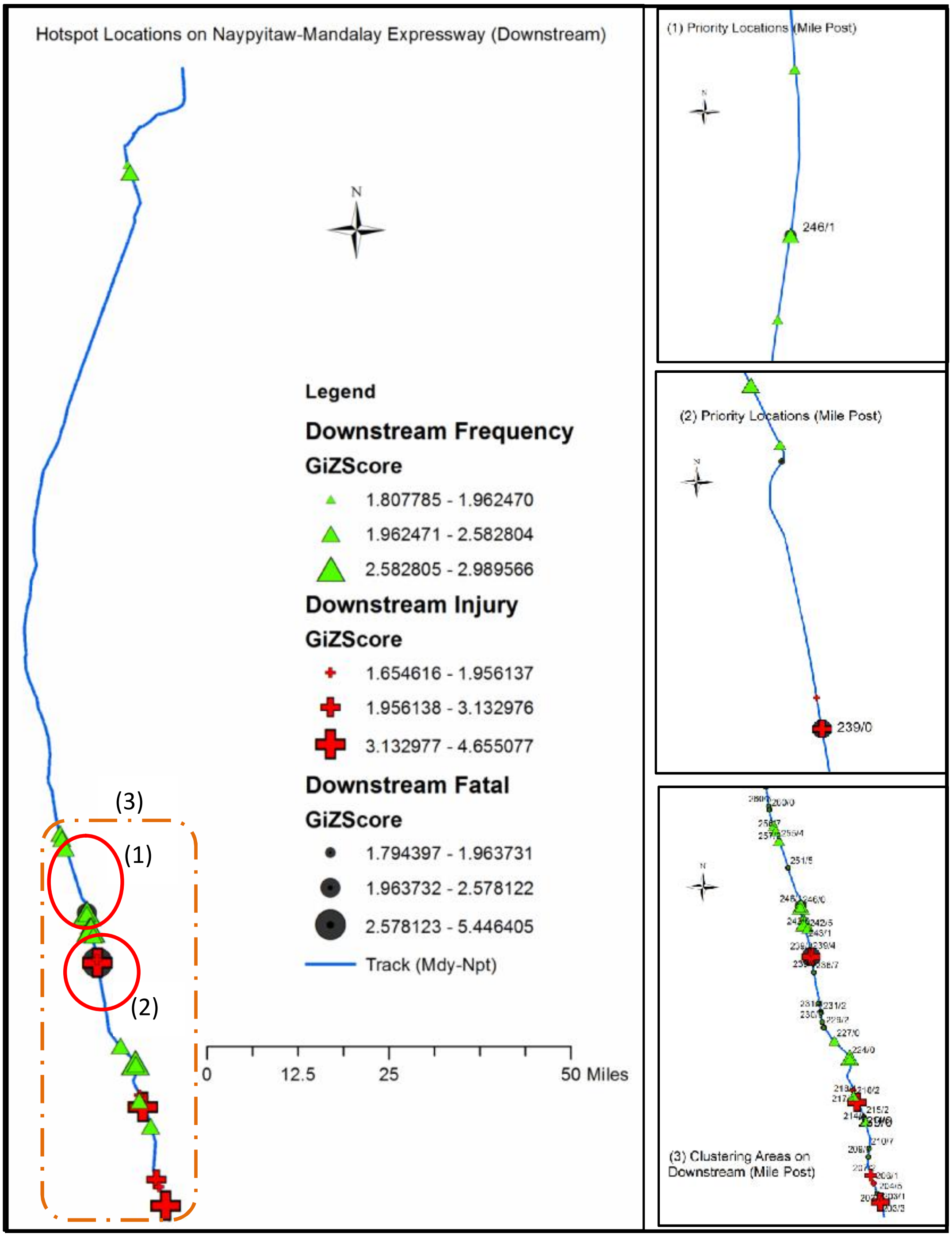
$$S = \sqrt{\frac{\sum_{j=1}^{N} x_j^2}{N} - (\bar{x})^2} \qquad (4.3)$$

Where, G_i^* is the Getis-Ord G_i^* *z-score* value including the value at segment i, x_j is relative crash rate of segment *i*, *d* is fixed band radius around segment *i*, w_{ij} is spatial weight matrix for all segment *j* within distance *d*, and *N* is the number of weighted points.


Significance Level
(p-value)
0.01
0.05
0.10

0.10
0.05
0.01
Critical Value
(z-score)
< -2.58
-2.58 - -1.96
-1.96 - -1.65
-1.65 - 1.65
1.65 - 1.96
1.96 - 2.58
> 2.58
(Random)
Significant
Significant
0.01 0.05 0.10
-2.58 -1.96 -1.65
0.10 0.05 0.01
1.65 1.96 2.58
p-values
z-scores


Hotspot Locations on Naypyitaw-Mandalay Expressway (Upstream)
(1)
(2)
(3)
N
Legend
Upstream Frequency
GiZScore
1.664066 - 1.966755
1.966756 - 2.577566
2.577567 - 9.742325
Upstream Injury
GiZScore
1.747175 - 1.963847
1.963848 - 2.582130
2.582131 - 4.020267
Upstream Fatal
GiZScore
1.839614 - 1.961916
1.961917 - 2.583980
2.583981 - 4.106494
Track (Npt-Mdy)
0
12.5
25
50 Miles
(1) Priority Locations (Mile Post)
357/5
357/6
357/0
(2) Priority Locations (Mile Post)
316/4
(3) Priority Locations (Mile Post)
241/2



Hotspot Locations on Naypyitaw-Mandalay Expressway (Downstream)
N
Legend
Downstream Frequency
GiZScore
1.807785 - 1.962470
1.962471 - 2.582804
2.582805 - 2.989566
Downstream Injury
GiZScore
1.654616 - 1.956137
1.956138 - 3.132976
3.132977 - 4.655077
Downstream Fatal
GiZScore
1.794397 - 1.963731
1.963732 - 2.578122
2.578123 - 5.446405
Track (Mdy-Npt)
(3)
(1)
(2)
0
12.5
25
50 Miles
(1) Priority Locations (Mile Post)
246/1
(2) Priority Locations (Mile Post)
239/0
(3) Clustering Areas on Downstream (Mile Post)

After analyzing, dangerous points have been shown as hotspots by points which exceed the upper limit of *z-scores* and *p-value*. The results of this study indicated that, road accidents causing injuries to people frequently happen along upstream of the expressway between the mile post number 210/3 – 227/2, 241/2 – 262/4, 311/3 -321/3, and 350/6 – 357/6. Among the frequent accidents, heavy accidents causing the death and injuries to people always happen around the locations of 241/2, 316/4, 357/0, 357/5, and 357/6, these areas included roundabouts, intersections and sharp curves in geometric design of highway and they must be considered as priority areas.

Moreover light accidents happened on downstream of the expressway occurred frequently between 223/6 – 227/0, 255/4 – 257/5, 351/6 – 352/7, and road accidents causing injuries to people frequent occurred between 203/3 – 207/2, then high risk clustering accidents causing injured people to death happened between mile posts number of 214/4 – 219/2 and 239/0 – 246/3. Heavy accidents causing death and injuries to people always happen at the mile post number 239/0 and 246/1. This can be identified as the most important areas determine to priority locations on downstream accident prevention.

All dangerous locations which considered as priority areas on both upstream and downstream of the expressway and the severity of those points of different features are specified numerically in Table 4.1.

Table 4.1 Summary of significant accident point locations.

Location (M/F)	Frequency	Injury	Fatal	Z-score			P-value		
				Frequency	Injury	Fatal	Frequency	Injury	Fatal
<u>Upstream</u>									
241/2	-	19	5	-	2.551	3.257	-	0.010	0.001
316/4	3	16	-	2.379	2.082	-	0.017	0.037	-
357/0	2	14	6	2.055	1.999	4.106	0.039	0.045	0.000
357/5	3	16	-	2.991	2.265	-	0.002	0.023	-
357/6	1	15	-	2.173	2.136	-	0.029	0.033	-
<u>Downstream</u>									
239/0	-	17	8	-	3.727	5.446	-	0.000	0.000
246/1	2	-	1	2.760	-	2.016	0.005	-	0.043

The results of hotspots identification were analyzed by using Gi* showing the different accident severities. Regarding the *z-scores* and *p-values* from Gi*, it can be concluded that the road accidents always happen at the mile post number 357/5, where is the highest severity location in term of the frequent occurrences of losses, injuries, following with the mile post number 357/0 and 316/4 respectively on Naypyitaw-Mandalay expressway. On the other hand, the highest severity location of Mandalay-Naypyitaw expressway is at the mile post number 239/0 and 246/1 respectively, as highlighted in Table 4.1. It is also found that some locations on the map do not have any hotspots, but some of the locations have the common incidents i.e. injury, fatal and light accidents on both upstream and downstream of the expressway shown in Table 4.1. Withal, injury and light accident are scattering significantly along upstream of the expressway, while the downstream occurred injury and light accidents are clustering at the end of the expressway.

4.5 Conclusions

This paper presents the identification of hotspots locations using statistical testing that is analyzed the different features significantly. In the current situation in Myanmar, National Road Safety Strategy has never been implemented successfully. This research is the first study using GIS to analyze the severity levels beneficial to road safety plan in Myanmar. A previous study used kernel density estimation method for identifying all clustering accidents based on accident frequency on this expressway, however, the severity levels have never been identified. As the results of this study, it is obviously shown that the prioritized mile post number 357/5, 357/0, 316/4, 239/0 and 246/1 are the high severity locations required the most urgent safety management among the dangerous areas on the expressway. This research has revealed the superiority in applying the Gi* to specifically improve the exact dangerous locations on the expressway. This technique is extremely useful to a country which lacks of the financial support employed to improve the safety on entire expressway in full scale.

This technique produced accurate and distinctive hotspots from current mixed traffic conditions, i.e. frequency, dead number, injury number by sorting the common conditions and presents the analyzed results associated with locations on map. This analysis would have more helpful, accurate, descriptive and reliable if the accidents were recorded in digital format associated with occurrence locations. GPS is suggested in this study to be used to provide the recorded locations of road accidents rather than named them as the mile posts. Howbeit, this method can be applicable in other similar road networks especially using different accident parameters and considering all segments of roads. Future study aims the utilization of base map of high resolution image to support and explore the actual causes of accidents and safety improvements using spatial analysis methods on the expressway.

4.6 References

Black, W. R., Thomas, I. (1998). **Accident onBelgium's Motorways: a Network Autocorrelation Analysis.** *Journal of Transport Geography, 6*(1), 23-31.

Choudhary, J., Ohri, A., Kumar, B. (2015). ***Spatial and Statistical Analysis of Road Accidents Hot Spots Usign GIS*.** Paper presented at the 3rd Conference of Transportation Research Group of India (3rd CTRG).

Erdogan, S. (2009). **Explorative spatial analysis of traffic accident statistics and road mortality among the provinces of Turkey**. *J Safety Res, 40*(5), 341-351. doi:10.1016/j.jsr.2009.07.006

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.

Flahaut, B., Mouchart, M., Martin, E. S., & Thomas, I. (2003). **The Local Spatial Autocorrelation And The Kernel Method for Identifying Black Zones: A Comparative Approach.** *Accident Analysis And Prevention, 35*(6), 991-1004.

Getis, A., & Ord, J. K. (1992). **The Analysis of Spatial Association by Use of Distance Satistics.** *Geographical Analysis, 24*, 189-206.

Getis, A., & Ord, J. K. (1996). **Local Spatial Statistics: An Overview.** In Longley, P., Batty, M. (Eds.), **Spatial Analysis: Modeling in a GIS Environment.** *Cambridge: Geoinformation International*.

Gundogdu, I. B. (2010). **Applying linear analysis methods to GIS-supported procedures for preventing traffic accidents: Case study of Konya**. *Safety Science, 48*(6), 763-769. doi:10.1016/j.ssci.2010.02.016

Hauer, E. (1996). **Identification of Sites with Promise.** ***Transportation Research*** *Record: Journal of the Transportation Research Board, No. 1542*, 54-60.

Htut, K. Z., Piyatadsananon, P., & Ratanavaraha, V. (2016). ***Identifying the Spatial Clustering of Road Traffic Accidentson Naypyitaw-Mandalay Expressway.*** Paper presented at the Proceeding ofATRANS Symposium: Young Researcher's Forum 2016 "Transportation for A Better Life: Safe and Smart Cities", Bangkok, Thailand.

Kassawat, S., Sarapirome, S., & Ratanavaraha, V. (2015). I**ntegration of Spatial Models for Web-based Risk Assessment of Road Accident.** *Walailak Journal, 12*(8), 671-679.

Khan, G., Qin, X., & Noyce, D. A. (2008). **Spatial Analysis of Weather Crash Patterns.** *Journal of Transportation Engineering, 134*(5), 191-202.

Kingham, S., Sabel, C. E., Bartie, P. (2011). **The impact of the 'school run' on road traffic accidents: A spatio-temporal analysis.** *Journal of Transport Geography, 19*(4), 705-711. doi:10.1016/j.jtrangeo.2010.08.011

Liang, L. Y., Ma'soem, D. M., & Hua, L. T. (2005). **Traffic Accident Application Using Geographical Information System.** *Journal of the Eastern Asia Society for Transportation Studies, 6,* 3574 - 3589.

Mitchell, A. (2005). ***The ESIR Guide to GIS Analysis*** **(Vol. 2): Spatial Measurements.** California: ESIR Press.

O'Sullivan, D., & Unwin, D. J. (2003). ***Geographic Information Analysis*** **(2nd ed.)**: John Wiley & Sons, Inc., Hoboken, New Jersey.

Pulugurtha, S. S., Krishnakumar, V. K., & Nambisan, S. S. (2007). **New methods to identify and rank high pedestrian crash zones: an illustration**. *Accid Anal Prev, 39*(4), 800-811. doi:10.1016/j.aap.2006.12.001

Road Safety in Myanmar (2015). **World Health Organization.**

Schneider, R. J., Ryznar R.M, & A.J, K. (2004). **An Accident Waiting to Happen: a Spatial Approach to Proactive Pedestrain Planning**. *Accident Analysis And Prevention, 36*(3), 193-211.

Steenberghen, T., Aerts, K., Thomas, I. (2010). **Spatial Clustering of Events on a Network.** *Journal of Transport Geography, 18*(3), 411-418. doi:10.1016/j.jtrangeo.2009.08.005

Truong, L. T., & Somenahalli, S. V. C. (2011). **Using GIS to Identify Pedestrian-Vehicle Crash Hot Spots and Unsafe Bus Stops**. *Journal of Public Transportation, 14*(1), 99-114.

World Health Organization. ***Global Status Report on Road Safety 2015*.** Switzerland: WHO Press.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

In this thesis, a GIS-based safety analysis application tool was developed by using ArcGIS 10.1 program. This tool can select and analyze traffic accidents and perform a number of traffic safety analysis procedures for both intersection and roadway segments, which can assist an analyst in determining hazardous locations (hotspots). Under this chapter, three main results of the study according to its three research objectives included (1) to identify the hazardous road locations on the Naypyitaw-Mandalay expressway based on their dangerous factor (DF) value (2) to identify the clustering accidents along the highway by using spatial analysis tools in ArcGIS (3) to investigate the hotspots locations by applying Getis-Ord Gi* tool in ArcGIS, are separately concluded and some recommendations are also suggested for future research and development.

5.1 Identification of hazardous locations based on dangerous factor

This study calculated the dangerous factor of each segment on upstream and downstream of Naypyitaw-Mandalay expressway depend on 2013-2015 accident records such as; their average daily traffic value, accident number and time period by using accident rate and quality control method. According to the analysis results, 22 segments on Naypyitaw-Mandalay (upstream) and 14 segments on Mandalay-Napyitaw (downstream) of the expressway were found as the dangerous segments while their dangerous factor values greater than 1. 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 expressway as a result in graphical map format.

In addition, most of the hazardous locations were founded near the bridges, curve areas, near roundabout, upgrade, downgrade, and slippery road surface areas on both direction of the highway. Since the main problem of the traffic accident analysis was the data collection, it was very important to improve the data collection method and the methodology of these processing data and spatial analysis for improving traffic safety analysis.

5.2 Identifying the spatial clustering accidents on the expressway

Nowadays, traffic accidents are threatening the people over the world. All relevant organization and authorities have been attempted to reduce the number of accidents and mitigate the severity of those accidents in several ways. In order to reduce these serious situations, the first afford is we need to identify the locations of the accidental occurrence areas. This research proposed a technique which evaluated clusters of traffic accidents on the Naypyitaw-Mandalay expressway and identified these locations according to their severity. Kernel density estimation was a spatial analysis technique used in clustering hotspots which were also verified and ranked their severity based on the clustering locations.

As a result, it was found that there were five dangerous scattering sections on Naypyitaw-Mandalay (Upstream), while Mandalay-Naypyitaw (Downstream) of the expressway consists of a long way of most dangerous and a tiny spot of the most dangerous part. Therefore, the road users should be noticeable that the upstream of the expressway have more several dangerous parts than the downstream of the expressway. The explored locations of the most dangerous parts on these expressways were extremely important and beneficial to the relevant highway traffic organizations to consider safety improvements, either strategies or practices, on these expressways.

5.3 Investigation of hotspots locations by applying Getis-Ord Gi*

This study proposes a procedure which evaluates hazardous locations of traffic accident and organizes them according to their significant. Normally, accidents are frequently happened because the lack of the information recorded about the causes of accident. Therefore, we need to find out what is the cause of those dangerous locations on the highway. This study used the Getis-Ord Gi* statistic to identify the hotspots locations and explore the severity level of those dangerous areas on Naypyitaw-Mandalay expressway.

As a consequence of the application, the hotspots have been evaluated by the number of accidents, studying with only accident numbers and mapping of them alone are not sufficient. The number of injury and fatality must be taken as information clusters individually and then hotspots locations must be assessed through inter-sectional clusters of individual information clusters. This research examined the hazardous locations on the basic feature of not only the number of accidents, but also the number of injury and fatality within three years from 2013 to 2015. These locations have been determined over their features' significant z-scores (>1.65) and p-values (<0.1) of each accident point. According to the result of data analysis, the dangerous severity locations are occurred as scattering and three are three dangerous clustering locations which occurred around the beginning, middle and third-quarter length on the upstream of the expressway. While, all features of the dangerous severity are occurred as a tiny spot of dangerous around beginning of expressway and long way of dangerous clustering sections at the end of the downstream of the expressway.

5.4 Recommendations

In this study, different accident analysis methods were performed with GIS technique to identify the hazardous locations on the Naypyitaw-Mandalay expressway in Myanmar. However, this study may have limitation that needs to be enhanced for future study as in the following recommendations.

1) Accident data collection and systematic reporting system is very important to road safety management, analyze and visualize hazardous locations. Therefore, accident report and accident database should be accurate, detailed, 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. This system has a lot of advantages such as quick access for obtaining information data storage, output and integrity. Moreover, the importance of accident reports must be explained to the highway polices and if necessary training exercise must be performed.

2) There are many techniques to identify high rate accidental areas, in which different techniques produce different hotspots in terms of shape, size and locations. This study used three different techniques based on GIS application as mentioned in section 5.1, 5.2, and 5.3, but their analysis results are nearly the same locations. According to section 5.1 and 5.3 results, hotspots are mostly located near roundabouts, sharp curves, near bridges and slippery road segment areas. In order, the results of section 5.2 shows that there are five dangerous clustering locations on upstream and two dangerous clustering locations on downstream of the expressway, while the results of section 5.3 show that there are almost same clustering dangerous severity locations with section 5.2 on upstream and downstream of the expressway. Therefore, the researcher would like to recommend that these three techniques can be applicable together to accurate the results in other similar road networks and considering all segments of roads (Htut, Piyatadsananon, & Ratanavaraha, 2016).
3) Based on the findings of hazardous location analysis, the researcher would like to propose to improve the roadway facilities, such as installation of warning signs to warn the drivers to get a caution, speed detector, drainage repairs and fencing to prevent people, animals and vehicles entering from local road on both sides along the expressway. Deficient slippery areas should be provided with surface treatment such as chip seal, or overlaying a new layer of asphalt. Moreover the shoulder rumble strip should be installed, which is renowned as a safety device to alert drivers and to prevent run-off-road accidents (Ratanavaraha & Jomnonkwao, 2015).

4) Severity of hotspots can also be defined by considering not only the number of accidents in it but also the total number of injuries and fatalities. This research is extremely beneficial to the relevant highway traffic organization to consider the safety improvements, with either strategies or practices, on Naypyitaw-Mandalay expressway.
5) Regarding the analyzed result of this research, the relevant organizations and authorities can use the explored results of this study in enhancing the safety of that expressway with their responsible and authorized ways in term of both strategies and practices. Eventually, it is also crucial to explore the causes of those accidents in the future study.

5.5 References

Htut, K. Z., Piyatadsananon, P., & Ratanavaraha, V. (2016). ***Identifying the Spatial Clustering of Road Traffic Accidentson Naypyitaw-Mandalay Expressway***. Paper presented at the Proceeding ofATRANS Symposium: Young Researcher's Forum 2016 "Transportation for A Better Life: Safe and Smart Cities", Bangkok, Thailand.

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 B 36*, 109-118.

APPENDIX

LIST OF PUBLICATIONS

List of Publication

Htut, K. Z., Piyatadsananon, P., Ratanavaraha, V. (2016). *Identifying the Spatial Clustering of Road Traffic Accidents on Naypyitaw-Mandalay Expressway.* **Paper presented at the Proceeding of ATRANS Symposium: Young Researcher's Forum 2016 "Transportation for A Better Life: Safe and Smart Cities"**, Bangkok, Thailand.

Htut, K. Z., Mon, E. E., Johnstone, L., Pueboobpaphan, R., Ratanavaraha, V., Goodary, R., & Beeharry, R. (2016). *Application of GIS to Traffic Accident Analysis: Case Study of Naypyitaw-Mandalay Expressway (Myanmar).* **International Journal of Building, Urban, Interior and Landscape Technology (BUILT)**, Vol(7).

BIOGRAPHY

Mr. Kyaw Zin Htut was born on May 24, 1988 in Pakokku, Magway Region, Myanmar. He studied civil engineering at the undergraduate course at Technological University (Pakokku) and got the Bachelor of Engineering (Civil) in 2010. After graduation, he worked as a Junior Engineer (Civil) for Bridge Construction Special Unit (4) (Pakokku Bridge Construction Project) (2011-2013), and Road Department (Estimate Section), Naypyitaw under Ministry of Construction (2013-2014). In 2014, he got the scholarship from the Thailand International Development Cooperation Agency (TICA), for Master of Transportation Engineering under the 3-year HRD programmed of the Technical Cooperation Framework between Myanmar and Thailand (2013-2015), to study at Suranaree University of Technology in Thailand. Then Ministry of Construction dispatched him to study in Thailand for 2 years and 3 months. At present, he works as a Junior Engineer for Road Department (Road and Airport Design Section), under Ministry of Construction in Naypyitaw.