SPATIAL ANALYSIS ON CAUSES OF FATAL ROAD ACCIDENTS IN BLACK SPOT AREA: A CASE STUDY IN THE NORTHEAST DISTRICT OF PENANG, MALAYSIA

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ABSTRACT
The main objective of this study is to analyze the spatial pattern and the main cause of fatal road accidents in the black spot area. This study used fatal road accident data in the Northeast District of Penang, Malaysia for the years 2011 and 2012. By applying Geographic Information System (GIS), Kernel Density Estimation (KDE) analysis was used to identify the black spot area of fatal road accidents. The total number of fatal road accidents in 2011 and 2012 was 90 and 88 respectively. The analysis shows that the highest fatal road accidents, which were 55 cases, were caused by skidding vehicles while the nethermost cause was the impinged side of the vehicles, mechanical, reversal and U laps, respectively with only 1 case for each factor. The major causes of fatal road accidents at the black spot area were due to the skidding vehicle, driver changing route, grazed vehicle, road users crossing roads and drivers using opposite routes. From the analysis, this study shows that each black spot area had different causes for the fatal road accident. Even though human attitude or drivers' behavior has been accepted as the main cause of fatal road accidents, however, there are also a few other causals for black spot area of fatal road accidents causal such as road physical factors, population density factors, economic and social activity factors. This is because the human attitude or behavior would be influenced by these causes which then stimulate the good or bad conduct of a driver. Therefore, the monitoring and prevention conducted to reduce the rate of fatal road accidents should take into account and stress more on the cause of the accident.

Keywords: Fatal road accident, factor, Geographic Information System (GIS), Kernel Density Estimation (KDE), pattern, road

INTRODUCTION

In these present days and time, transportation, regardless of its type and class, are an essential for human to move from one place to another place for the use of work, education, health and many more. Road accident is one of the global problems that occur around the world, especially among the developing countries (Mohd Khairul *et al.*, 2018; Noorliyana *et al.*, 2017; Abdul Kareem, 2003; World Bank, 1993). The number of road accidents in Malaysia is constantly increasing each year (Akmal, 2016). It also increases in tandem with the rate of population growth (Manan, 2011). In 2010, a number of 414,421 accident cases were recorded compared to 397,330 cases in 2009.

A road accident is a tragedy for the victim himself, family, community or country as the consequences of the accident will cause severe injury which may result in a permanent injury or death. Despite having and running various campaigns and programs like *Ops Pacak, Ops Sikap,* as well as *Ops Statik* and so on, this scenario does stay worrying to the parties who involve directly or indirectly with it (Noorliyana *et al.*, 2017).

LITERATURE REVIEW

Generally, a road accident can be defined as a collision between drivers with objects due to loss of control (Bergel-Hayat *et al.*, 2013). While, according to Prasetijo *et al.* (2014), road accident happens when skirmishes between vehicular movements which then causes interruption and traffic congestion traffic. In Malaysia, the definition of a road accident for statistical purposes is as contained in Malaysia Road Accident Statistics Report 2012, where is the road accident is an incident that happens on the public road or private that caused either from negligence or lack of anybody or caused by environmental factors causing any collision that involve at least a moving vehicles where is damage or injury including death that faced by anybody, property, vehicle, structure or animal that involve the incident and complained to the police (Polis Diraja Malaysia, 2009). It is one of the main factors to the cause of human fatal after chronic diseases such as stroke, heart disease and lung infection (Mohd Khairul *et al.*, 2018; Wan Muhammad Taufik and Tarmiji, 2015; World Health Organization, 2013).

"The main influencing factors can be classified into three categories, which are road engineering and traffic conditions, vehicle features and capacities, as well as drivers' behaviors and performance" (Tarmiji *et al.*, 2018, p. 133). Jaafar *et al.* (2003) supported that user or human factor is the main cause of road accidents besides infrastructure of road quality, traffic volume and the environment. Among the consumer factors are driving over speed limits, using mobile phones while driving, trailing other vehicles with close proximity, not adjusting the speed of the vehicle with the road condition, losing focus, failing to stop at the crossroads and so on (Peter *et al.*, 2012). According to Sabey and Staughton (1975), consumer factors account for 95% of the road accidents while related factors between road users and the environment contribute 25% of the

road accidents. The unpredictable environmental aspects are such as winding and steep roads, no signs, unsuitable road geometries and design and so on (Talib *et al.*, 2003).

General Theory of Human Behavior especially the driver's behavior while driving has been generally accepted as the main factor which causes an accident. Among the models that can be seen in identifying these human behaviors is based on Interface Theory which illustrates the general model of human driven behavior (Fuller, 2000; Fuller & Santos, 2002). Referring to the Interface Model, the level of task difficulty arises between requests in the driving task and the ability of a driver. If the capability exceeds the demand, then the driving task will be easy, whereas if the capabilities are the same as the demand then a driver will be at the maximum limit of his driving capability which is at a very difficult driving level. On the other hand, if the demand exceeds the ability then a person's drive will be too difficult and can be invoked on driving failure, lost control and subsequently causing a violation of fellow vehicles or vehicles crashing.

Location identification of roads with problems is one of the most important aspects on accident studies. Even though there is no standard definition at the international level in determining the black spot area of accidents, however the study conducted by Mark *et al.* (2013) has used the term "black spot area" as part of a road with a higher number of accidents than the other areas. However, studies conducted by Oulha *et al.* (2013) uses two approaches in determining the black spot area of road accidents through the analysis of goods and person movement and the Kernel Density Estimation analysis approach. Through this approach, the black spot area is determined by taking into account which areas are experiencing repeated recurrence of three to five cases within a year.

The study conducted by Talib (2003) which aims to analyze road accidents involving motorcyclists has shown that the main cause of accidents is due to the human attitude factors. This is because more than 59% of accidents occur on straight roads, more than 59% of accidents occur in rural areas and more than 62% of accidents involve consumers at the age of between 10 t0 30 years old. The results of the study have also shown that motorcyclists have the lowest probability of being involved with road accidents for every 1,000,000 km of registered vehicles compared to the other vehicles. In addition, the study conducted by Nizam *et al.* (2011) which aims to test the relationship between traffic injuries with the economic growth by using Malaysia's time series data from 1979 to 2007 indicates that the findings of this study have been supported by previous researchers who have conducted their studies in the developed countries.

METHODOLOGY

The Northeast District is part of the Penang Island with a total area of 121 km^2. The area is connected to the mainland by Penang Bridge and water transportation such as ferry. The location of this study area is located at latitude 5 ° 22 '16.28' 'N and longitude 100 ° 14' 14.22 " E. The Northeast District is the most populous

area in Penang with a total population of 508,181 people with a density of 4,200 people per square kilometer in 2010. The district is divided into seven Mukim namely Mukim 13, Mukim 14, Mukim 15, Mukim 16, Mukim 17, Mukim 18 and Georgetown.

The number of fatal road accidents in the Northeast District was the second highest in Penang in the years 2011, 2012 and 2013 with 90, 88 and 91 cases respectively. The area has 13 police stations and 83 police sectors. The police stations included in the study area were Lebuh Pantai, Dato Keramat, Central, Patani Road, Kampung Baru, Batu Feringghi, Tanjung Tokong, Ayer Itam, Bandar Baru, Taman Desa Permai Community, Jelutong, Sungai Nibong and Pulau Tikus as shown in Figure 1.

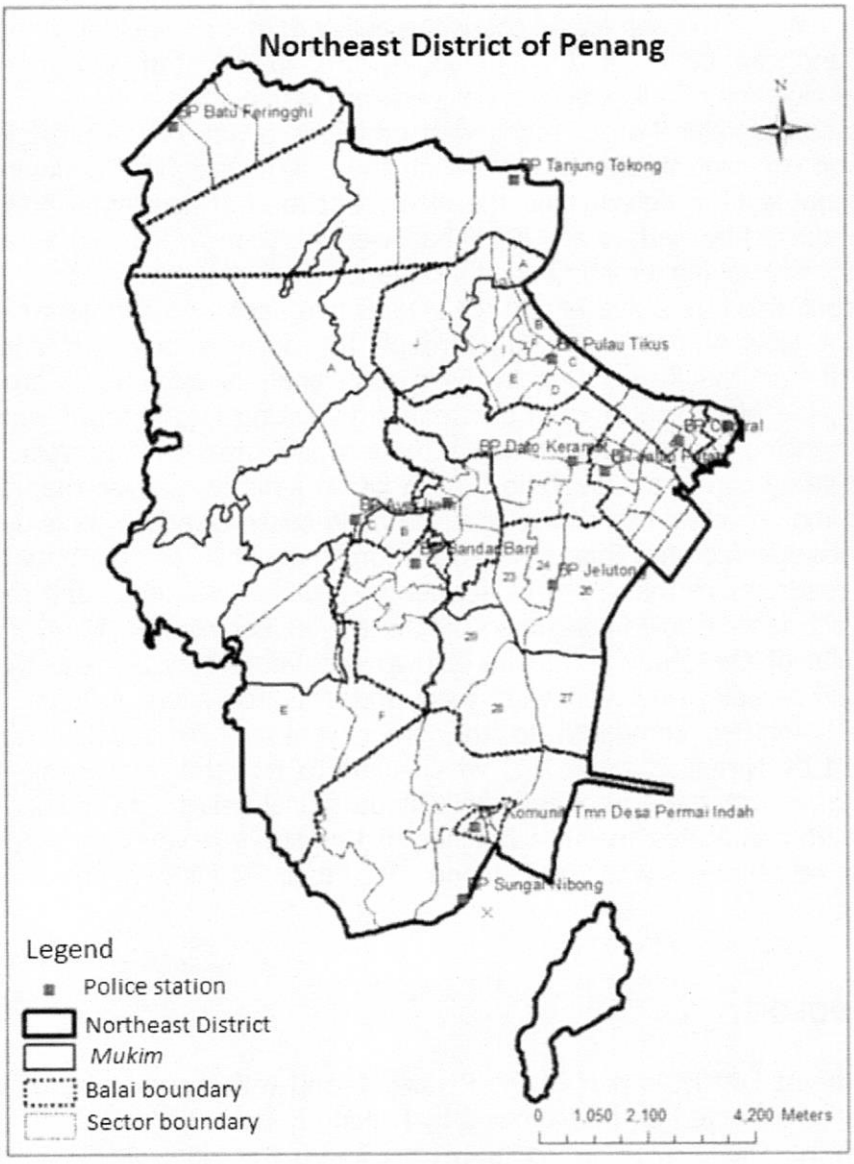

Figure 1: Map of the Northeast District of Penang

This study used two types of data namely spatial data and non-spatial data to show the number of fatal road accidents in the study area. Spatial data is important in this study as it involves mapping and analysis of spatial element by using GIS software. Among the spatial data used in this study were the coordinates of fatal road accidents, the Northeast District maps, *mukim* maps, police station boundary maps, police sector boundary maps and road maps whereas non-spatial were the time of fatal road accidents, years and causes of fatal road accidents. The data was obtained from Bahagian Trafik, Ibu Pejabat Polis Kontinjen Pulau Pinang. The method used in this study was the estimation method of KDE by using spatial analysis tool in ArcGIS 10.3 software to identify the black spot area involving fatal road accident. This method calculated the density of the properties studied along the road in accordance with the search radius of 500 meters. KDE method was used to determine the black spot area because it has the ability in calculating the density of point characteristics in a nearby range along the path of the study area.

The definition of black spot areas used by the researcher for this study is parallel with the definition of black spot area used in the study conducted by Mark *et al.* (2013). In their study, Mark *et al.* (2013) defined black spot area as a road section with higher number of fatal accidents compared to the other areas. Furthermore, based on a study conducted by Apparao *et al.* (2013) which aimed at identifying the black spot of fatal road accidents also used a similar definition of black spot areas.

RESULTS AND DISCUSSION

Table 1 shows the main cause of fatal road accidents for the years 2011 and 2012. The highest number that were 55 cases happened due to skidding vehicle, followed by 17 cases of collision from behind while 15 cases were due to pedestrian crossing as well as drivers changing route suddenly, respectively with the same number of 15 cases. The nethermost cause of fatal road accidents was caused by vehicle collision on the side, mechanical problems, U turn in the wrong place, respectively with only 1 case for each factor.

Based on Table 2, the presence of main cause of fatal road accident was highly happened within the police station boundaries of Balai Polis Dato Keramat followed by Balai Polis Jelutong. While, the nethermost cause of fatal road accidents happened within the police boundaries of Balai Polis Kampung Baru and Balai Polis Komuniti Taman Desa Permai with zero cases respectively.

Table 1: Causes of Fatal Road Accidents in the Northeast District of Penang

Cause	Number of cases		
	2011	2012	Total
Grazed vehicle	4	7	11
Front and front collision	2	1	3
Collision at the road junction	6	6	12
Collision from behind	9	8	17
Hit and run	3	3	6
Driver crash on pedestrian	3	0	3
Collision on the side of vehicles	1	0	1
Driver using opposite route	3	0	3
Driver using wrong route	0	3	3
Mechanical problem of vehicles	1	0	1
Vehicle move against traffic/current	1	1	2
Pedestrian crossing	6	9	15
Vehicle moves backward	2	0	2
Reverse vehicle	0	1	1
Vehicle that makes U turn	0	1	1
Skidding vehicle	29	26	55
Driver do not obey the traffic lights	3	2	5
Driver changing route suddenly	12	3	15

Table 2: Number of Fatal Road Accidents Due to Vehicle Skidding according to Police Station Boundary

Police Station Boundary	Number of Fatal Road Accidents
Balai Polis Lebuh Pantai	5
Balai Polis Dato Keramat	12
Balai Polis Central	1
Balai Polis Jalan Patani	3
Balai Polis Kampung Baru	0
Balai Polis Batu Feringghi	1
Balai Polis Tanjung Tokong	3
Balai Polis Ayer Itam	1
Balai Polis Bandar Baru	4
Balai Polis Komuniti Taman Desa Permai	0
Balai Polis Jelutong	11
Balai Polis Sg Nibong	7
Balai Polis PulauTikus	7

Figure 2 and Figure 3 show the black spot area of fatal road accidents in the years 2011 and 2012. The fatal road accident area in the year 2011 mostly occurred at the exit area to Penang Bridge, Lebuhraya Dr Tun Dr LCE road section along the exit to Jalan Jelutong and Lebuhraya Thein Teik between the junctions to Jalan Tun Mohd Salleh Ismail until the junction to Jalan Zoo. Black spot area for fatal road accident in the year 2012 were at Gat Lebuh Nordin section between Lebuhraya Mc Nair up to Jalan Brick Klinn and Jalan Masjid Negeri between the junction to Persiaran Mas and junction to Jalan Hamilton. Table 3 shows the black spot areas of fatal road accidents according to the year and the main cause.

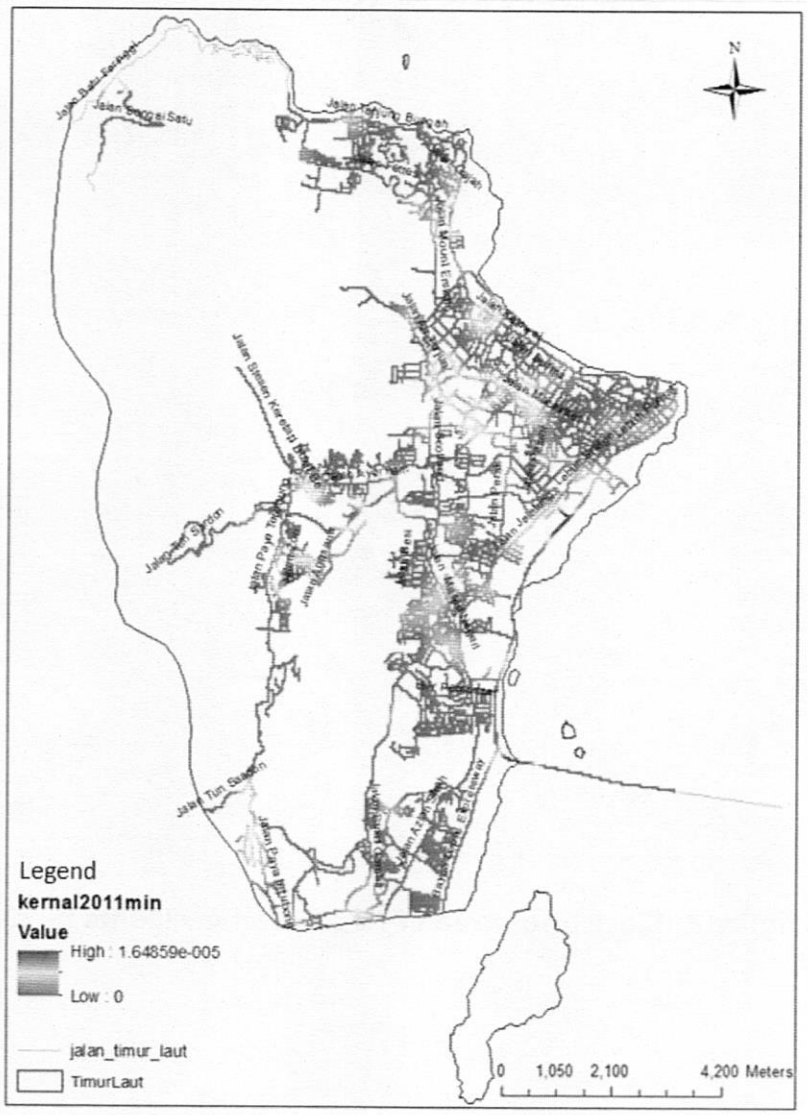

Figure 2: Black Spot Area of Fatal Road Accidents in 2011

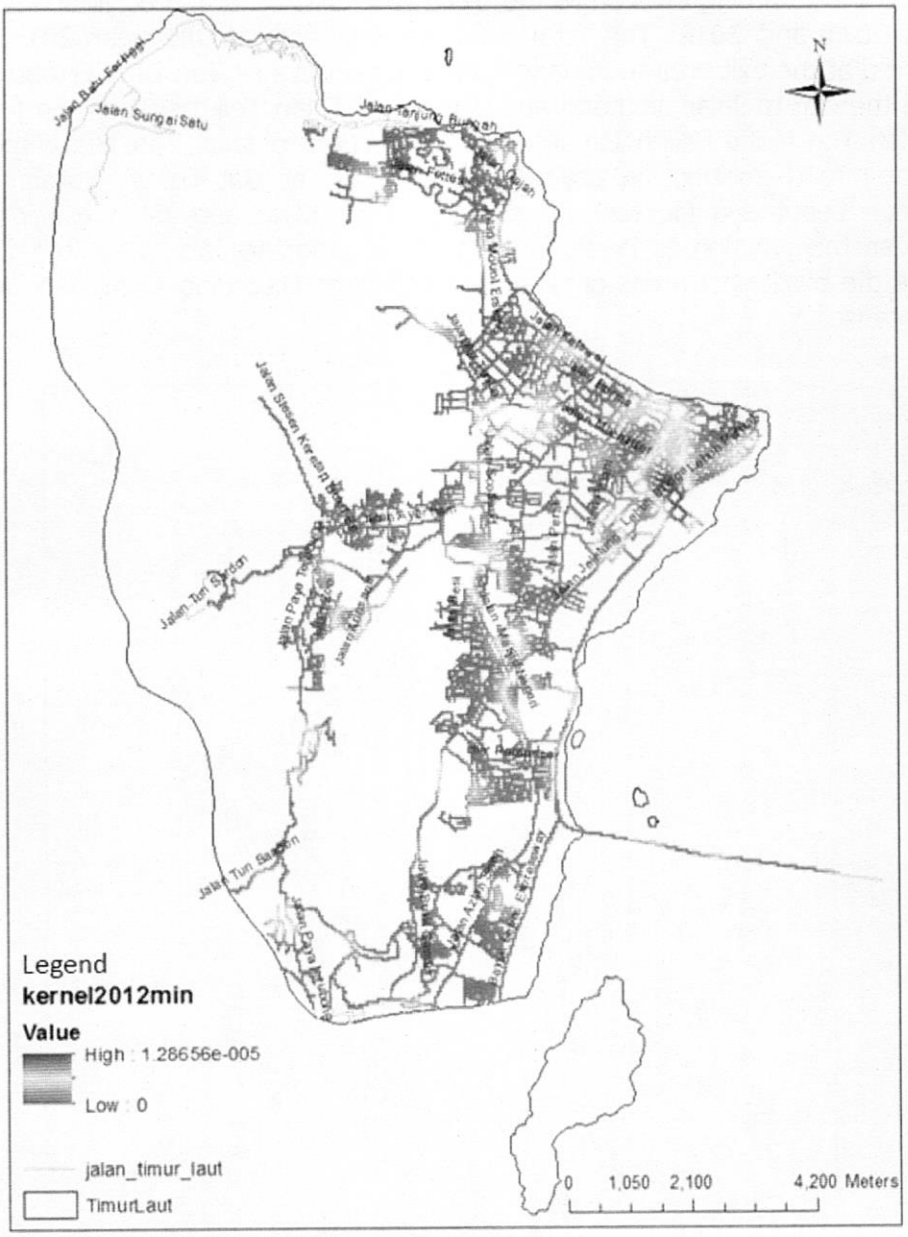

Figure 3: Black Spot Area of Fatal Road Accidents in 2012

Table 3: Black Spot Area of Fatal Road Accidents According to the Main Cause

Year	Black spot area	Main cause
2011	Exit to Penang Bridge	Grazed vehicle
	Lebuhraya Dr Tun Dr LCE along the exit to Jalan Jelutong	Pedestrian crossing
	Lebuhraya Thein Teik between the junction to Jalan Tun Mohd Salleh Ismail until the junction to Jalan Zoo	Changing lane
2012	Jalan Lebuh Nordin between Lebuhraya Mc Nair and Jalan Brick Klinn	Pedestrian crossing
	Jalan Masjid Negeri between the junction to Persiaran Mas and junction to Jalan Hamilton	Skidding

Based on Figure 4, the black spot area of fatal road accidents were at Lebuhraya Thean Teik from the junction to Jalan Tun Mohd Salleh Ismail to Jalan Medan Angsana, Lebuhraya Tun Dr Lim Chong Eu from the exit to Jalan Ahmad Nor up to Metro Avenue, part of Lebuhraya Tun Dr Lim Chong Eu starts from Sungai Pinang Bridge to Gat Lebuh Nordin, Jalan Residensi starts from the junction of Jalan Hospital to the junction of Jalan Macalister, the side of the exit road to the Penang Bridge, the section of Jalan Paya Terubong starts from Lebuh Relau to Tingkat Bukit Jambul, Jalan Utama section starts from four intersections of Jalan Scottland to Jalan Nunn junction, Jalan Tanjung Tokong section strats from the junction to Jalan Pantai Molek up to the junction of Jalan Fettes and the part of Jalan Masjid Negeri starts from the junction of Jalan Besi to the junction of Lorong Batu Lancang. Table 4 shows the fatal road accident black spot areas according to the main cause of the accidents.

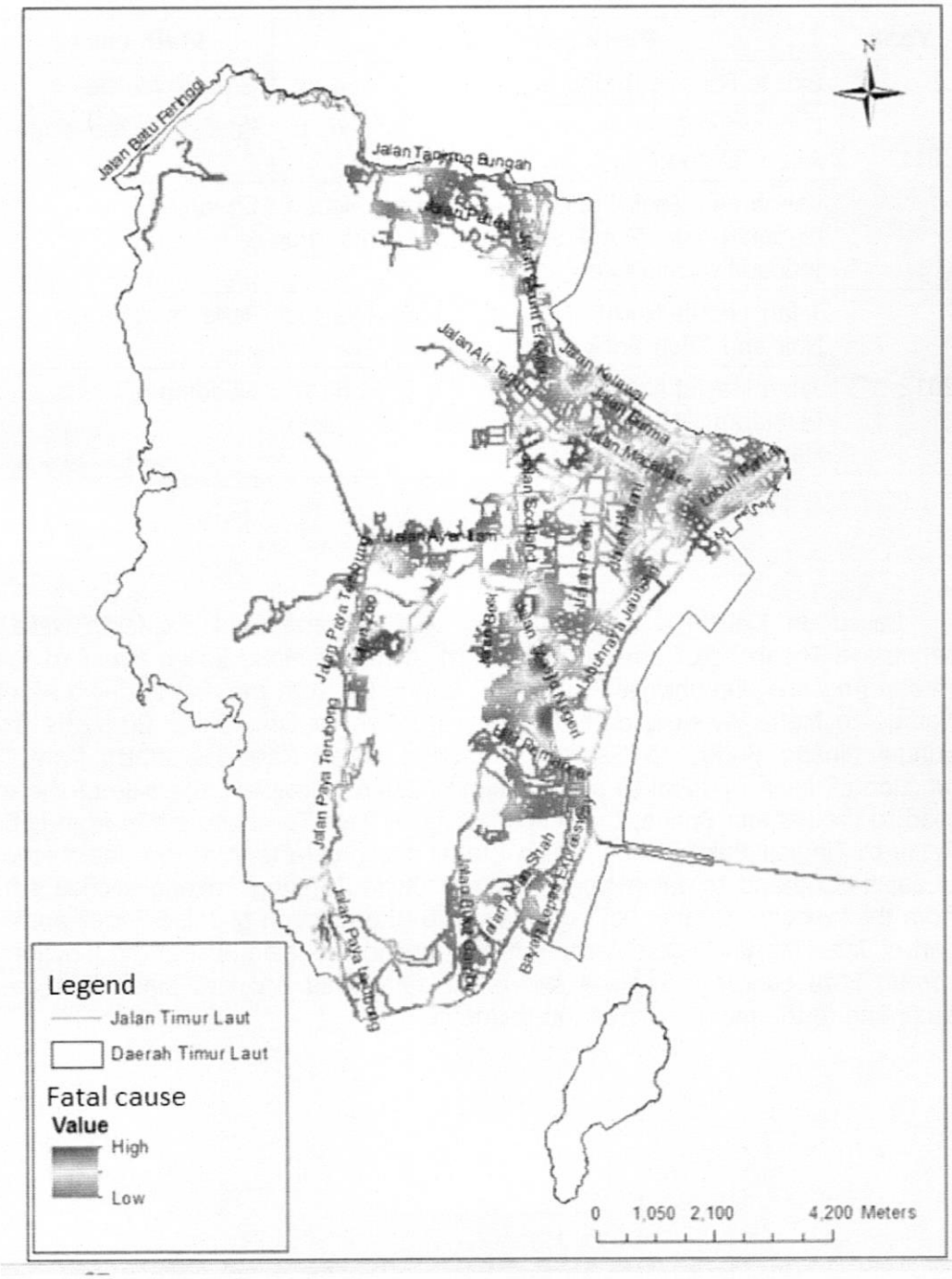

Figure 4: Black Spot Area of Fatal Road Accidents in 2011 and 2012

Table 4: Black Spot Area of Fatal Road Accidents According to Main Cause

Black spot area	Main cause
Jalan Lebuhraya Thean Teik starts from the junction to Jalan Tun Mohd Salleh Ismail to Jalan Medan Angsana junction	Skidding vehicle and drivers changing route suddenly
Jalan Lebuhraya Tun Dr Lim Chong Eu starts from the exit to Jalan Ahmad Nor to Metro Avenue	Pedestrian crossing
Jalan Lebuhraya Tun Dr Lim Chong Eu starts from Sungai Pinang Bridge to Gat Lebuh Nordin	Grazed vehicle
Jalan Residensi starts from the junction of Jalan Hospital to the junction of Jalan Macalister	Skidding vehicle
Exit road to Penang Bridge	Grazed vehicle
Jalan Paya Terubong starts from Lebuh Relau to Tingkat Bukit Jambul	Drivers using opposite routes
Jalan Utama starts from the four intersections of Jalan Scotland to Jalan Nunn junction	Skidding vehicle
Jalan Tanjung Tokong starts from the junction to Jalan Pantai Molek to the junction of Jalan Fettes	Pedestrian crossing
Jalan Masjid Negeri starts from the junction of Jalan Besi to the junction of Lorong Batu Lancang	Skidding vehicle

Figure 5 and 6 show the black spot area of fatal road accidents by time. Based on Figure 5, the black spot area of fatal road accidents during day time were at the side of Lebuhraya Thean Teik which starts from the junction to Jalan Tun Mohd Salleh Ismail up to Medan Angsana junction, Jalan Paya Terubong road section starts from Lebuh Relau junction up to Bukit Jambul junction and part of Lebuhraya Tun Dr Lim Chong Eu starts from Sungai Pinang Bridge to Gat Lebuh Nordin junction. Figure 6 shows that the black spot areas were at the part of Lebuhraya Tun Dr Lim Chong Eu which starts from the intersection of Jalan Akuarium to the junction of Jalan Tengku Kudin, Jalan Residensi section starts from Jalan Hospital to the junction Jalan Macalister and Jalan Tanjung Tokong section starts from Jalan Pantai Molek to Jalan Fettes. Table 5 below shows the fatal road accidents of black spot areas according to the time and the main cause of the accident.

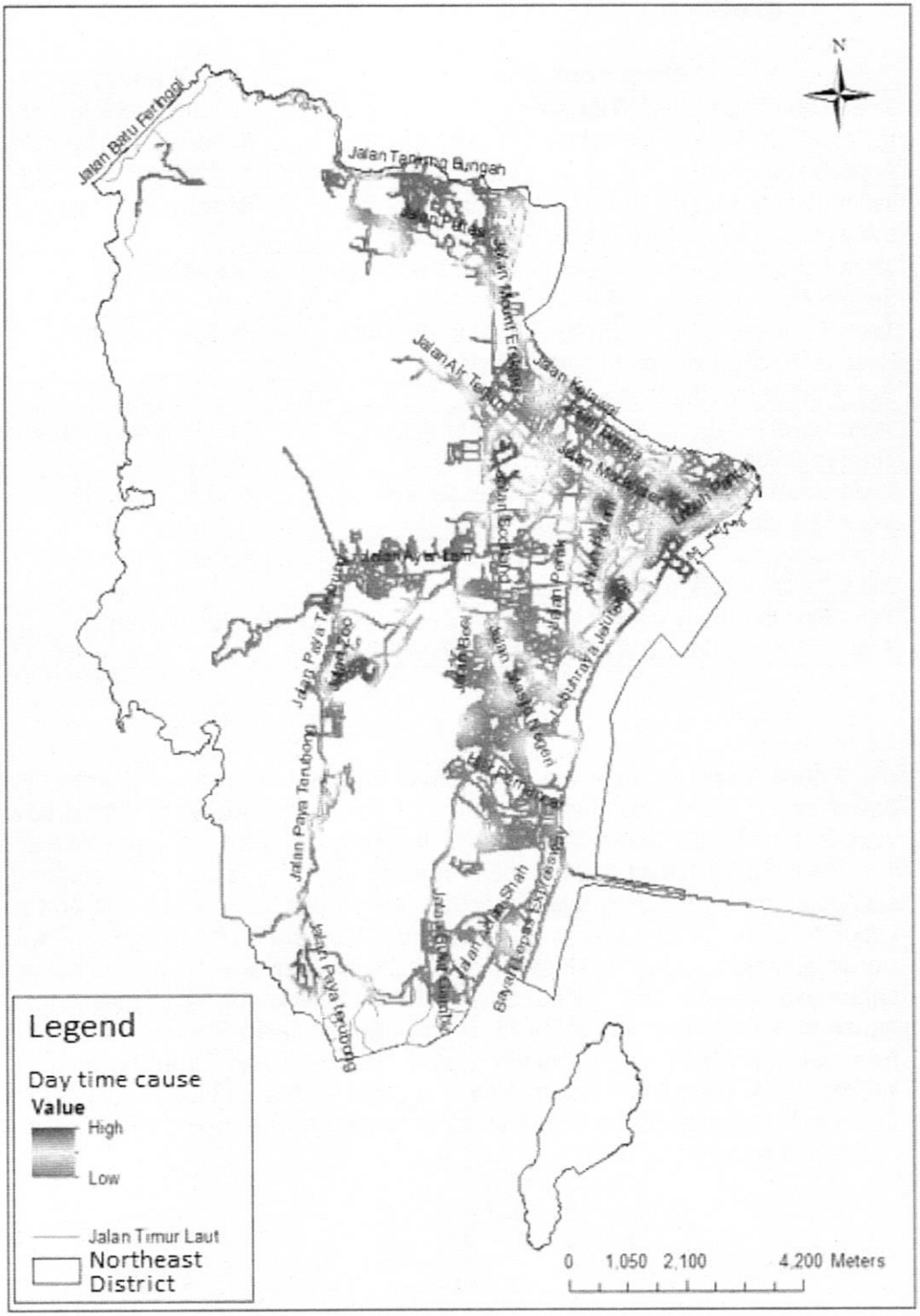

Figure 5: Black Spot Area of Fatal Road Accidents During Day Time

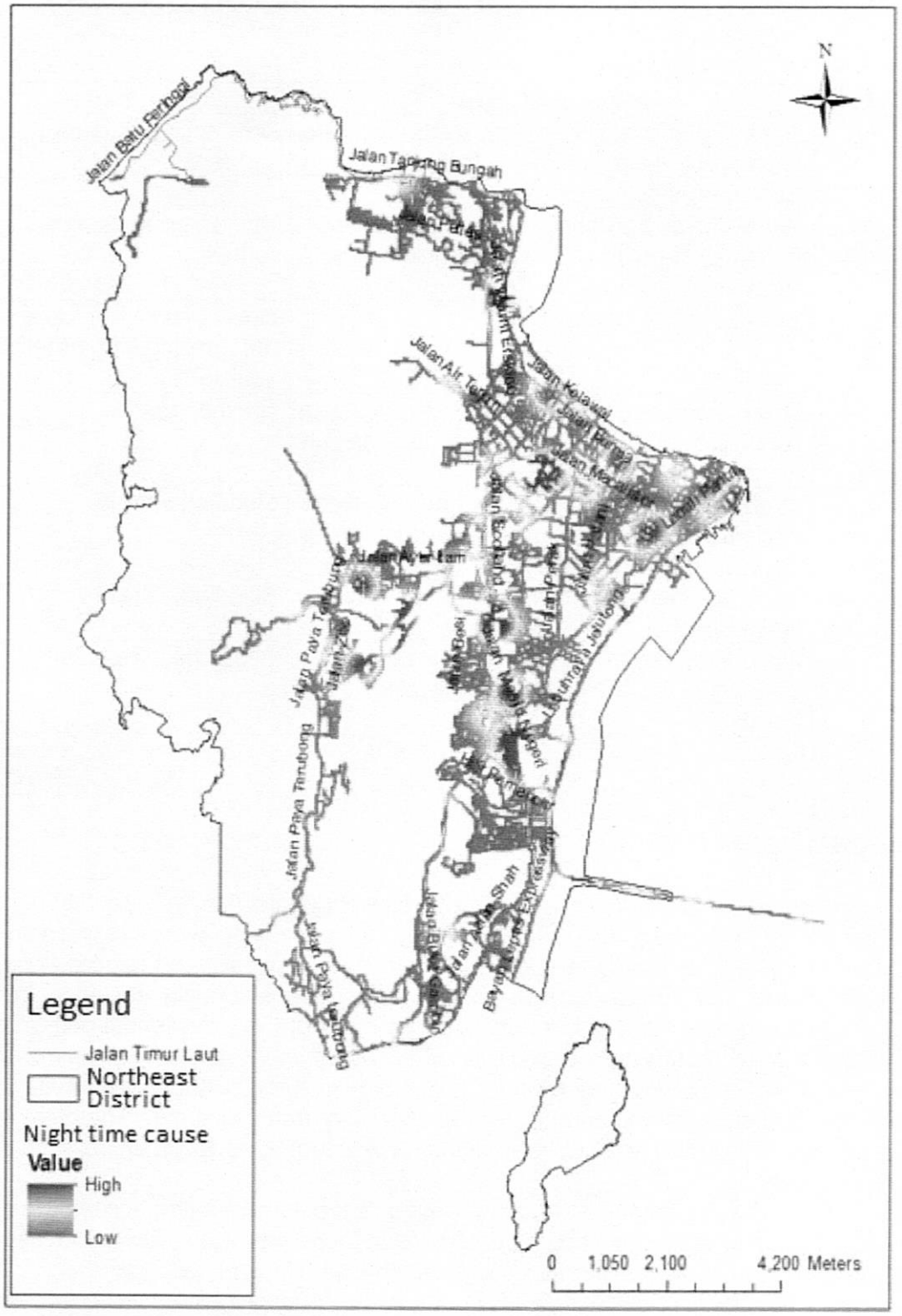

Figure 6: Black Spot Area of Fatal Road Accidents during Night Time

Table 5: Black Spot Area of Fatal Road Accidents According to Main Cause

Time	Black spot area	Main cause
Day time	Jalan Lebuhraya Thean Teik starts from the junction to Jalan Tun Mohd Salleh Ismail up to Medan Angsana junction	Drivers changing route suddenly
	Jalan Paya Terubong starts from Lebuh Relau junction up to Tingkat Bukit Jambul junction	Drivers using opposite routes
	Exit to Penang Bridge	Drivers changing route and grazing with other vehicle
	Jalan Lebuhraya Tun Dr Lim Chong Eu starts from Sungai Pinang bridge to Gat Lebuh Nordin junction	Grazed vehicle
Night time	Jalan Lebuhraya Tun Dr Lim Chong Eu starts from the junction of Jalan Akuarium up to Jalan Tengku Kudin junction	Skidding vehicle
	Jalan Residensi starts from the junction of Jalan Hospital to Jalan Macalister junction	Skidding vehicle
	Jalan Tanjung Tokong starts from the junction of Jalan Pantai Molek to Jalan Fettes	Pedestrian crossing

CONCLUSION

In conclusion, the main cause of fatal road accidents (cause with the highest number or frequency) in the Northeast District of Penang was skidding vehicle. This is due to the human attitude that often drives speedily and recklessly which then causes the vehicle to lose control. It is then eventually resulting in the vehicle being driven out of the drivers' control. In addition, the spatial pattern also shows that the main cause of the road accidents happens at the boundary of Dato Keramat Police Station and Jelutong Police Station because these two areas were a major road network and usually had a high traffic volume. Therefore, the potential of skidding vehicles was higher when compared to other police station boundaries.

Even though human attitude or drivers' behavior has been accepted as the main cause of fatal road accidents, however there are also a few other causals such as road physical factors, population density factors, economic and social activity factors. This is because the human attitude or behavior will be influenced by these causes which then stimulate the good or bad conduct to the driver. Therefore, the monitoring and prevention actions, especially from The Malaysian Institute of Road Safety (MIROS) should take into account and stress more on the

factor of accidents. To be precise, the stoppage should be planned appropriately and applicably according to each of the causes in order to gain maximum effect of deterrence.

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REFERENCES

Abdul Kareem. (2003). Review of Global Menace of Road Accidents with Special Reference to Malaysia – A Social Perspective. *Malaysian Journal of Medical Sciences, 10*(2), pp. 31-39.

Akmal Abdelfatah. (2016). Traffic Fatality Causes and Trends in Malaysia. *Malaysia Sustainable Cities Program, Working Paper Series.* pp. 1-19.

Apparao, G. P. & Mallikarjunareddy, G. R. (2013). *Identification of Accident Black Spots for National Highway Using GIS*. International Journal of Scientific & Technology Research. Vol. 2(2). pp. 154-157.

Bergel-Hayat, R., Debbarh, M., Antoniou, C., & Yannis, G. (2013). Explaining the Road Accident Risk: Weather Effects. *Accident Analysis and Prevention, 60,* pp. 456-465.

Fuller, R. (2000). *The task–capability interface model of the driving process*, Recherche Transports S´ecurit´e 66, 47–59.

Fuller, R., Santos, J.A. (2002). *Psychology and the highway engineer. In: Fuller, R., Santos, J.A. (Eds.).* Human Factors for Highway Engineers. *Pergamon,* Oxford, pp. 1–10.

Jaafar, T. R., Mustafa, M. F., Kemin, S., & Kasiran, R. (2003). Kemalangan Jalan Raya: Analisis Data Membabitkan Pengguna Motosikal. *Jurnal Teknologi, 38*(B), pp. 1–14.

Manan, W.N.W. (2011). *Accident Prediction Model at Un-Signalized Intersections Using Multiple Regression Method* (Master Thesis). Universiti Tun Hussein Onn Malaysia.

Mark, R. D. L., Nelson, D., Hussein, L. & Jun, C. (2013). Black Spot Cluster Analysis of Motorcycle Accidents. *Proceedings of The Eastern Asia Society for Transportation Studies.* Vol. 9.

Mohd Khairul Amri Kamarudin, Noorjima Abd Wahab, Roslan Umar, Ahmad Shakir Mohd Suhaidi, Muhammad Hafiz Md Saad, Nik Rozaireen Nik Rosdi, Sarah

Alisa Abdul Razak, Muhamad Murtadha Merzuki, Abdul Salam Abdullah, Siti Amirah & Asyraff Mohd Ridzuan. (2018). Road Traffic Accident in Malaysia: Trends, Selected Underlying, Determinants and Status Intervention. *International Journal of Engineering & Technology, 7*(4.34), pp. 112-117.

Nizam B. Ahmat, Nor Ghani Md Nor, Ahmad Mohd Zin & Abu Hassan Shaari Md Nor (2011). *Hubungan Kecederaan Trafik Dengan Pembangunan Ekonomi Malaysia.* Jurnal Ekonomi Malaysia. Vol. 45. pp. 81-87.

Noorliyana Omar, Joewono Prasetijo, Basil David Daniel & Mohd Asrul Effendi Abdullah. (2017). Accident Analysis and Highway Safety. MATEC Web of Conferences. Retrieved from https://www.matec-conferences.org/articles/matecconf/pdf/2017/17/matecconf_iscee2017_08002.pdf

Oulha, R., Brahimi, K., Boumediene, A., Dali, F. & Madouche, M.A. (2013). *GIS contributing to Identify Accident Black Spots On National Highway: Case Study of Wilaya of Mascara*. International Journal of Chemical, Environmental & Biological Sciences (IJCEBS). Vol. 1 (5). pp. 775-778.

Polis Diraja Malaysia (PDRM). (2009). Laporan Tahunan PDRM 2009 (Royal Malaysia Police annual report, 2009). Royal Malaysia Police.

Peter, L., Zulkifli Abd Aziz & Rusman Bassri (2012). *Prihatin: Sentiasa Bersama Mu*. SpancoSdn. Bhd. Batu Caves.

Prasetijo, J., Razzaly, W., Wu, N., Ambak, K., Sanik, M. E., Rohani, M. M. & Ahmad, H. (2014). Capacity Analysis of Priority Intersections with Flare Under Mixed Traffic Conditions, Procedia - Soc. Behav. Sci., 138, pp. 660–670.

Sabey, B. E. And Staughton (1975). Interacting Roles of Road Environment, Vehicle and Road-User in Accident. *IAATM 5th International Conference. London, Spetember.*

Talib Ria Jaafar, Mohd Faizar Mustafa, Sutiman Kemin & Ramlan Kasiran (2003). *Kemalangan Jalan Raya: Analisis Data Membabitkan Pengguna Motosikal.* Jurnal Teknologi. Vol. 38(B). pp. 1-14.

Wan Muhammad Taufik Wan Hussin and Tarmiji Masron (2015). Analisis trend dan pola keruangan kemalangan maut jalan raya di Malaysia: Kajian kes di Daerah Timur Laut, Pulau Pinang. *GEOGRAFIA Online Malaysian Journal of Society and Space, 11*(13), 104-114.

Tarmiji Masron, Wan Muhammad Taufik Wan Hussin, Mohd Norarshad Nordin, Nur Faziera Yaakub and Mohd Azizul Hafiz Jamian. (2018). Applying GIS in Analysing Black Spot Areas in Penang, Malaysia. *Indonesian Journal of Geography 50*(2), 133-144.

World Bank. (1993). Investing in health world development report 1993. Oxford University Press.

World Health Organization (WHO). (2013). *Global Status Report On Road Safety 2013.* WHO.