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Analyzing The Violent Crime Patterns In Peninsular Malaysia : Exploratory Spatial Data Analysis (ESDA) Approach

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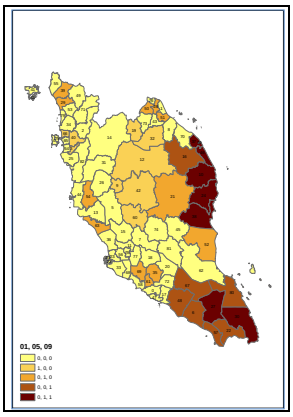

Abstract

The objective of this study is to analyze the spatial cluster of crime cases in Peninsular Malaysia by using the exploratory spatial data analysis (ESDA). In order to identify and measure the spatial autocorrelation (cluster), Moran's *I* index were measured. Based on the cluster analyses, the hot spot of the violent crime occurrence was mapped. Maps were constructed by overlaying hot spot of violent crime rate for the year 2001, 2005 and 2009. As a result, the hypothesis of spatial randomness was rejected indicating cluster effect existed in the study area. The findings reveal that crime was distributed nonrandomly, suggestive of positive spatial autocorrelation. The findings of this study can be used by the goverment, policy makers or responsible agencies to take any related action in term of crime prevention, human resource allocation and law enforcemant in order to overcome this important issue in the future.

Keywords: Violent crime; Moran's *i* index; hot spot mapping.

Abstrak

Objektif kajian ini adalah untuk menganalisis pengelompokan reruang kes-kes jenayah di Semenanjung Malaysia dengan menggunakan analisis data reruang penerokaan (ESDA). Dalam usaha untuk mengenal pasti dan mengukur autokorelasi reruang (kelompok), indeks Moran, *I* telah diukur. Berdasarkan analisis pengelompokkan, *hotspot* berlakunya jenayah kekerasan akan dipetakan. Peta telah dibina dengan menggabungkan lapisan *hot spot* kadar jenayah kekerasan bagi tahun 2001, 2005 dan 2009. Hasilnya, hipotesis rawak reruang ditolak, menunjukkan kewujudan kesan pengelompokan di kawasan kajian. Dapatan kajian menunjukkan bahawa jenayah tertabur secara tidak rawak, menandakan wujud autokorelasi reruang yang positif. Hasil kajian ini boleh digunakan oleh kerajaan, pembuat dasar atau agensi yang bertanggungjawab untuk mengambil tindakan yang berkaitan dalam aspek pencegahan jenayah, peruntukan sumber manusia dan penguatkuasaan undang-undang untuk mengatasi isu yang penting ini pada masa hadapan.

Kata kunci: Jenayah keganasan; indeks Moran's i; pemetaan *hot spot*

1.0 INTRODUCTION

Criminal activities are inevitable social problems that are faced by most of the countries worldwide. Various plans and strategies have been taken by law enforcement agencies and local government to address these problems. These problems have a large impact on countries around the world whether developed countries, developing countries and not forgetting, for the undeveloped countries. In order to take any appropriate action in dealing with crime problems, the study on the crime situation and the distribution should be carried out.

There are a number of previous studies related to crime in various countries. Dutt and Venugopal [5] studied the crime patterns in India by using data of 14 different types of crime for 99 cities in India. They used standard correlation methods to analyze the relationships between types of crime and the spatial patterns. The occurrences of crime are associated with other crimes or crimes inspire others. They also found that crime rates are higher in cities than in rural area. Meanwhile, Tsushima [19] studied the impact of economic structure on crime (1986-1988) in 47 prefectures of Japan by using multiple regression analysis. They found that unemployment rates have a positive relation with homicide and robbery and the degree of inequality has positive correlation with larceny. Another previous study is done by Appiahene-Gyamfi [7], which investigated the robbery trends and patterns in Ghana from 1982 until 1993. In order to discuss the trends and patterns, the author used descriptive statistics based on total crime, total robbery, total population and then the rate of robbery per 100,000 people. Based on the analysis the author concluded that many robbery cases occurred in a central of socio-economic activities such as at cities and urban area.

In Malaysia, Sidhu [16] studied the crime situation from 1980-2004 by looking at the overall pattern of crime and also property crime and violent crime by using descriptive statistics analysis. He analyzed the crime situation based on rate of crime and then discussed the factors that are believed to give impact on crime situation. Furthermore, Sidhu [17] extended his work in studying the crime situation using the same data set. He found that, crime situation was also affected by global economic situation. When economic downturn or recession happened, unemployment rate will rise and people faced difficulty in finding a higher paying job. This scenario will increase the crime rate. Based on the population growth rate, the projection of crime rate was done starting from 2002 to 2015. Another study on crime issue was done by Cole and Gramajo [4]. They explore the relationship between homicide rates in 91 countries and several types of factors such as socio-economic, cultural and institutional factors. These countries were grouped into seven categories along geographic and socio-economic lines which are established market economies, formerly socialist economies, middle east crescent, other Asia and islands, Sub-Saharan Africa, Latin America and the Caribbean. In order to examine this relationship, the regression analysis was employed. They found that the higher level of cultural and ethnic heterogeneity will increase the rate of homicide. They also reported that education was significantly associated with homicide rates.

The pattern of crime problem can be detected differently based on specific types of environments. It is believed that, crime was higher in the most developed and densely populated area such as at large cities, town or urban area compared to underdeveloped area such as rural area. This situation happened because of several factors such as environment characteristic (i.e. densely populated), economics, social, political and demographics (Appiahene-Gyamfi [8]; Perreault et al. [14]; Savoie et al.[15]. The result of a study done by Gyamfi [8] was parallel with this finding. The author reported that crime was highest in southern Ghana where this is the more developed and densely populated region. In addition, crime cases increased from the northern to southern Ghana, with a heavy concentration in Ashanti, the most populous region. Savoie et al. [15] also found that the property crime highly happened in the city centre of the Island of Montreal. Meanwhile, Perreault et al. [14] reported that, youth crime is distributed over many small hot spots across the entire island of Montreal.

Recently, the opportunities for using social science data (i.e. crime data, disease data and accident data) to estimate spatial patterns and relationships increased rapidly because of the development in tools and methods in spatial analysis field. Spatial analysis is a method that is widely used to study an issue related to space, place or geographical circumstances. In spatial analysis, the location where an event occurs may provide an indication the reason why that particular event occurs. In the beginning, spatial analysis involves mapping methods, reviews and geographic location without formal techniques. Starting from 21st century, spatial modern analyses were widely developed and focus on specific use of computer-based. Mapping is one of the most widely used techniques in spatial analysis (Chaikaew, Tripathi, & Souris [3]; Berke [2]).

In crime studies, one of the important issues is spatial clustering. It is very useful especially in identifying the relationship between exposure and the cases concerned. However, this technique only can be used in identifying cluster visually but not statistically. In order to overcome the lacking of this conventional mapping technique, several methods can be used to identify spatial clustering such as spatial scan statistics, Getis's G index and Tango' C index. However, many previous research indicate that the most commonly index used is Moran's I (Pacheco & Tyrrell [13]; Sridharan et.al. [18]; Holt & Lo [9]; Zhang et. al [21]; Osei & Duker [12]; Erdogan [12]; Ye & Wu [20]).

In Malaysia, limited studies have been done on crime data using statistical method. Most of the past studies focused on expert opinion or knowledge and discussed about causes and effects of crime, such as studies done by Kanyo and Norizan [11], Sidhu [16] and Sidhu [17]. The investigation of the crime situation will become more significant by using the combination of qualitative and quantitative techniques. In order to understand crime occurrence, it is important to observe the surrounding circumstances and to measure the similarities with neighbouring districts in the study area. It is believed that geographical and socio-economic characteristic of local and neighbourhood area have an impact on crime. In order to overcome this problem, the objective of this study was to analyze the spatial cluster of violent crime cases in Peninsular Malaysia by using the Exploratory Spatial Data Analysis (ESDA). Instead of to identify the patterns of the data by using Exploratory Data Analysis (EDA), the ESDA technique was able to detect the spatial patterns of the data. The global Moran's I index will be used to measure the global spatial autocorrelation to identify the existence of autocorrelation in the study area. Meanwhile, the local Moran's I index was employed to detect the individual locations of spatial autocorrelation by taking into consideration the effect of the neighboring regions or districts.

2.0 DATA

Malaysia comprises of Peninsular Malaysia and East Malaysia. According to 2000 census, Malaysia is divided into 14 states, 82 administrative districts in Peninsular Malaysia and 53 administrative districts in East Malaysia (Jabatan Perangkaan Malaysia, 2000). In this study, administrative district is used as the unit of analysis. Due to data availability, only twelve states located in Peninsular Malaysia consist of 82 administrative districts were considered in this study (Appendix A).

The data employed in this study is the number of crime cases, which were obtained from the Royal Malaysia Police (PDRM). There are two categories of crime cases included in the index crime statistics known as violent and property crime. The definition of index crime statistics is the crimes that are reported with sufficient regularity and with sufficient significance to be meaningful as an index to the crime situation (Sidhu [16]). This study only considered the type of crime that included in index crime measurement which is violent crime.

The violent crime included murder, gang robbery with firearm, gang robbery without firearm, robbery with firearm, robbery without firearm, rape and voluntarily causing hurt. The data crime from the year 2000 until 2009 according to each districts reported in Peninsular Malaysia was analyzed in this study.

3.0 EXPERIMENTAL

Moran's I index was used to identify and measure the spatial autocorrelation. Global autocorrelation is defined as :

$$I = \left(\frac{1}{s^2}\right) \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{3.1}$$

where $s^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$. X_i is the violent crime rate value in area i and x_j is the violent crime rate value in area j $(j \neq i)$. $\bar{x}$ is the average value of x_i with the sample number of n. w_{ij} is a weight that measure connectivity in area i with neighbour area j. In this study, we used contiguity weight (sharing a common border) known as rook contiguity weight as written below:

$$w_{ij} = \begin{cases} 1 & \text{if location i and j sharing boundary} \\ 0 & \text{otherwise} \end{cases} \quad (3.2)$$

The range of possible values of I lies between -1 and 1. Positive values indicate that the location under study have similar values as its neighbour thus the pattern is clustered. Meanwhile, negative values indicate the pattern is dispersed and 0 value means there is no spatial autocorrelation exist where it indicate the pattern is random.

The global Moran's I value was use to check the clustering of spatial pattern in the study area globally, but it did not show the location of the cluster. In order to measure the local spatial correlation, the local Moran's I_i will be used (Anselin [1]). The local Moran's I_i is given by:

$$I_i = \left(\frac{(x_i - \bar{x})}{s^2}\right)\sum_{j=1}^{n} w_{ij}(x_j - \bar{x}) . \quad (3.3)$$

The spatial autocorrelation could be divided into four categories. A high positive value of I_i indicate that the location under study is spatially clustered. A high-high cluster shows that high value in a location is surrounded by high value in neighbours. Low-low cluster shows that low value in a location is surrounded by low value in neighbours. On the other hand, a high negative value of I_i means that the location under study is a spatial outlier. High-low outlier means that high value in a location is surrounded by low value in neighbours. Low-high outlier showed that low value in a location surrounding with high value in neighbours. Other areas are categorized as an area that does not have a significant clustering of crime.

To test the statistical significance of local Moran's I_i index, null hypothesis states that there is no spatial clustering exist in the study area. According to Anselin [1], the significance of I_i values can be tested by using z-score $z = \left[I_i - E(I_i)\right] / \sqrt{\text{var}(I_i)}$. Under the total permutation hypothesis, the expected value of I_i is

$$E(I_i) = \frac{-W_i}{n-1} \quad (3.4)$$

with variance

$$Var(I_i) = \frac{W_{i(2)}(n-b_2)}{n-1} + \frac{(W_i^2 - W_{i(2)})(2b_2 - n)}{(n-1)(n-2)} - \left(\frac{-W_i}{n-1}\right)^2 \quad (3.5)$$

where W_i is the sum of the weights connected to location i , $W_i = \sum_{j=1}^{n} w_{ij}$, $W_{i(2)}$ is the sum of the squared weights connected to location i, $W_{i(2)} = \sum_{j=1}^{n} w_{ij}^2$ and

$$b_2 = \frac{m_4}{m_2} = \frac{n\sum_{i=1}^{n}(y_i - \bar{y})^4}{\left[\sum_{i=1}^{n}(y_i - \bar{y})^2\right]^2} \quad (3.6)$$

Moran's I_i index maps were constructed using Geographic Information System, ArcGis 9.3 software (ESRI, U.S).

4.0 RESULTS AND DISCUSSION

As a preliminary analysis, Fig. 1 shows the line graph of crime cases in Malaysia from the year 2000 to 2009. It shows that the violent crime cases have remained along the same gradual growth from year 2000 until year 2005 and was slightly higher from year 2006 until 2009. On the other hand, the property crime cases showed fluctuation trends throughout the study period. From year 2000 until 2001 and between years 2008 until 2009, the property crime cases showed the downward trend, whereas for year 2002 until 2007, it shows an upward trend. The figure also shows that the property crime cases were the main contributor to the total crime since the patterns of this crime were very similar to the pattern of total crime cases. The violent crime cases have increased from 21561 in 2000 to 40738 in 2009. This is an increase of 88.9%. The property crime cases have increased from 145569 in 2000 to 168679 in 2009 and have increased of 15.9% in this period. Although the number of cases for violent crime was less than the number of cases for property crime, violent crime was growing at a faster rate compare to property crime. Overall, the total crime cases had increased about 25.3% from year 2000 until 2009.

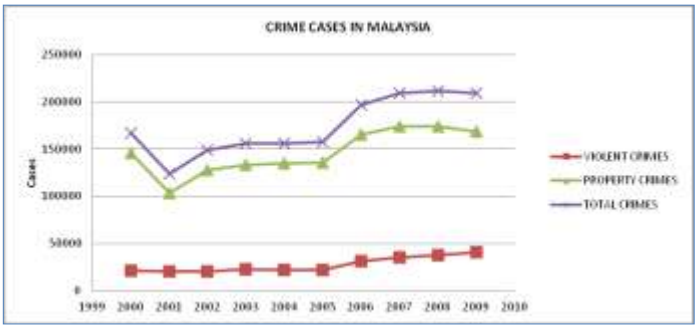

Figure 1 Crime cases (violent crimes, property crimes, total [violent and property crimes]) in Malaysia 2000 – 2009

For the purpose of the mapping, a three year time points, 2001, 2005 and 2009 were chosen. These years were selected based on the crime situation (Figure 1) which represents the turning time point to different crime trends period.

Global Moran's *I* was used to assessed the global autocorrelation. Table 1 showed the general trend of global spatial autocorrelation from the year 2000 until 2009. Based on permutation approach applied in S-Plus software, the results obtained showed positive spatial autocorrelation with significant p-values in all years throughout the study period. The variations of log rate of violent crime across space showed that the presence of spatial pattern in the study area based on the Global Moran's I value in Table 1. For further analysis, local indicator spatial autocorrelation (LISA) used to measure the local spatial cluster which can help to identify the existence of spatial autocorrelation in each location (district) known as local Moran's I_i.

Table 1 Global Moran's *I* of log rate of violent crime

Year	Moran's *I* (p- value)
2000	0.1776 (-0.005)
2001	0.1412 (0.020)
2002	0.1977 (0.002)
2003	0.216 (0.004)
2004	0.3266 (0.000)
2005	0.4452 (0.000)
2006	0.3320 (0.000)
2007	0.4188 (0.000)
2008	0.4486 (0.000)
2009	0.3772 (0.000)

In this study, we defined hot spot as the area with positive and statistically significant of I_i. Hot spot area for log rate of violent crime means area with high log rate of violent crime tend to have high log rate of violent crime (high-high cluster) or vice versa (low-low cluster). The map of hot spots were constructed by overlaying hot spot in 2001, 2005 and 2009 for log rate of violent crime. Figure 2 showed that there are five categories of temporal hot spot for log rate of violent crime. By overlaying hot spot for these three years, the groups were divided into eight categories. Because of no district fall in three categories, only five categories are shown in the Figure 2. A district is labelled as "1, 1, 1" if it is in hot spot category for all three years (2001, 2005, 2009). If the area is hot spot for the log rate of violent crime for 2005 and 2009 but not in 2001, it is labeled as "0, 1, 1". Hence, the label of "0, 0, 0" suggest that that district has never been a hot spot for all the three years. There were 35 districts in four categories for hot spots of log of violent crime rate. Another 47 districts has never been hot spot of violent crime rate for these particular years.

There were nine districts in the "1, 0, 0" hot spot category, twelve districts in " 0, 1, 0" category, seven districts in "0, 0, 1" and seven districts in "0, 1, 1" hot spot category respectively.

In the maps shown in Figure 2, that the districts in darker color indicates that it was a hot spot for more years in the study area compared to the districts with brighter color. Based on Figure 2, seven districts fall in the hot spot category in two years (2005, 2009). Five of the districts were located in the east coast of Peninsular Malaysia and two districts were located in the south part. The crime situation in these five districts was very similar to the crime situation in their neighboring areas either in the low-low or high-high clustering.

The results of this exploratory spatial analysis suggested that the characteristics and neighborhood conditions believed to affect the situation in the areas surveyed point. Therefore, the various factors that influence must be identified and studied in detail to understand the situation of crimes in an area. Statistical validation analysis should be done such as regression analysis aimed to assess the level of significance relationship between these factors in the crime rate.

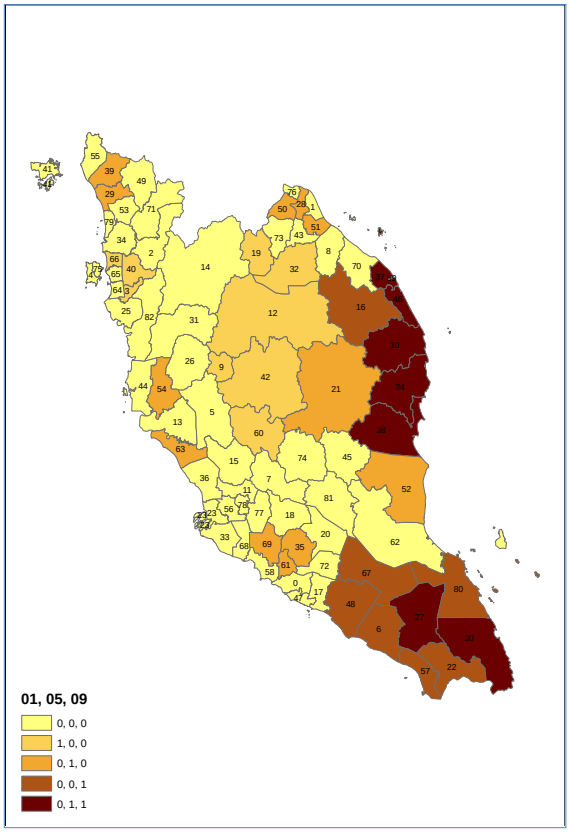

Figure 2 Temporal hot spots of violent crime rate (2001, 2005, 2009).

5.0 CONCLUSION

Crime is one of the major problems that have been faced by most of the countries in the world including Malaysia. This social problem will cause not only loss of property, lives and misery but it also gives large impact on many aspects such as psychological and economical. Mass media plays an important role in public's perception on the incident of crimes. The sensational news of crime that is widely disseminated by press and media has caused more fear amongst public compared to the official statistics reported by police.

This study reported empirical finding about spatial variations in log odds of crime according to districts in Peninsular Malaysia. GIS and spatial statistics facilitate analysis and decision at the regional level with regard to the problematic area and precautionary measures. The hot spot area identified and reported visually give a clearer picture of crime situation in Peninsular Malaysia. The neighborhood characteristics are important and should be considered in understanding the pattern of crime. Therefore, proposed actions or strategic planning in controlling

and addressing the crime problem in the high risk areas not only has to consider the factors that influence crime in that particular area, but also the situation of neighboring areas. Thus, policy maker or police force in the country can give serious attention of these risk areas, and make appropriate solution planning and resource allocation to overcome the crime situation of the nation.

It is believed that a study on spatial and demographic patterns of crime could provide useful information for the government, agencies and policymakers to make appropriate planning especially in resource allocation and to develop suitable strategies for future plan in order to overcome the crime problems. The forecast information of future trends by using past data is a valuable tool for policy makers to develop crime prevention programmes. However, it is impossible to provide crime forecasts with high degree of accuracy because it depends on so many factors such as socioeconomics, demographics and environments. Although there is no intelligence formula that can be used to reveal future crime situations, information of the past reported crime cases can be one of the useful sources to predict the crime situation in the future. These outcomes can be used to target particular populations and develop interventions so that actions are better adapted to environmental and socioeconomic setting. Therefore, well organized data collections are very important. It could allow spatial pattern analysis over space and time become easier and effective.

However, this study can be used as a preliminary analysis because the aimed of this article is to explore the spatial patterns of violent crime only. In order to explore and measure the relationship between crime and the independent variables, some statistical modelling can be used. One of the possible methods is by using spatial regression model.

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Appendix A

STATE	ID	DISTRICT
JOHOR	22	JOHOR BAHRU
	48	MUAR
	6	BATU PAHAT
	67	SEGAMAT
	27	KLUANG
	57	PONTIAN
	30	KOTA TINGGI
	80	MERSING
KELANTAN	28	KOTA BHARU
	73	TANAH MERAH
	50	PASIR MAS
	76	TUMPAT
	19	JELI
	32	KUALA KRAI
	43	MACHANG
	51	PASIR PUTEH
	1	BACHOK
	12	GUA MUSANG
MELAKA	47	MELAKA TENGAH
	0	ALOR GAJAH
	17	JASIN
PULAU PINANG	75	TIMUR LAUT
	4	BARAT DAYA
	66	SEBERANG PERAI UTARA
	65	SEBERANG PERAI TENGAH
	64	SEBERANG PERAI SELATAN
PERLIS	55	PERLIS
SELANGOR	56	PETALING
	23	KLANG
	11	GOMBAK
	77	ULU LANGAT
	33	KUALA LANGAT
	36	KUALA SELANGOR
	15	ULU SELANGOR
	63	SABAK BERNAM
	68	SEPANG
TERENGGANU	37	KUALA TERENGGANU
	24	KEMAMAN
	10	DUNGUN
	8	BESUT
	46	MARANG
	16	HULU TERENGGANU
	70	SETIU
WPKL	78	W.P. KUALA LUMPUR
PERAK	54	PERAK TENGAH
	14	ULU PERAK
	5	BATANG PADANG
	25	KERIAN
	31	KUALA KANGSAR
	82	LARUT & MATANG
	44	MANJUNG
	13	HILIR PERAK
	26	KINTA
PAHANG	38	KUANTAN
	74	TEMERLOH
	81	BERA
	7	BENTONG
	60	RAUB
	21	JERANTUT

	52	PEKAN
	42	LIPIS
	9	CAMERON HIGHLANDS
	62	ROMPIN
	45	MARAN
NEGERI SEMBILAN	69	SEREMBAN
	72	TAMPIN
	58	PORT DICKSON
	20	JEMPOL
	35	KUALA PILAH
	18	JELEBU
	61	REMBAU
KEDAH	2	BALING
	3	BANDAR BAHARU
	29	KOTA SETAR
	34	KUALA MUDA
	39	KUBANG PASU
	40	KULIM
	41	LANGKAWI
	49	PADANG TERAP
	71	SIK
	79	YAN
	53	PENDANG
	59	PULAU-PULAU

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