

THE MAPPING OF SPATIAL PATTERNS OF PROPERTY CRIME IN MALAYSIA: NORMAL MIXTURE MODEL APPROACH (PEMETAAN CORAK RERUANG KES JENAYAH HARTA BENDA DI MALAYSIA: PENDEKATAN MODEL CAMPURAN NORMAL)

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Abstract: The objective of the study is to explore the geographic distribution and temporal patterns of property crime cases in Peninsular Malaysia by using spatial analysis. The property crime data from the year 2000 until 2009 was used in this study. To obtain the optimum number of crime components, the space-time Normal Mixture Models was used. Based on the results of this model, the mapping was presented. This map displays the spatial distribution of crime occurrence in 82 districts of Peninsular Malaysia. From this analysis, property crimes can be categorized into two components. There is a relationship between the property crime rate with household income and poverty. It was observed that as the household income increased in Johor, Selangor and Kuala Lumpur, the rate of property crime decreased. Also, the high incidence of poverty increased property crime rate. This scenario can be seen at the states situated at the east coast region of the study area. The findings of this study can be used by the government, policy makers or responsible agencies to take any related action in crime prevention, human resource allocation and law enforcement.

Keywords: Property crime, space-time, Normal Mixture Model, household income, poverty.

Abstrak: Objektif kajian ini adalah untuk mengetahui taburan geografi dan corak masa kes-kes jenayah harta benda di Semenanjung Malaysia dengan menggunakan analisis reruang. Data jenayah harta benda dari tahun 2000 hingga 2009 telah digunakan dalam kajian ini. Bagi memperoleh jumlah komponen jenayah yang optimum, model Campuran Ruang – Masa telah digunakan. Hasil dari penggunaan model berkenaan, pemetaan dapat dijana. Peta ini memaparkan taburan reruang bagi kejadian jenayah di 82 daerah di Semenanjung Malaysia. Dari analisa ini, jenayah harta benda dapat dikategorikan kepada dua (2) komponen. Terdapat hubungan antara kadar jenayah harta benda dengan pendapatan isi rumah dan kemiskinan. Didapati bahawa dengan peningkatan pendapatan isirumah di Johor, Selangor dan Kuala Lumpur, kadar jenayah harta benda menurun. Juga, peningkatan kes kemiskinan menyebabkan kadar jenayah harta benda meningkat. Senario ini dapat dilihat di negeri-negeri yang terletak di kawasan kajian sebelah pantai timur. Hasil dari kajian ini dapat diguna pakai oleh pihak kerajaan, penggubal polisi mahupun agensi yang bertanggungjawab dalam mengambil tindakan wajar bagi membanteras jenayah, peruntukan sumber manusia dan penguatkuasaan undang-undang.

Kata kunci: Jenayah harta benda, Model Campuran Normal, pendapatan isi rumah, kemiskinan.

Introduction

Crime is one of the major problems faced by most countries in the world. The most common indicator used to measure crime cases is the crime rate. The pattern of this social problem can be detected differently based on specific

types of environments. Crime is believed to be higher in the more developed and densely populated area such as at large cities, towns or urban areas compared to undeveloped areas such as the rural area. This situation happens because of several factors such as environment

characteristic, economics, social, political, demographics and so forth. The result of a study conducted by Gyamfi (2002) parallels with this fact. The author reported that crime rate was highest in southern Ghana, where it 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.* (2006) also discovered that property crime was highly occurred in the city centre of the Island of Montreal. Meanwhile, Perreault *et al.* (2008) found that youth crime is distributed over many small hot spots across the entire island of Montreal. Crime situation was also affected by global economic situation (Sidhu, 2005). During the economic downturn or recession, the unemployment rate rises and people face difficulties in finding jobs. Hence, the crime rate increases. The labor market conditions are also believed to have links with crime. This association studied by Lee and Slack (2008). They found that an index of low hour and seasonal employment have negative relationship with crime rates.

Recently, the opportunities using social science data (i.e., crime, disease, accident) to estimate spatial patterns and relationships increased because of the rapid development in tools and methods in the field of spatial analysis. Spatial analysis is a method that is widely used to study issues related to space, place, or geographical circumstances. The location where an event occurs may provide an indication of the reason why that particular event occurs. In the beginning, spatial analysis involves mapping methods, reviews, and geographic location without formal techniques. In the beginning of 21st century, spatial modern analyses were widely developed and focused on specific use of computer-based techniques. Mapping is one of the most widely used techniques in spatial analysis. It is very useful especially in identifying the relationship between exposure and the cases concerned. Beginning in this century, spatial analysis has become more attentive in many areas. It is not only used by researchers in the

field of geography, but also applied in many fields of study such as epidemiology (Forand *et al.*, 2002; Kandala *et al.*, 2006), biology, demography (Osei & Duker, 2008), health (Gatrell *et al.*, 2004; Holt & Lo, 2008; Waller & Gotway, 2004), sociology (Ngamini Ngui *et al.*, 2014; Sparks, 2011), statistics, information technology, safety (Erdogan, 2009; Erdogan *et al.*, 2008), mathematics (Kakamu *et al.*, 2008), science and computer science (Corcoran *et al.*, 2007).

The most frequent traditional mapping method used is percentile method. However, the classification based on percentile is arbitrary because it could not be confirmed whether this classification is able to detect high-risk or low-risk areas efficiently. An alternative method that can be used for classifying the risk of each study area is a mixture model (Bohning & Seidel, 2003; Schlattmann & Böhning, 1993; Schlattmann, 2003). Based on simulation study carried out by Schlattman and Böhning (1993) aimed to compare the mapping based on the percentile method with mixture model methods found that a mixture model approach provides higher percentage of correct classification than traditional methods.

Combinations of theoretical and statistical analyses are believed to be very useful in crime study. A study done by Ackerman and Murray (2004) used this combination to investigate spatial patterns of crime cases in Lima, Ohio by using geographical information systems (GIS) and quantitative techniques. They analyzed the violent and property crime at the macro, meso, and micro level. Apart from that, several other studies also investigated the impact factors on crime cases and suggestions for strategic planning to overcome the problems. For example, Kanyo and Norizan (2007) studied the trend of crime by investigating the factors that are believed to have significant effects on crime cases in Penang, Malaysia. They also provided several suggestions about actions that can be taken to overcome crime problems. Felson and Poulson (2003) studied the simple indicators of crime in 13 middle-sized American cities

by using robbery data from the year 1999 until 2001. However, these studies were analyzed without taking into consideration the spatial effects. Nevertheless, analyses of crime cases by using spatial technique had been growing from time to time. Rogerson and Sun (2001) analyzed the geographic patterns of crime using spatial method by combining the nearest neighbour statistic and cumulative sum method. They described a new procedure for detecting changes over time in the spatial pattern of crime point events in Buffalo, New York. Collins *et al.* (2006) examined the basic theory and methods that have been used to analyze spatial lattice data and applied the method in crime cases analysis. Also, they used two forms of simultaneous autoregressive model known as spatial lag and spatial error model. Other studies are by Ackerman and Murray (2004) who used geographic information system, GIS and quantitative techniques to explore spatial characteristic of crime and Gyamfi (2002) who examined socio spatial environment factors that might have significant effects on macro geographic crime trends and patterns in Ghana.

The crime problems have also become a major concern for policy makers in Malaysia. Crime has been on an increasing trend year by year (Sidhu, 2005). This situation can be seen from crime data given by the Royal Malaysia Police (PDRM). These problems will not only cause loss of property, lives, and misery, but it affect many aspects such as psychology, economy, and so on. Sidhu (2006) reported that crime trends developed from simple crime and then became more complex global crimes. This situation makes the work harder especially for police department to detect and solve the crime cases reported by the public.

In Malaysia, limited studies have been done on crime data using statistical method. Most of the studies focused more on expert opinion or knowledge, and discussed about causes and effects of crime, for example, studies done by Kanyo and Norizan (2007), Sidhu (2005) and Sidhu (2006). The investigation of the crime situation can be more significant when

analysed using combination of qualitative and quantitative techniques. The objective of this study is to explore the geographic distribution and temporal patterns of violent crime cases in Malaysia using spatial analysis tools and techniques and this study will provide a general picture of violent crime patterns in Malaysia.

Research Methods

Data

Malaysia comprises two major parts known as Peninsular Malaysia and East Malaysia. According to the 2000 census, Malaysia is divided into 14 states, 82 administrative districts in Peninsular Malaysia and 53 administrative districts in East Malaysia. In this study, administrative district is used as the unit of analysis. There are twelve states located in Peninsular Malaysia, consists of 82 districts.

The number of crime cases employed in this study was obtained from Royal Malaysia Police (PDRM). Two categories of crime cases are included in index crime statistics, known as violent and property crime. The definition of index crime statistics is the crime that is reported with sufficient regularity and with sufficient significance to be meaningful as an index to the crime situation (Sidhu, 2005). The property crime including housebreaking and theft in the day time, housebreaking and theft at night, theft of lorries and van, theft motor car, theft of motorcycles and scooters, snatch theft and other form of theft. The data from the year 2000 until 2009 for each district reported in Peninsular Malaysia will be analyzed in this study.

Property crime rate (PR) standardized by total crime cases is defined as the total number of property crime divided by the total number of crime, T . Then, the value of rate will take a logarithmic transformation. This transformation will ensure that the variables are on the same scale. Values of the log of rate, x_i will follow approximately normal distribution that takes any real number, \mathbb{R} (Ceccato & Dolmen, 2011; Cole, 2009; Collins, Babyak, & Moloney,

2006; Wang, 2005). Further analysis will be implemented by using statistical techniques based on assumption of normal distribution. The formula for rate of property crime is given as follows:

$$PR = \frac{P}{T}$$

Where P is the number of property crime cases and T is the total number of crime occurred. In this study, event is referred to the number of property crime cases and T , is the number of violent crime coupled with property crime cases. Instead of common rate known as crime rate based on population at risk, this rate used as an alternative solution for the small number problem (Waller & Gotway, 2004). Rates based on the small populations with small numbers of property crime cases will be higher than the rate based on large populations with small number of violent crime cases. For example, there are two districts with 100,000 population and 1,000 population. These two districts recorded the same number of violent crime cases which is 45. The rate will be 0.00045 for the first district and the rate for the second district is 0.045. The rates do not reflect the true risk based on the crime incident.

Mixture Model of Normal Distribution

Traditional method of classification of risk such as percentile is rather arbitrary and also no guarantee that such a classification can correctly detect high or low risk area. As an alternative method, mixture model can be used. In this study, the Normal Mixture Model was used to classify districts into optimum component. This approach provides higher accuracy percentage of classification (Bohning & Seidel, 2003; Schlattmann & Böhning, 1993; Schlattmann, 2003). The mixture model assumes that the population under study comes from a certain distribution but consists of components with different levels of risk incidence, which then becomes a heterogenous case (Rattanasiri, Böhning, Rojanavipart, & Athipanyakom, 2004). Each component will follow a normal distribution with mean, $\hat{\mu}_k$

and standard deviation, $\hat{\sigma}_k$ and represents a certain proportion, \hat{p}_k of the total district unit.

As suggested by Everitt and Hand (1981) the parameter estimation is done by using Maximum Likelihood Estimation (MLE). The probability density functions for vector random variable, x of dimension n have the following form:

$$f(x; p, \sigma, \mu) = \sum_{k=1}^c p_k g_k(x; \sigma_k, \mu_k) \tag{2.1}$$

In equation (3.1), $p = (p_1, p_2, \dots, p_{c-1})$ are the $c-1$ independent mixing proportions of the mixture where

$$0 < p_k < 1 \text{ and } p_c = 1 - \sum_{k=1}^{c-1} p_k, \tag{2.2}$$

with μ_k and σ_k are the mean and standard deviation vector, respectively. The log of the likelihood function is given by

$$L = \sum_{i=1}^n \log_e \left\{ \sum_{k=1}^c p_k g_k(x_i; \sigma_k, \mu_k) \right\}. \tag{2.3}$$

The maximum likelihood equations are obtained by equating the first partial derivatives of (3.3) with respect to p_k , the elements of each σ_k , and those of each vector μ_k , to zero. Let the probability of observations x_i belongs to the component s denoted by $P(s|x_i)$, where

$$P(s|x_i) = \frac{p_s g_s(x_i; \sigma_s, \mu_s)}{f(x_i; p, \sigma, \mu)}. \tag{2.4}$$

Using the equation (3.4), the estimated value of parameters are given in the following form:

$$\hat{p}_k = \frac{1}{n} \sum_{i=1}^n \hat{P}(k|x_i)$$

$$\text{where } \begin{cases} p_k, & k = 1, \dots, c-1 \\ 1 - \sum_{k=1}^{c-1} p_k, & k = c \end{cases} \tag{2.5}$$

$$\hat{\mu}_k = \frac{1}{n \hat{p}_k} \sum_{i=1}^n \hat{P}(k|x_i) x_i$$

$$\text{where } k = 1, \dots, c \tag{2.6}$$

$$\hat{\sigma}_k = \frac{1}{n\hat{p}_k} \sum_{i=1}^n \hat{P}(k|x_i) (x_i - \hat{\mu}_k)^2$$

where $k = 1, \dots, c$ (2.7)

The next step is to determine the optimum number of components that are compatible with the data. This can be done by computing the Likelihood Ratio Statistic (LRS) for testing the hypothesis:

- H_0 : number of components = k
- against
- H_1 : number of components = k + 1

The likelihood ratio test is defined as

$$LRS = -2 \times [L_k - L_{k+1}],$$

where L_k is the maximum likelihood estimator under the null hypothesis and L_{k+1} is the maximum likelihood estimator under the alternative hypothesis. The LRS test has an asymptotic null distribution of χ^2 with degree of freedom equal to the difference number of parameters under the null and alternative hypothesis. However, as reported by McLachlan (1987) that regularity conditions of conventional LRS result do not hold for this distribution. To solve this problem, several previous studies have proposed a method known as parametric bootstrap to obtain a critical value. McLachlan (1987) and Shlattmann and Bohning (1993) provided more details on bootstrap procedure.

By applying parametric bootstrap, B bootstrap samples are generated from the mixture density $f(x;p,\sigma,\mu)$ of original sample based on the number of components under the null hypothesis. In this study, total bootstrap samples of 200 replications were generated. Parameter estimation using MLE method is applied for the null and alternative hypotheses for each bootstrap sample. Then, the value of LRS is computed for these bootstrap samples to get the B replicated values of LRS. Hence, the distribution of the LRS under the null hypothesis is assessed. Hypothesis testing of the null hypothesis versus alternative hypothesis is tested with a bootstrapped critical

value and compared with the LRS value from original sample.

Space Time Mixture Modelling

The basic idea of space-time mixture model technique is to consider the space-time data as one data set which consists of data combination for several years. Let x_{it} be the violent crime rate for area i, $i, i = 1, \dots, n$ and time t, $t = 1, \dots, T$, the mixture probability density of normal distribution is defined as

$$f(x; p, \sigma, \mu) = \sum_{k=1}^c p_k g_k(x_{it}; \sigma_k, \mu_k), \quad (2.8)$$

where

$$i = 1, \dots, n \text{ and } t = 1, \dots, T,$$

$$0 < p_k < 1 \quad p_c = 1 - \sum_{k=1}^{c-1} p_k .$$

The log of the likelihood function is given by

$$L = \sum_{t=1}^T \sum_{i=1}^n \log_e \left\{ \sum_{k=1}^c p_k g_k(x_{it}; p, \sigma_k, \mu_k) \right\} . \quad (2.9)$$

The maximum likelihood equations are obtained by equating the first partial derivatives of (2.8) with respect to the p_k , the elements of each matrix σ_k , and those of each vector μ_k , to zero. One advantage of using the space-time mixture model is that it provides fewer parameters for comparison. For example, in this study, only 1 set of parameters is estimated, instead of 10 sets of parameters that need to be estimated for the mixture model applied separately for each year of the study period.

Results and Discussion

Figure 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 were slightly higher from year 2005 until 2009. On the other hand, the property crime cases showed fluctuation trends throughout the study period. From year 2000 until 2001 and between year 2008 to 2009, the property crime cases showed the downward

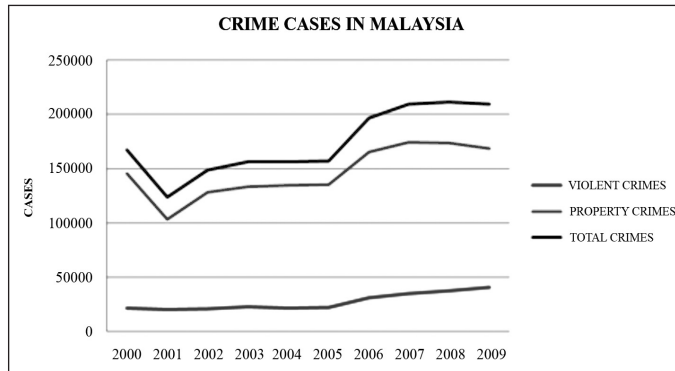


Figure 1: Crime cases in Malaysia 2000 - 2009

Table 1: Result of fitting space time mixture model to property crime rate (from the year 2000 to 2009)

Component	Proportion, p	Mean, μ	Standard Deviation, σ	Log Likelihood, L	LRS, $-2 \times [L_k - L_{k+1}]$
k=3	0.2885781	-0.5481284	0.2981073	835.1559	-433.1781
	0.3822742	-0.5001643	0.4181996		
	0.3291477	-0.4272934	0.4584243		
k=2	0.4802369	-0.5632076	0.3851548	841.9132	-13.51462
	0.5197631	-0.4540701	0.5026193		
k=1	1	-0.5839925	0.7294795	898.6344	-113.4425

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. That is one of the reasons why only the analysis of property crime is discussed in this study. The violent crime cases have increased from 21,561 in 2,000 to 40,738 in 2009. This is an increase of 88.9%. The property crime cases have increased 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 compared to property crime. Overall, the total crime cases had increased about 25.3% from year 2000 until 2009.

For further analysis, the normal space-time mixture model as discussed in the methodology section was applied to violent crime data in Peninsular Malaysia from the year 2000 to

2009. This space time methods will make the comparisons of the map much easier because it has the same scale, where each year has the same number of component and parameter estimates. On the contrary, the separate mixture model will give different number of the component for each year with different parameter estimates. This is rather arbitrary in which it will make the map comparison difficult. For illustration purposes, Table 1 shows the result of estimated parameters value for the space-time mixture model for the data 2000 until 2009.

The main question arises whether the risk of crime for each district in the study area is homogeneous or heterogeneous. If the risk is homogeneous, the number of component is one. The hypothesis testing to test $k = 1$ against $k = 2$ is done. It can be seen that the improvement in log-likelihood model with two components is quite large compare to model with one component (Table 1). However, the log-likelihood improvement showed a small difference between the models

with 2 components versus the model with 3 components.

The first hypothesis tested the number of components $k = 2$ against $k = 3$. From the bootstrapped result, the 95% confidence interval of LRS distribution is (-51.42819, -7.922263). Meanwhile, the value of LRS from original sample is -13.51462. The value of LRS from original sample is within the confidence interval. Therefore, there is no sufficient evidence to reject the null hypothesis.

For application of the mixture model to the space time period of 2000-2009, the optimum number of categories obtained was two components. The first component has a mean of 0.56938 ($\exp(-0.56321)$) and standard deviation of 0.385155. It means that, there were approximately 6 cases of property crime occurs for every 10 criminal cases. For this space time period, 48.0% of districts were allocated in the first component and 52% in second category. There are more districts included in the component with higher property crime rates which is component 2 where the rate is 0.635038 ($\exp(-0.4540701)$).

The map was constructed based on the mean of property crime rates where the darker area have higher rate. Based on the map, it can be observed the pattern of crime occurrence for each district. For illustration purpose, four maps for the year 2001, 2003, 2006 and 2009 were provided. For example, from Figure 2, the darkest areas have the rate of 0.635038 while the most promising areas had 0.56938 rates mean. In other words, for every 1,000 cases of total crime that occurred approximately 635 cases of property crime occur in riskiest area and 569 cases occurred in less risky area.

As shown in Figure 2 to Figure 5, the number of districts with higher mean (shown by darker colour on map) was decreasing during 2001 until 2009. The obvious changes can be seen in the area of southern Peninsular Malaysia. For the year 2001, all districts in Johor State fall in the riskiest component, but for the year 2003 and 2006, it showed that only a few districts in Johor within riskiest

components. However, approximately all the districts in the south fall into the category with the lowest crime rates in 2009. The same scenario happened in the state of Negeri Sembilan, where no districts were in categories that have highest crime rate value in 2009 compared with previous years. Meanwhile, Wilayah Persekutuan Kuala Lumpur falls within the component of lowest property crime rates in all four years in study period. This situation has been attributed by the mean monthly gross household income in Malaysia. For example, the income in Johor in 2002 was RM2,963, while this income increased to RM3,835 in 2009. The household income in Selangor in the year 2002, 2004, 2007 and 2009 are respectively RM4,406, RM5,175, RM5,580 and RM5,962. Wilayah Persekutuan Kuala Lumpur recorded the highest household income where RM4,930 for the year 2002, RM5,011, RM5,322 and RM5,488 in the year 2004, 2007 and 2009 respectively. From the result in this study, this state fell in the less risky component for all four years (2001, 2003, 2006 and 2009). It can be assumed that the property crime rate is decreased by increasing of mean monthly gross household income.

The reverse situation occurred in the districts located in East Coast states where most districts in this area fall into the highest property crime rate for all four years. One of the factors that may be associated with the incidence of crime is poverty level. In 2002, the incidence of poverty was 14.9%, while in 2004, 2007 and 2009 recorded 15.4%, 6.5% and 4.0% of poverty incidence respectively. Although it showed decreasing in incidence, there is a very large gap with the state with lowest incidence of poverty crime which is Wilayah Persekutuan Kuala Lumpur. This state had 0.5% incidence of poverty in 2002, 1.5%, 1.5% and 0.7% in 2004, 2007 and 2009, respectively. From this data, it can be concluded that when the poverty is high, property crime rate will increase. To find a clear picture of the relationship between property crime rate with the household income and incidence of poverty, further detailed analysis needs to be carried out, such as by

using geographically weighted regression method. This can be done by further research.

Also, the application of the mixture model to crime data by district in Peninsular Malaysia is able to produce smoother map compared to the traditional methods which is known as Choropleth method. It removes the random variability from the map. For example, maps

constructed based on Choropleth method that is, quintiles (divided into 5 groups) of the crime rates from original data were presented in Figure 7 to Figure 10. As shown in both figures, we can see that the map based on mixture model provides clearer picture of high risk and low risk area.

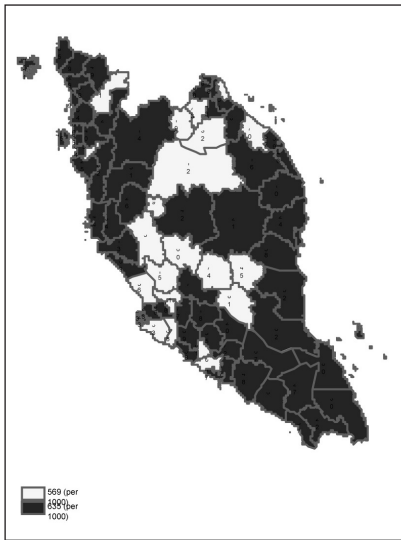


Figure 2: Map of property crime rate using space-time mixture model for year 2001

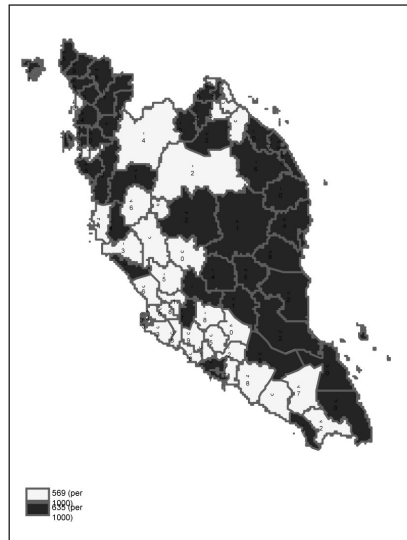


Figure 3: Map of property crime rate using space-time mixture model for year 2003

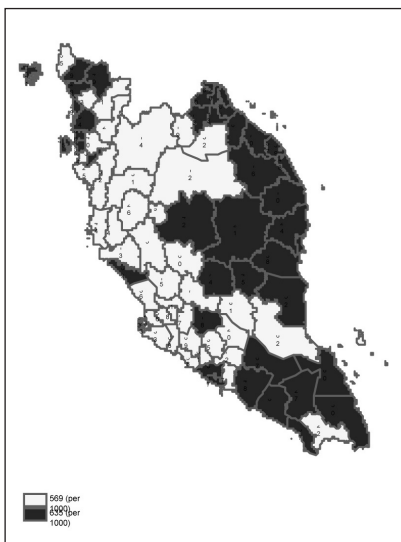


Figure 4: Map of property crime rate using space-time mixture model for year 2006

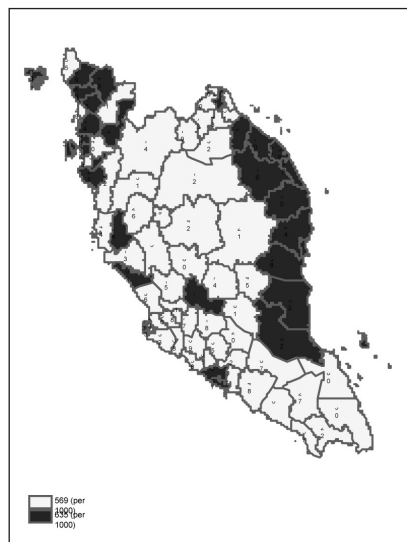


Figure 5: Map of property crime rate using space-time mixture model for year 2009

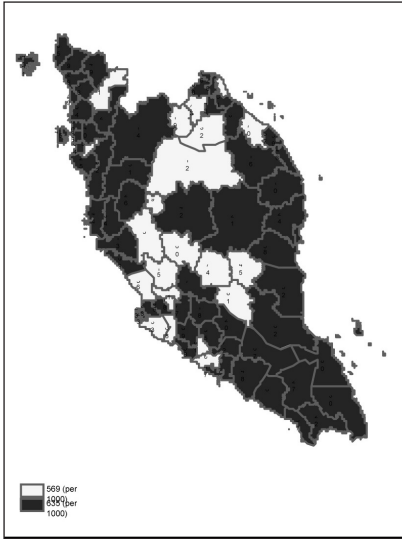


Figure 6: Map of property crime rate using percentiles method for year 2001

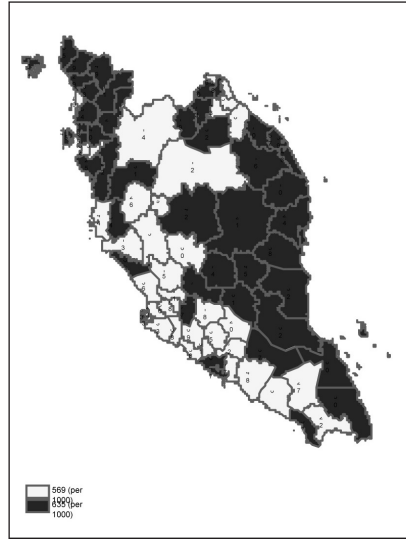


Figure 7: Map of property crime rate using percentiles method for year 2003

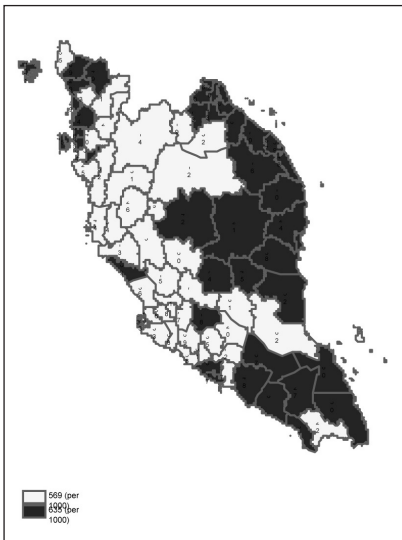


Figure 8: Map of property crime rate using percentiles method for year 2006

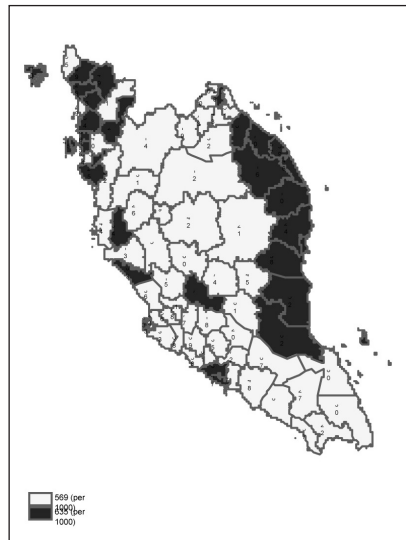


Figure 9: Map of property crime rate using percentiles method for year 2009

Conclusion

Crime is one of the major problems 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 of life such as psychology, economy and so on. Based on the analysis, there is a relationship

between the rate of property crime with household income and poverty. The increasing of household income will decreased property crime rate. Besides, the high incidence of poverty increased the property crime rate in the states on the east coast. To measure the relationship between property crime rate with household income and poverty, further analysis should be

performed using some statistical analysis such as Geographically Weighted Regression.

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. This can be done by using GWR in order to investigate the relationship between crime cases with several possible factors. Although there is no intelligence formula that can be used to reveal future crime situations, information of the past which reported crime cases can be one of the sources to predict the crime situation in the future. Crime mapping is one of the methods that can be used to analyze the crime situation in a country. Based on the maps obtained, the high and low crime areas can be identified. Therefore, the authorities should pay more attention to those high risk areas in taking necessary actions to overcome this problem. Usually, the main concern is to reduce both crimes because they affect not only the people in particular, but also the nation in general.

It is believed that a study on spatial and demographic patterns of crime in Malaysia will provide useful information for the safety department and policymakers to make appropriate planning especially in resource allocation and to develop suitable strategies for future plan in crime problems. The forecast information of future trends by using past data is a valuable tool to policymakers to develop crime prevention programmes. These outcomes can be used to target particular populations and develop interventions so that actions are better adapted to the environmental and socioeconomic setting. However, well organized data collection and computer storage are very important. It will improve spatial pattern analysis over space and time. Thus it can provide accurate and precise action plan with the crime situation in Malaysia.

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