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Spatial Distribution of Crimes Against Property: A Case Study in Nakhon Pathom Province

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Received: *11 January 2023* / **Revised:** *8 March 2023* / **Accepted:** *19 April 2023*

Abstract

Crimes against property were correlated with the recession of the economy. According to the Royal Thai Police report, crimes against property continue to increase. The criminal statistics showed that the second-highest number of crimes against property was found in Nakhon Pathom Province. The purposes of this study were to 1) examine the pattern of crimes against property using Moran's I, 2) investigate the spatial distribution of crimes against property using Getis-Ord Gi*, 3) find out the directional distribution of crimes against property using a standard deviational ellipse, and 4) explore the spatial relationship between crimes against property, land use, and population density. Secondary data on crime cases were collected from the Mueang Nakhon Pathom Police Station criminal report book between 2013 and 2018 and then converted to spatial data. The results of the study were as follows: 1) The pattern of the cases over 5 years was clustered; 2) the spatial distribution of cases revealed hotspot areas with a GiZscore greater than 1.65 over 5 years covering residential and village areas, city and town areas, commercial areas, entertainment venues, local education institutes, the boulevard, dark alleys, and deserted streets; 3) the directional distribution of the cases over 5 years was distributed to the west of the study area; and 4) urban and built-up land was discovered where most cases occurred. Overall, the crimes against property clustered around crowded residential areas and villages, dark alleys, and deserted streets. This study facilitates investigations, defense, and control of crimes against property.

Keywords: Crimes against property, Geo-statistic analysis, Moral's I, Getis-Ord Gi*, Standard deviational ellipse

1. Introduction

Thailand has developed from an agricultural to an industrial country. This change has impacts on the economy and society including the higher cost of living and unemployment. The rising cost of living and unemployment can cause higher crime. Moreover, the expansion of urbanization has affected more crime, more complex patterns, and violent tendencies, especially crimes against property (Phuaksomon, 2020).

Crimes against property have become a major problem affecting peace and social security in Thailand (Phuaksomon, 2020). The statistics report of arrested crimes divided by cases and provinces in Thailand between 2007 and 2016 revealed the highest number of the cases were crimes against property including robbery and embezzlement (National Statistical Office, 2016). Similarly, the National Economic and Social Development Council data reported that overall criminal cases in the third quarter of 2021 increased, as did the 17.3% increase in crime against properties (12,623 cases), with the highest number of theft (45.4%) (Royal Thai Police, 2021). The criminal cases discovered in Nakhon Pathom Province between 2007 and 2018 were the following; 91.18% of theft cases, 4.72% of snatching cases, 3.20% of robbery, and 0.90% of gang robbery cases (Rattanapongs & Gulabutr, 2020).

In the criminal code of Thailand, crimes against property were categorized into 11 major groups (Dharmniti, 2019): 1) theft, the taking of

another person's property by dishonesty (Article 334), 2) robbery, the stealing in front of the owner (Section 336), 3) extortion, the compelling others to allow oneself or others to gain an advantage in an asset way by threatening to harm life, body, liberty, reputation, or property (Section 337), 4) robbery, the getting something, especially money, from someone by using force or threats (Section 338), 5) stealth, theft "by force" (Article 339), 6) gang robbery, a robbery by committing more than three people offences (Section 340), 7) fraud, the deceiving other people by displaying false statements or concealing true statements (Section 341), 8) embezzlement, the possession of another person's property and then corruptly claiming that property as one's own or a third person (Section 352), 9) offenses of receiving stolen property, helping to conceal, sell, help to take away, buy, pledge, or otherwise accept (Section 357), 10) mischief, damaging, destroying, depreciating, renders useless" of property belonging to another person (Section 358), and 11) trespassing, the entering into someone else's immovable property, to take possession of that immovable property, in whole or in part, or to do any act that disturbs the normal possession of the immovable property (Article 362) (Thailand Lawyer, 2020).

To our knowledge, the geo-spatial analysis approach is widely applied in spatial analysis. (Paramasivam & Venkatramanan, 2019). Hence, the characteristics of crimes can be considered geographically using crime mapping and the geo-statistical analysis techniques. Autocorrelation Moran's I, which is one of the geo-statistical analysis techniques, can be used to identify the clustering of crimes across the study area (on a global scale) (Mitchell, 2005; Prasannakumar, Vijith, Charutha, & Geetha, 2011) applied this technique to observe the overall pattern of crime incidents. Getis-Ord Gi* referred to as a geo-statistical method can be applied to identify specific clusters of high or low-crime incidents.

Standard Deviational Ellipse (SDE) is one of the standard methods to facilitate investigations and the prioritization of police work, crime prevention, and suppression planning (Balogun, Okeke, & Chukwukere, 2014; Srithamarong, 2016; Yiampisan & Srivanit, 2010) employed Moran's I approach to evaluate crime-risk areas and crime patterns. High-incident areas known as hotspots (In-ain, 2018) were identified by using the Getis-Ord Gi* technique. Srithamarong (2016) further studied the directional distribution of crime incidents using the Standard Deviational Ellipse (SDE). SDE allowed us to see if the distribution of crimes was elongated and hence had a particular orientation (Wang, Shi, & Miao, 2015). Dechsiri and Robert (2019) also investigated crime-risk areas of drug smuggling based on Moran's I, Getis-Ord Gi*, and SDE. Mohammed and Baiee (2020) identified the riskiest area for Baltimore City using the Getis-Ord Gi* technique. Achu, Aju, Suresh, Manoharan and Reghunath (2019) investigated the spatial and temporal patterns of road accidents using autocorrelation in Moran's I and Getis-Ord Gi*. Chutia et al. (2020) analyzed spatio-temporal incidents of crime in Shillong, Meghalaya, India. Incremental autocorrelation in Moran's I technique made it possible to explain the pattern of crime, and Getis-Ord Gi* described clusters of high- or low-crime incidents. Ahmed and Salihu (2013) disclosed the spatial pattern of crimes in the area of Dala L.G.A, Kano State, Nigeria, using Moran's I and Getis-Ord Gi*. The results showed that the crime rate was higher than outside the city wall, and more hotspots were found outside the city because of the absence of police stations.

The objectives of this research were 1) to examine the pattern of offences against property cases, 2) to investigate the spatial distribution of offences against property cases, 3) to determine trends and directions of distribution of offences against property cases, and 4) to discover the spatial relationship between a crime against property, land use, and population density. The study area was Nakhon Pathom Province, the 9th province with the most crimes against property reported in 2011 (National Statistical Office, 2011) and the 2nd highest crimes against property found between 2013 and 2017

2. Materials and Method

2.1 Materials

Table 1 explains the data used in this investigation. The study area is Mueang Nakhon Pathom, as seen in Figure 1. The statistics of criminal data including cases, arrest points, and date and time of incidents reported, were secondary data retrieved from the Criminal Statistics Reported Book of Mueang Nakhon Pathom Police Station between 2013 and 2018. After that, the criminal-reported books were converted to .xlsx and spatial.

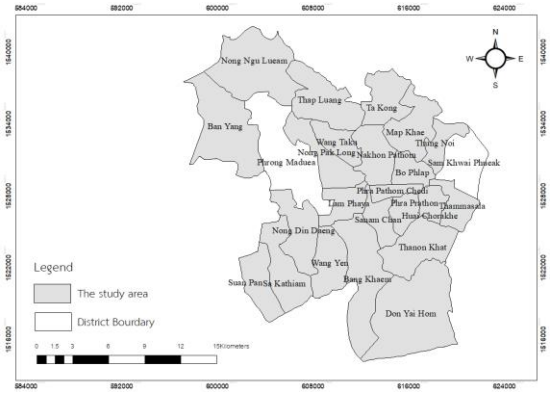

Figure 1. Responsibility area of Mueang Nakhon Pathom Police Station, the study area.

Figure 2. Methodology of the study consists of the following steps: first, input criminal data (.xlsx). After that, the criminal data was converted to a suitable .shp before 4 steps of analysis: 1) Global geo-statistic, Moran's I to evaluate the pattern of similar correlation overall in the study area. 2) Local geo-statistic, Getis-ord Gi* for evaluation of a specific area. Then, hotspot results were continued to be analyzed with 3) Directional distribution for predicting the trend and distribution of crime. Finally, 4) Find the spatial relationship between land use, population density, and crime.

2.2 Methods

Figure 2 displays the workflow of this study, which is 2.2.1) identifying patterns of crimes against property using Moran's I, 2.2.2) finding the prevalence of crimes against property using Getis-Ord Gi*, 2.2.3) determining trends and direction of distribution of crimes against property using standard deviational ellipse, and 2.2.4) discovering the spatial relationship between crimes against property, land use, and population density.

Table 1. Data and data source of the study.

Data	Detail	Data source / Year
Crimes Statistics Reported of Mueang Nakhon Pathom Police Station, Nakhon Pathom Province, 2013 to 2018	cases, arrest point, date and time of reporting, date and time of arrest	Crimes Statistics Reported book of Mueang Nakhon Pathom Police Station, Nakhon Pathom Province, retrieved from 2013 to 2018
Administrative district	The administrative district of Mueang Nakhon Pathom, Nakhon Pathom Province, ratio 1:25,000 (.shp)	Land Development Department (2015 and 2017)
Land use	The administrative district of Mueang Nakhon Pathom, Nakhon Pathom Province, ratio 1:25,000 (.shp)	Land Development Department (2010 to 2017)
Population density	Population per yearly, per sub-district (.xls)	Department of Provincial Administration (2013 to 2017)

2.2.1 Identifying patterns of crime against property using Moran's I

Moran's I is a correlation coefficient that is used for finding patterns in complicated data sets. Moran's I result shows a value from -1 to 1. If the value approaches 1, the data is clustered. If the value is close to -1, the data is scattered, and if the value approaches 0, the distribution is random (Dechsiri & Robert, 2019), as seen in equation (1).

$$I = \left(\frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}} \right) \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}\left(x_i - \bar{X}\right)\left(x_j - \bar{X}\right)}{\sum_{i=1}^{n}\left(x_i - \bar{X}\right)^2} \quad (1)$$

Where I = Moran's I Index value

$\sum_{i=1}^{n}\left(x_i - \bar{X}\right)^2$ = The sum of the squares of the difference between the event value and mean, where xi and xj are the statistics of crime against property cases in Mueang Nakhon Pathom Police Station's responsibility area

$\bar{x}$ = Mean of arrests for crime against property cases in the Mueang Nakhon Pathom Police Station's responsibility area from 2013 to 2017

N = The scope of the study

$\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}$ = Sum of polygons enclosed which matched in the study. The area obtained from the weighted matrix of the i and j where a value approaching 1 means i and j are neighbors meanwhile a value approaching 0 means i and j are not together

$\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}\left(x_i-\bar{X}\right)\left(x_j-\bar{X}\right)$ = The weighted value of the difference between the event values and meaning of neighbours where X_i and X_j are the numbers of occurrences of the interest factor in i and j

2.2.2 Finding the prevalence of crime against property using Getis-Ord Gi*

Getis-Ord Gi* or Hot Spot Analysis based Getis-Ord Gi* is a specific spatial statistic used to identify high- and low-incident areas the study area. If the value of GiZscore is greater than 1.65, the study area has a very high incidence and if the value of GiZscore is less than -1.65, it means the study area has a very low incidence (Abdulhafedh, 2017) as shown in equation (2).

$$G_i^*(d)=\frac{\sum_j w_{ij}(d)x_j-w_i^*\bar{X}}{S\left\{\left[\left(nS_{ij}^*\right)-W_X^{*2}\right]/(n-1)\right\}^{1/2}} \quad (2)$$

where x_j = value of variable x at location j

w_{ij} = elements of the weight matrix

n = the number of crimes

S = the variance of Getis-ord Gi* where

$$S=\sqrt{\frac{\sum_j x_j^{\,2}}{n}-\left(\bar{X}\right)^2}$$

$\bar{x}$ = mean of the variable x

2.2.3 Determining trends and direction of distribution of crime against property cases using Standard Deviational Ellipse

Directional distribution (Standard Deviational Ellipse or SDE), is the dispersion direction analysis for measuring the distribution of crime points by calculating distances in x- and y-axis directions; the values of x- and y- can determine the ellipse's axis size and thus show the distribution of incidents and also indicate the rotation angle of the ellipse or the distribution direction of the data as demonstrated in equations (3) and (4) (ESRI, 2009a, 2009b, 2009c).

$$SDE_y=\sqrt{\frac{\sum_{i=1}^{n}\left(y_i-\bar{Y}\right)^2}{n}} \quad (3)$$

$$SDE_x=\sqrt{\frac{\sum_{i=1}^{n}\left(x_i-\bar{X}\right)^2}{n}} \quad (4)$$

where x_i = crimes point at I position and x axial

y_i = crimes point at I position and y axial

$\bar{x}$ = mean center of crime along the x-axis

$\bar{y}$ = mean center of crime along the y-axis

n = number of crimes point.

the determine of rotation angle as shown in equations (5) to (8), respectively.

$$\tan\Theta=\frac{A-B}{C} \quad (5)$$

$$A=\left(\sum_{i=1}^{n}\bar{X}_i^2-\sum_{i=1}^{n}\bar{Y}_i^2\right) \quad (6)$$

$$B=\sqrt{\left(\sum_{i=1}^{n}\bar{X}_i^2-\sum_{i=1}^{n}\bar{Y}_i^2\right)^2+4\left(\sum_{i=1}^{n}\bar{X}\bar{Y}\right)^2} \quad (7)$$

$$C=2\sum_{i=1}^{n}\bar{X}_i\bar{Y}_i \quad (8)$$

where $\bar{x}_i$ = deviation of x position from the central mean

$\bar{Y}_i$ = deviation of Y position from the central mean

2.2.4 Discovering the spatial relationship between crime against property, land use and population density

The spatial relationship between land use and the occurrence of crime against property was analyzed using the overlay technique, i.e., hot and cold spots of crime acquired from Getis-Ord Gi*

were spatially overlaid with land use data to investigate spatial relationships. Afterward, population density data were included discover the spatial relationship between crime incidents and population density.

3. Results and Discussion

3.1 Patterns of crime against property

The patterns of crime against property between 2013 and 2017 in Mueang Nakhon Pathom were all clustered according to Moran's I value, which was discovered at 0.32, 0.27, 0.29, 0.27, and 0.23, as shown in Figures 3-7. The pattern results were concentrated in the city center, with some scattered in villages and on deserted roads with insufficient lighting. Spatial autocorrelation analysis results were displayed in Figures 8-12, respectively.

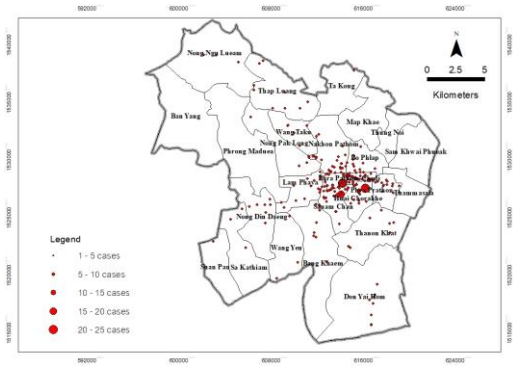

Figure 3. The crime against property pattern in 2013.

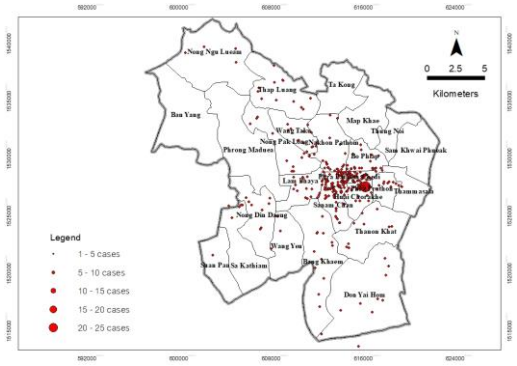

Figure 4. The crime against property pattern in 2014.

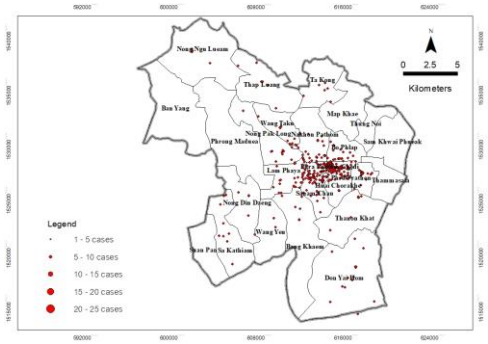

Figure 5. The crime against property pattern in 2015.

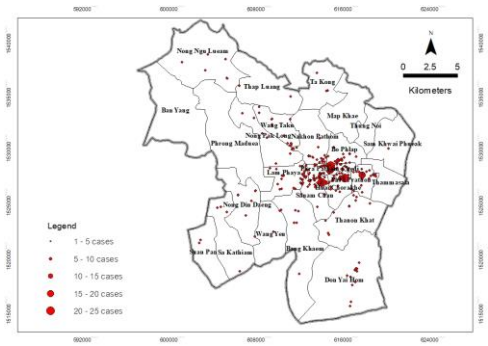

Figure 6. The crime against property pattern in 2016.

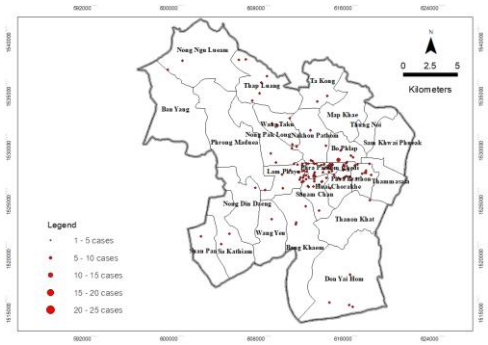

Figure 7. The crime against property pattern in 2017.

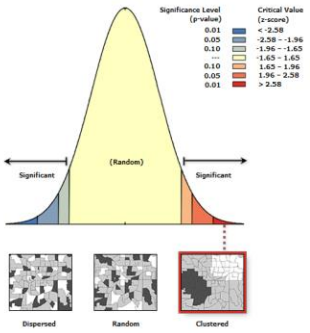

Figure 8. Spatial autocorrelation report of crime against property in 2013.

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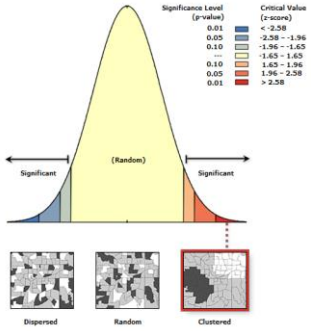

Figure 9. Spatial autocorrelation report of crime against property in 2014.

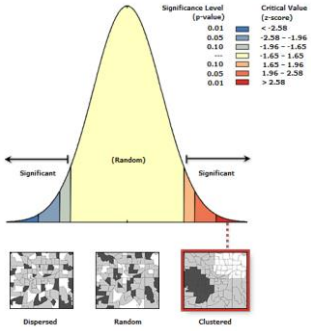

Figure 10. Spatial autocorrelation report of crime against property in 2015.

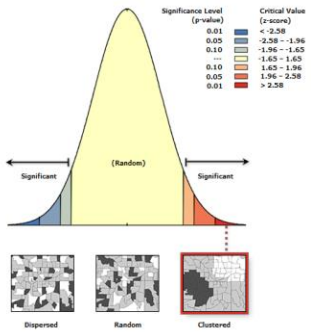

Figure 11. Spatial autocorrelation report of crime against property in 2016.

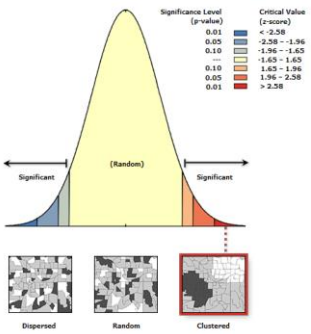

Figure 12. Spatial autocorrelation report of crime against property in 2017.

3.2 Hotspot analysis of crime against property based Getis-Ord Gi*

The crime against property cases from 2013 to 2017 in Mueang Nakhon Pathom were discovered high-incidence areas with a GiZscore greater than 1.65. In this case, those areas were as follows: Huai Chorakhe, Phra Prathon, and Thammasala district in 2013 (Figure 13); Huai Chorakhe, Bo Phlap, Thammasala, Phra Prathon, and Thanon Khat district in 2014 (Figure 14); Huai Chorakhe and Phra Prathon district in 2015 (Figure 15); Bo Phlap, Phra Phathom Chedi, Phra Prathon, Sanam Chan, Huai Chorakhe and Thanon Khat district in 2016 (Figure15); Huai Chorakhe and Phra Prathon district in 2017 (Figure 16); The results indicate that, a high incidence of crime was around the city and slightly towards the Mueang Nakhon Pathom borderland and adjacent provinces.

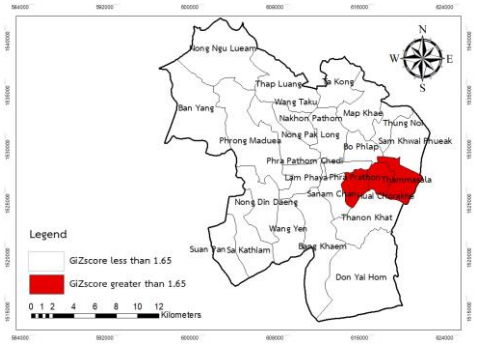

Figure 13. Hotspot analysis of crime in 2013.

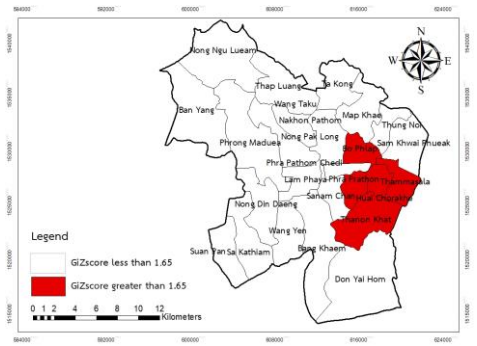

Figure 14. Hotspot analysis of crime in 2014.

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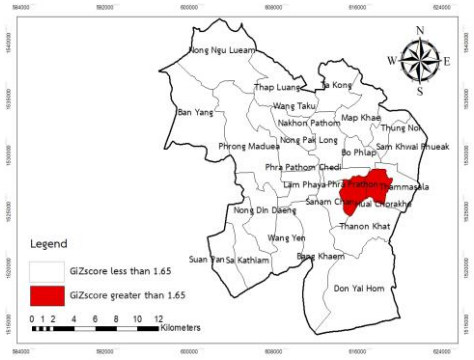

Figure 15. Hotspot analysis of crime in 2015.

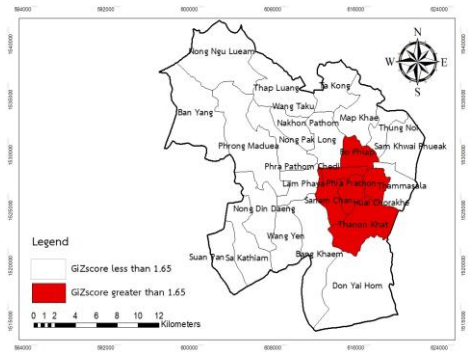

Figure 16. Hotspot analysis of crime in 2016.

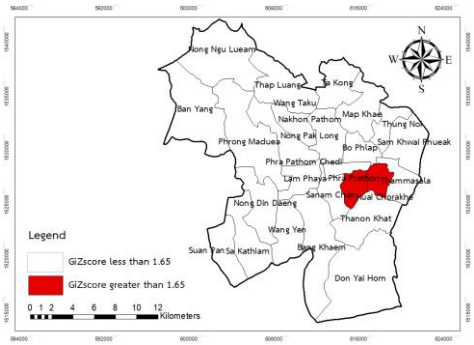

Figure 17. Hotspot analysis of crime in 2017.

3.3 Direction distribution results of crime against property with standard deviational ellipse

The trend and distribution of crime against property cases in Mueang Nakhon Pathom revealed that all of the distribution directed to the west covered Bo Phlap, Phra Prathon, Phra Prathom Chedi, Huai Chorakhe, and Thanon Khat districts in 2013 (Figure 18); the rotation value of 115.58 covered Bo Phlap, Phra Prathon, Phra Prathom Chedi, Huai Chorakhe, and Thanon Khat districts in 2014 (Figure 19). The rotation value of 143.09 covered Bo Phlap, Phra Prathon, Phra Prathom Chedi, Huai Chorakhe, Thanon Khat, Nakhon Pathom, and Sanam Chan districts in 2015 (Figure 20). The rotation value of 125.43 covered Bo Phlap, Phra Prathon, Phra Prathom Chedi, Huai Chorakhe, Thanon Khat, and Nakhon Pathom districts in 2016 (Figure 21). The rotation value of 144.34 covered Bo Phlap, Phra Prathom Chedi, Phra Prathon, Huai Chorakhe, Thanon Khat, Nakhon Pathom, and Sanam Chan districts in 2017 (Figure 22). All of the distribution had a direction to the west of the study area, covering the town center and heading to the borderland to adjacent provinces, the main, long roads to Bangkok, and Samut Sakhon Provinces, which sometimes did not have enough light.

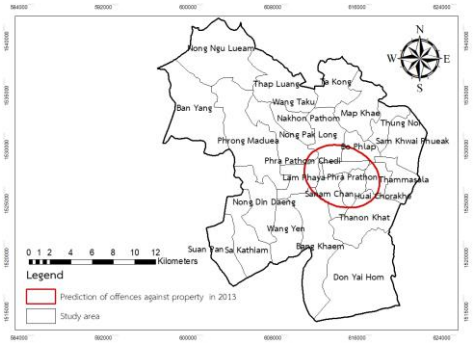

Figure 18. Trend and distribution of crime against property in 2013.

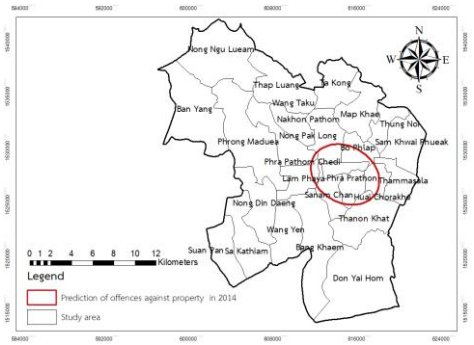

Figure 19. Trend and distribution of crime against property in 2014.

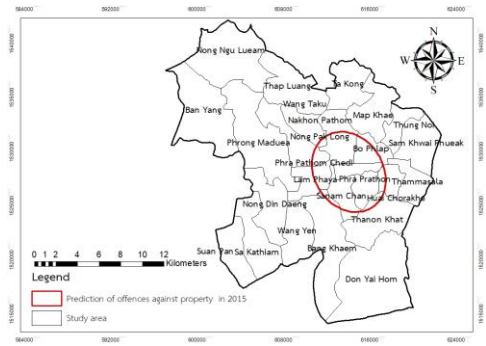

Figure 20. Trend and distribution of crime against property in 2015.

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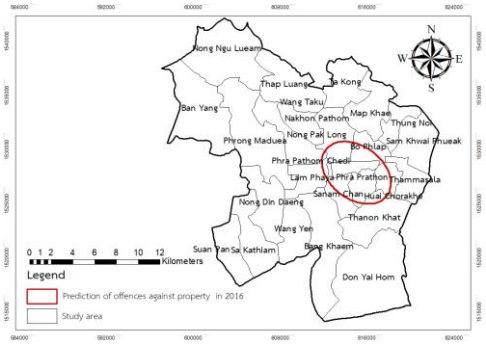

Figure 21. Trend and distribution of crime against property in 2016.

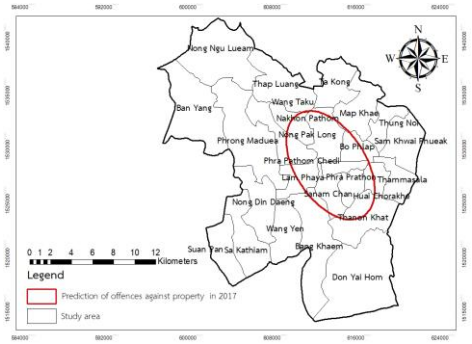

Figure 22. Trend and distribution of crime against property in 2017.

Table 2. Analysis results of crime against property using standard deviational ellipse.

Years	Center X	Center Y	X Std Dist	Y Std Dist	Rotation
2013	100.05710	13.81252	0.034028	0.025081	110.14535
2014	100.06022	13.81491	0.031438	0.023738	115.57669
2015	100.05246	13.81789	0.035852	0.029069	143.09139
2016	100.06135	13.81553	0.032435	0.022277	125.43046
2017	100.04804	13.82184	0.051394	0.030611	144.33950

3.4 Validation of predicted spatial trend and distribution of crime incidents

The spatial trend and distribution of crime incidents were validated using predicted cases and actual incidents, as shown in Table 3. The average of crime incidents from 2013 to 2017 was used to validate actual crime cases discovered in 2018. The result of the average rotation was 127.72 degrees toward the west direction. The spatial distribution of actual crime incidents in 2018 was at a 108.40-degree rotation. This explained why the precision of the predicted spatial trend and distribution of crime was 94.18%.

Table 3. The result of the validation of the analysis.

Crime against property cases	Rotation
predict of cases	127.71668
actual cases	108.40097

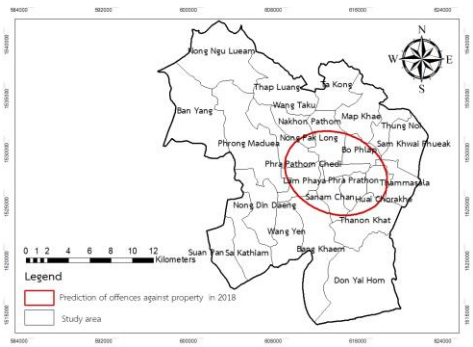

Figure 23. Trend and distribution of crime against property in 2018.

3.5 Spatial relationship between crime against property, land use and population density

The spatial relationship between the occurrence of crime against property and land use in the same years (2015 and 2017) was analyzed. The data for 2015 showed 453 crimes against property cases with 219 incident coordinates in urban and built-up areas (48.34%) (Figure 24). Similarly, the data for 2017 showed 348 crimes against property cases with 158 incident coordinates in urban and built-up areas (45.40%) (Figure 25). In addition, the results showed incidents of crime were almost exclusively found in cities, towns, and commercial areas (49.44%), institutions (18.74%), and villages (15.12%), respectively.

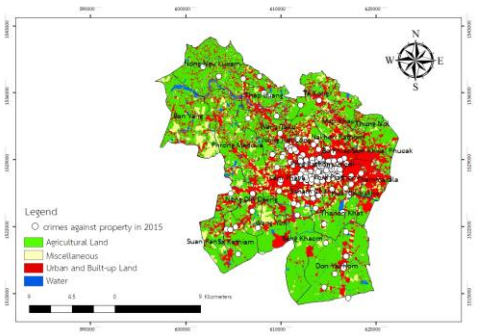

Figure 24. The relationship between land use and crimes against property in 2015.

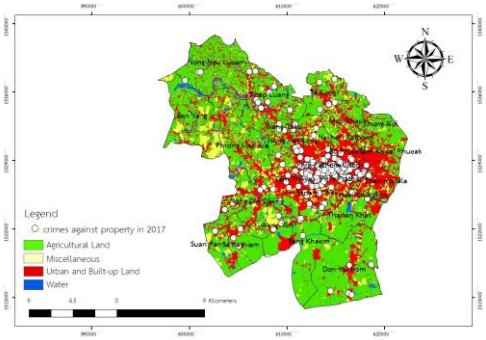

Figure 25. The relationship between land use and crime against property in 2017.

Moreover, the spatial relationship between a crime against property and population density was analyzed. The result showed a spatial relationship between population density and a crime against property in the Phra Pathom Chedi district, the location of the city center consists of tourist attractions, schools, residences, villages and community malls (Figure 26). The results showed a correlation in Sanam Chan district, where there is a low population density but a large number of temporary residents, a passive population, and a cluster of entertainment venues and on-premise and off-premise alcohol retailers because Sanam Chan district is located near universities, schools, dormitories that are always crowded, and a large number of commercial establishments (Figure 27).

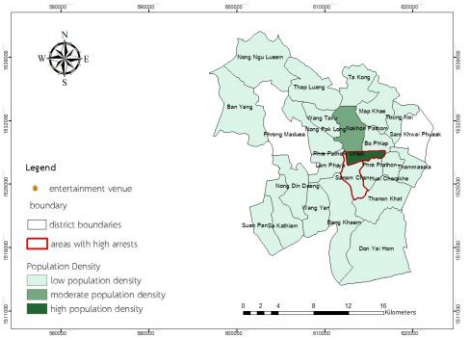

Figure 26. The spatial relationship between land use and crimes against property.

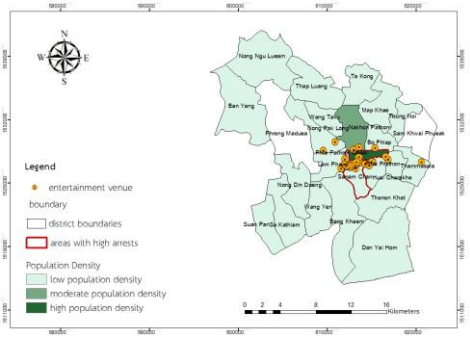

Figure 27. The spatial relationship between crimes against property, land use, and entertainment venues.

4. Conclusions

The geo-spatial analysis of crime against property in Mueang Nakhon Pathom was a great approach to examining the patterns, hotspots, trends and distribution direction, and spatial relationships of crimes. The results of this analysis revealed that the pattern of cases involving crimes against property in the responsibility area of Mueang Nakhon Pathom Police Station from 2013 to 2017 was clustered. The pattern of crime against property is obviously clustered around the center of Mueang Nakhon Pathom, where schools, universities, residences, villages, markets, communities, dormitories, entertainment venues, alcohol stores, tourist attractions, and deserted and dark roads are located. Hot spot analysis showed high incidence areas that had a GiZscore more than 1.65 as follows. the center of the city, the place that consists of a large number of villages, community malls, markets, schools, universities, the bypass road, and slightly towards the borderland, forward to adjacent provinces, heading to Bangkok and Samut Sakhon, farm, and deserted place. The trends of crimes showed the direction of the distribution to the west, directed to the main road to Bangkok and Samut Sakhon, the long, deserted road toward Bangkok and Samut Sakhon Provinces, which sometimes did not have enough light. The spatial relationship between the occurrence of crime against property and land use in 2015 and 2017 showed the most incidences in urban and built-up areas (92.66% and 94.61%, respectively). Evidence indicates that crowded villages and communities are obviously risk and a thief attraction. Moreover, the results illustrated the relationship between crime against property and the population density area in the center of Mueang

Nakhon Pathom, where crowded, markets, schools, universities, community malls, tourist attractions, and government offices are located. The Sanam Chan district showed high crime incidents because of the many passive populations and a cluster of entertainment venues. Property crime is always associated with crowded, deserted, and dark places, as well as built-up and community areas. In addition, the results showed incidents of crime were almost found in cities, towns, and commercial areas (49.44%), institutions (18.74%), and villages (15.12%), respectively. Finally, the overall results of this study help make relevant staff and police officials aware of the overall crime incident so that they can predict and develop prevention plans, suppression strategies, and deterrence tactics for crime reduction.

Acknowledgement

The authors would like to thank Mueang Nakhon Pathom Police Station, Nakhon Pathom Province for contributing crime data. We are also grateful to the Program in Forensic Science and Criminal Justice, Faculty of Science, Silpakorn University for the support throughout this research.

References

Abdulhafedh, A. (2017). A novel hybrid method for measuring the spatial autocorrelation of vehicular crashes: Combining Moran's Index and Getis-Ord G_i* statistic. *Open Journal of Civil Engineering*, *7*(2), 208-221. doi:10.4236/ojce.2017.72013

Achu, A. L., Aju, C. D., Suresh, V., Manoharan, T. P., & Reghunath, R. (2019). Spatio-temporal analysis of road accident incidents and delineation of hotspots using geospatial tools in Thrissur district, Kerala, India. KN - *Journal of Cartography and Geographic Information*, *69*, 255-265. doi:10.1007/s42489-019-00031-1

Ahmed, M., & Salihu, R. (2013). Spatiotemporal pattern of crime using Geographic Information System (GIS) approach in Dala L.G.A of Kano State, Nigeria. *American Journal of Engineering Research (AJER)*, *2*(3), 51-58.

Balogun, T. F., Okeke, H., Chukwukere, C. I. (2014). Crime mapping in Nigeria using GIS. *Journal of Geographic Information System*, *6*(5), 453-466. doi:10.4236/jgis.2014.65039

Chutia, D., Santra, M., Nishant, N., Singh, P. S., Chouhan, A., & Raju, P. L. N. (2020). Mapping of crime incidences and hotspot analysis through incremental auto correlation – A case study of Shillong city, Meghalaya, India. *Journal of Geomatics*, *14*(1), 61-71.

Dechsiri, B., & Robert, O. P. (2019). Drug trafficking estimation based on geo-statistics. *Defence Technology Academic Journal*, *1*(3), 52-61.

Dharmniti. (2019). *Against property according to the Criminal Code*. Retrieved from https://www.dharmniti.co.th/

ESRI. (2009a). *How spatial autocorrelation (global Moran's I) works*. Retrieved from https://www.pro.arcgis.com/

ESRI. (2009b). *How hot spot analysis (Getis-Ord Gi*) works*. Retrieved from https://www.pro.arcgis.com/.

ESRI. (2009c). *Standard deviational ellipse (Spatial statistics)*. Retrieved from https://pro.arcgis.com/en/

In-ain, T. (2018). *Developing a spatial database for the application of GIS in drug offences analysis*. Retrieved from https://www.agi.nu.ac.th/nred/Document/is-PDF/2561/geo_2561_018_FullPaper.pdf

Mitchell, A. (2005). *The ESRI guide to GIS analysis, volume 2: Spatial measurements and statistics*. Retrieved from https://www.esri.com/en-us/esri-press/

Mohammed, A. F., & Baiee, W. R. (2020). Analysis of criminal spatial events in GIS for predicting hotspots. *IOP Conference Series: Materials Science and Engineering*, *928*, 1-8. doi:10.1088/1757- 899X/928/3/032071

National Statistical Office. (2011). *Top 10 statistics.* Retrieved from http://service.nso.go .th /nso/nsopublish/TopTen/Top_othsoc.html

Nation Statistical Office. (2016). *Statistics of reported and arrested for the crimes of interest group by type of reported cases and province: 2007-2016*. Retrieved from http://statbbi.nso.go.th/staticreport/

Paramasivam, C. R., & Venkatramanan, S. (2019). An introduction to various spatial analysis techniques. In S. Venkatramanan, M. V. Prasanna, & S. Y. Chung (Eds.), *GIS and geostatistical techniques for groundwater science* (pp. 23-30). Amsterdam, Netherlands: Elsevier.

Phuaksomon, K. (2020). *People participation in preventing crimes in Hatyai Municipality, Hatyai District, Songkhla Province* (Master's thesis). Kasetsart University, Thailand.

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. doi:10.1016/j.sbspro.2011.07.020

Rattanapongs, P., & Gulabutr, V. (2020). Safety management from crime: against properties of students living dormitories in Salaya district, Nakhon Pathom Province. *Journal of MCU Buddhapanya Review*, *5*(3), 114-129.

Royal Thai Police. (2021). *Cracking down on the crime problem in 2011, escalating non-stop, social threats aggravate the people during the Covid period*. Retrieved from https://www.thairath.co.th/scoop/theissue/2262011

Srithamarong, T. (2016). *Crime risk area assessment based geo-spatial statistics* (Master's thesis, Silpakorn University). Retrieved from http://www.sure.su.ac.th/xmlui/handle/123456789/20686

Thailand Lawyer. (2020). *Criminal code*. Retrieved from https://library.siam-legal.com/thai-law

Wang, B., Shi, W., & Miao, Z. (2015). *Confidence analysis of standard deviational ellipse and its extension into higher dimensional Euclidean space*. *PLoS ONE, 10*(3). doi:10.1371/journal.pone.0118537

Yiampisan, M., & Srivanit, M. (2010). Using the Kernel density estimation surface for criminal pattern: A case study in Phranakhon District, Bangkok. *Journal of Architectural/Planning Research and Studies*, *7*(1), 87-102.