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GIS for Risk Areas Analysis of Stolen Motorcycles Crime, Mueang Chonburi Police Station, Thailand

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Abstract

In 2023, Thailand exhibited the greatest motorbike usage rate on a global scale, as reported by the World Atlas website. The Department of Land Transport, Thailand recorded a total of 22,540,765 registered motorcycles in 2023. Motorcycle users in Thailand encounter the significant problem of vehicular theft. This research focused on the stolen motorcycle crime statistics under the jurisdiction of Mueang Chonburi Police Station, utilizing a dataset spanning five years from 2019 to 2023. This research recommends the implementation of Crime Prevention Through Environmental Design (CPTED) in high-risk areas. The concept of crime prevention in areas characterized by high crime rates or elevated risk factors has the potential to reduce overall crime levels. The objective of this study is to conduct crime analysis utilizing GIS-based methods, using ArcGIS Pro software version 3.0 to analyze the risk areas related to motorbike theft. The risk zones were assessed through spatial statistic analysis, including Global Moran's I approach of spatial autocorrelation and Getis-Ord Gi* statistics. The Inverse Distance Weight (IDW) method was applied to improve the visualization of hot spots. The results of these three techniques indicate that, from 2019 to 2023, Nong Mai Daeng was identified as the highest risk area, with varying degrees of confidence: medium (90% confidence level, Gi* = 1.65–1.96), high (95% confidence level, Gi* = 1.96–2.58), and very high (99% confidence level, Gi* > 2.56). The findings of the analysis are highly valuable and significant for supporting various departments within the Royal Thai Police. Police stations can utilize this information for operational planning and allocating patrollers to local communities.

Keywords: Crime analysis, GIS, Hot spot analysis, Risk areas

1. Introduction

A vehicle crime encompasses many criminal activities such as the complete or partial theft, fraudulent transactions involving the sale, purchase, insurance, or identification of a car, truck, motorbike, tractor-trailer, ATV, heavy equipment, or any other motorized vehicle, as well as the theft of its cargo or contents (Parker & Barrow, 2017). According to a report by the Royal Thai Police in 2015, a total of 10,674 motorcycles and 1,315 cars were recorded as stolen between October 2013 and September 2014. A significant number of stolen motorbikes are being transported to the border areas via Cambodia, Laos, Malaysia, and Myanmar. The areas within the jurisdiction of Mueang Chonburi Police Station exhibit various patterns of motorcycle theft, including the trafficking of motorcycles to the border area. Based on data obtained from the informants, it has been observed that motorcycle theft and trafficking are prevalent inside the border region of Cambodia.

In 2017, a total of 81 motorcycle theft incidents were reported in the Aranyaprathet, Pa Rai, and Ta Kham subdistricts of Thailand, involving trafficking operations to Cambodia (Makrit & Vichuwanich, 2021). According to the stolen motorcycle data of Mueang Chonburi Police Station, a total of 367 stolen motorcycle cases were reported during the years 2019 to 2023. This issue requires urgent resolution. The statistics indicate that the number of stolen motorcycles reported by police stations across Thailand, particularly at Mueang Chonburi Police Station, exceeds that of other vehicles such as cars or bicycles, which experience only a few incidents each month. This prevalence is attributed to the relative ease with which criminals can steal motorcycles compared to cars, as well as the simplicity of relocating them. The market price of motorcycles is higher than that of bicycles.

Nong Mai Daeng is the most vulnerable location for stolen motorcycles due to the land use types of city-town-commercial districts, villages, and industrial zones. Furthermore, the demographic composition of Nong Mai Daeng comprises a total of 12,333 individuals. Nong Mai Daeng is geographically situated between the districts of Khlong Tamru and Na Pa. The population of Khlong Tamru is 7,998 individuals, while Na Pa has a population of 38,548. The densely populated areas surrounding these zones can be attributed to the strategic location of the AMATA City Chonburi Industrial Estate in Khlong Tamru. The AMATA City Chonburi Industrial Estate is a highly competitive industrial project situated in Khlong Tamru. It spans an expansive area of 43 square kilometers, encompassing five districts and 23 subdistricts within the provinces of Chonburi and Chachoengsao. As of December 31, 2017, the factories in AMATA City Chonburi Industrial Estate employ a total of 200,000 individuals (Amta Company Limited [AMTA], 2017). Due to its predominantly industrial setting in Khlong Tamru, alongside Nong Mai Daeng. The lifestyle of employees uses motorcycles for transportation in daily life in Nong Mai Daeng, Khlong Tamru, and Napa. Therefore, the primary determinant contributing to the elevated risk level in Nong Mai Daeng is not solely attributed to land use variables within the area itself, but also to land use elements in the surrounding areas such as Khlong Tamru and Na Pa, which consequently impact the incidence of motorcycles theft in Nong Mai Daeng.

According to the third strategic plan policy of the Royal Thai Police, it has been acknowledged by police stations that conducting weekly crime analysis is necessary. However, the continually high occurrence of stolen motorcycles in Thailand can be attributed to the current shortage of crime analysis professionals and technologies for crime analysis, such as ArcGIS Pro within the Royal Thai Police Department. The potential consequences of this could influence the effectiveness of crime prevention strategies.

Stolen motorcycles are often linked to criminal activities that encompass a range of high-impact offenses, including terrorism, robbery or burglary, arson, drug trafficking, homicide, house invasion, and, shootings. By lacking crime statistics to substantiate trends or forecast criminal activity, the police lack necessary evidence-based authority. It is important to promote the use of new evidence to enhance the police's capacity to identify and apprehend offenders involved in a recurring sequence of criminal activities related to stolen motorbike crimes. Identifying potential locations of risk areas for stolen motorcycles helps effectively manage and mitigate crime in various other domains (Parker & Barrow, 2017). Patrol police officers play a crucial role in crime prevention by actively engaging with the community or patrolling high-risk locations. Therefore, comprehending the geographical aspects of crime through the examination of risk area assessment is a crucial

step towards investigating alternative approaches to crime resolution. Police officers responsible for patrol, investigation, forensics, community policing, and logistics can effectively utilize crime analysis methods, which serve as the key mechanism. It is widely acknowledged that crime analysis is necessary to achieve the objectives of problem-oriented policing. Crime mapping is also employed as a means to facilitate investigations aimed at apprehending suspects, preventing people from inflicting further harm upon future victims of crime.

This study aims to analyze the areas of high risk resulting from hot spot analysis of stolen motorcycles under the jurisdiction of Mueang Chonburi Police Station by using GIS-based approaches. One of the techniques, the Getis-Ord Gi*, is used to reveal the riskiest places based on spatial crime pattern and future hot spots. This method was introduced by Getis and Ord. It is used to identify a tendency for positive spatial clustering and can strongly distinguish between high and low spatial associations in stolen motorcycle location areas. The proposed statistical method can capture the events' frequency, associated values and spatial correlation, and is used to reveal the riskiest areas for spatial crime pattern and future hot spots (Alkaabi, 2023). In this research, the weighted interpolation method Inverse Distance was used to better visualize the outcome of the hot spot analysis (Mohammed & Baiee, 2020). Each method demonstrates effectiveness in isolation and can be employed according to specific requirements. If law enforcement authorities want to strategize for the augmentation of police red box checkpoints or police patrolling within high-risk areas. It is possible to utilize the outcomes obtained via Gitis-Ord Gi*, IDW, and Kernel Density Estimation (KDE). The utilization of weekly criminal hot spot analysis or quick response or Emerging Hot Spot analysis may be employed for the aim of analysis. However, the combined use of all these methodologies collectively may yield a superior answer. The findings of this assessment will be employed in research efforts aimed at benefiting several sectors inside the police station, including patrol police, investigation police, planning police, forensics police, and community policing police.

2. Materials and Methods

To evaluate areas of risk for motorcycle theft by spatial analysis, incident reports from 2019 to 2023 were gathered from the Mueang Chonburi Police Station. The dataset spanning five years contains pertinent details regarding motorcycle theft, including precise addresses. This police station serves 11 districts in Mueang Chonburi City, located in the Chonburi Province of Thailand's Eastern region. The Mueang Chonburi Police Station covers an area of responsibility of approximately 143.82 square kilometers and serves 11 districts, which include Khlong Tamru, Nong Mai Daeng, Bang Sai, Bang Pla Soi, Ban Khot, Ban Saun, Makham Yong, Samnak Bok, Nong Khang Khok, Nong RI, and Na Pa, as shown in Figure 1.

The total population amounts to approximately 435,380 individuals, nearly half a million. Chonburi Province is situated in the eastern part of Thailand, specifically at coordinates 13°13′N 101°11′E (WGS - 1984 and UTM zone 48N). The province has borders with neighboring provinces such as Rayong, Chanthaburi, and Chachoengsao. Bangkok serves as the western boundary. Pattaya is situated in Chonburi, a renowned global tourist destination. Thailand's maritime port is situated within the industrial zone of Chonburi, specifically known as Laem Chabang. As of December 31, 2018, the recorded population of Chonburi was 1.535 million. The province of Chonburi encompasses a total of 11 cities, specifically Mueang Chonburi, Ko Chan, Ban Bueng, Sattahip, Bo Thong, Nong Yai, Bang Lamung, Ko Sichang, Phan Thong, Phanat Nikhom, and Si Racha.

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Chonburi is one of the three Eastern Provinces—Rayong, Chonburi, and Chachoengsao—that have been officially designated by the Thai government as integral components of the Eastern Economic Corridor (EEC).

Nong Mai Daeng is the most vulnerable location for motorcycles theft due to its land use types, which include city-town-commercial districts, villages, and industrial zones. Furthermore, Nong Mai Daeng is geographically situated between the districts of Khlong Tamru and Na Pa. The densely populated areas surrounding these zones can be attributed to the strategic location of AMATA City Chonburi Industrial Estate in Khlong Tamru.

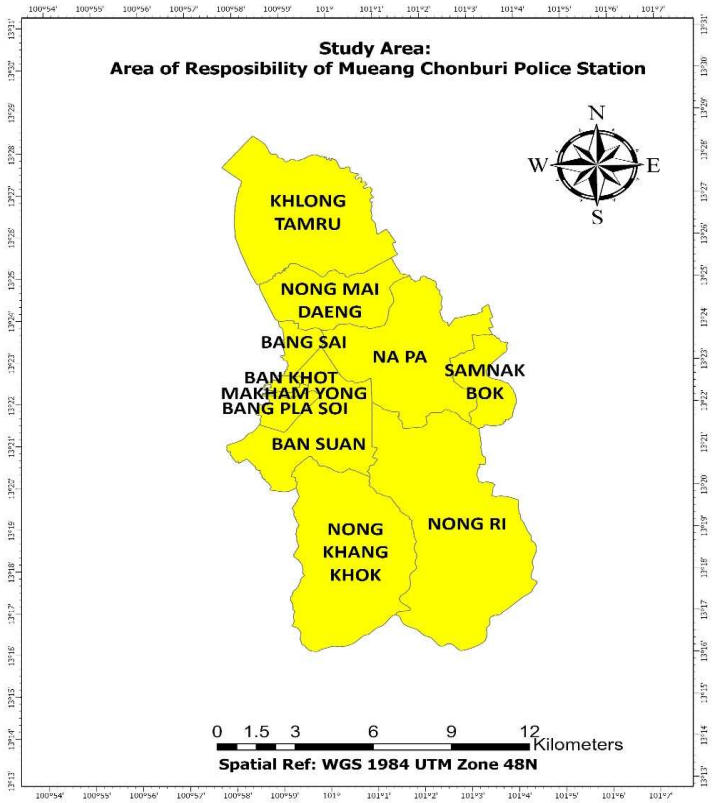

Figure 1 Study area of Mueang Chonburi Police Station, covering 11 districts

2.1 Stolen Motorcycles Crime Data Collection

This study aims to examine the occurrences of motorbike theft from 2019 to 2023 as reported by victims at Mueang Chonburi Police Station. The officer responsible for the criminal case database will record data daily in the police notebook for criminal cases, as well as in the computer system, and must report the cases to the Royal Thai Police Headquarters. By utilizing Geographic Information Systems (GIS) conduct hot spot analysis to evaluate places that are susceptible to vulnerability. A Shapefile is used to record stolen motorcycle crime data in the period from 2019 to 2023. The crime dataset was analyzed using an acronym for "shp." Visualizations were developed to identify regions with a high risk of crime and predict patterns of hot spots. These visualizations were then shown on a map. Over the past five years, there has been a significant surge in the incidence of stolen motorcycles under the jurisdiction of Mueang Chonburi Police Station. The study areas are 11 districts of Mueang Chonburi City, situated in the Chonburi Province of Thailand's Eastern area. Mueang Chonburi Police Station encompasses a geographical expanse of approximately 143.82 square kilometers a total population of 435,380 inhabitants.

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The research framework was developed to guide the spatial analysis of motorcycle theft using GIS-based methods. Figure 2 presents the conceptual framework, which outlines the flow of crime data collection, geolocation, GIS-based analysis, and its application in identifying risk areas to support police operations.

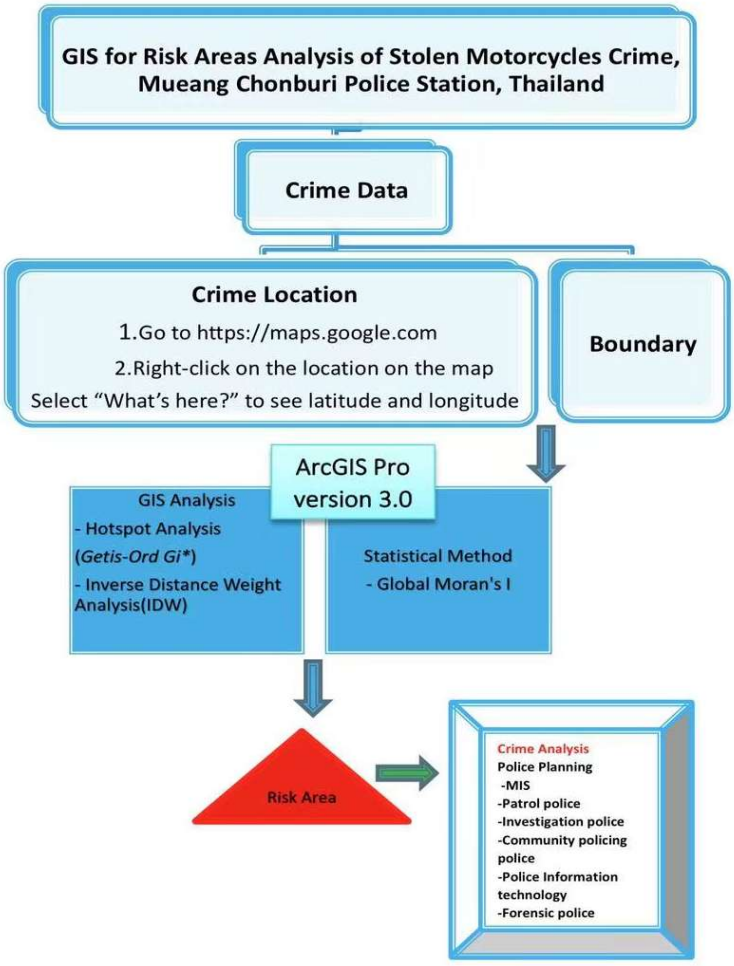

Figure 2 Conceptual Framework for GIS-based risk area analysis of motorcycle theft under the jurisdiction of Mueang Chonburi Police Station, Thailand

2.2 GIS Analysis of Risk Areas

2.2.1 Getis-Ord Gi*

One of the techniques Getis-Ord Gi* used to reveal the riskiest places to use in spatial crime pattern future hot spots. This method was introduced by Getis and Ord. It is used to identify a tendency for positive spatial clustering and can strongly distinguish between high and low spatial associations in stolen motorcycle location areas. The proposed statistical method can capture the events' frequency, associated value and spatial correlation used to reveal the riskiest areas to use in spatial crime pattern future hot spots (Alkaabi, 2023). This paper uses spatial crime mapping to detect the spatial crime patterns of the geographic data and concentrate on the result from the Gi* crime mapping which is the first stage. Hot Spot analysis's main aim is to define and produce useful information required to support decision-makers in implementing effective strategies to minimize and prevent crime. Crime spatial distribution helped to use the spatial correlation between the crime location and their relation in place. Gi* is the most popular and widely used in the spatial

distributions of the incident in spatial data. Predicting spatial crime patterns with crime records dataset and the GIS recent relative can be adopted for future research. Getis-Ord Gi* is used to predict the hot spots and reach out to areas where no crime in the future called cold spots or cold zones. By aggregating the Getis-Ord Gi* predicted hot spot places with more crime committed in the future and that is the second stage.

In the last stage using the output of the crime mapping zones outcome to be visualized in the future optimized spatial correlation and the hot spot predicting, it will show them in the data that will be processed and concentrated on the pattern of the Getis-Ord Gi* result of the crime. In this research, the weighted interpolation method Inverse Distance was used to better visualize the outcome of the hot spot analysis (Mohammed & Baiee, 2020).

A hot spot is a location or a small area within an identifiable boundary showing the concentration of incidents. The three major processes involved in the estimation of desired hot spot of incidents are collection of events, and mapping of clusters using the Getis-Ord Gi* function. Collect-event function available with the spatial statistic tool was used for performing the function, which in turn will yield a new weighted point feature class with a field I Count that indicates the sum of all the incidents that happened in a unique geographic location. This weighted point feature was used as the input for running the hot spot function (Getis-Ord Gi*) to identify whether features with high values or features with low values tend to cluster in the study area. This tool works by looking at each feature within the context of neighboring features. If a feature's value is high, and the values for all of its neighboring features are also high, it is a part of a hot spot. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is much different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score is the result. The statistical equation for calculating Gi* is presented as Equation (1).

$$Gi^*(\mathrm{d}) = \frac{\sum_j W_{ij}(\mathrm{d})\, x_j - W_i^* \bar{x}^*}{S^* \sqrt{\frac{\left[(n\, S^* 1_i) - W_i^{*2}\right]}{(n-1)}}} \qquad (1)$$

Where $W_{ij}(\mathrm{d})$ is a spatial weight vector with values for all cell j within distance d of target cell i, W_i^* is the sum of weights, $S^* 1_i$ is the sum of squared weights, and S^* is the standard deviation of the data in the cells. The Gi^* statistics is a Z score. For statistically significant positive Z scores, the larger the Z score, the more intense the clustering of high values. For statistically significant negative Z scores, the smaller the Z score, the more intense the clustering of low values (Prasannakumar et al., 2011).

2.2.2 Inverse Distance Weight Analysis (IDW)

In this research, the weighted interpolation method Inverse Distance Weight was used to better visualize the outcome of the hot spot analysis. This was inputted to produce a crime hot spot map, using Inverse Distance Weight analysis (IDW). The acquired crime spots were geocoded for each neighborhood separately to latitude–longitude point locations using ArcGIS Pro. This helped to achieve the objective of the determination of crime hot spot maps through the GIS Interpolation method (IDW). The interpolation of the data is done by using the inverse distance weighting method. This method is used to find the unknown value of a particular point by taking the average weight of surrounding known points. This depends on the guideline

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of spatial autocorrelation or spatial reliance, which estimates the level of relationship and reliance among close and far-off items. The Inverse Distance Weighted (IDW) function is used for a set of points that is dense enough to capture the extent of local surface variation needed for analysis. Interpolation is done for victimization points with known values and proposed values at alternate unknown points. It is meant for the prediction of the new data point, which is missing from the dataset with the help of known discrete data points. The IDW as a predictor is a weighted average observation, as shown in Equations (2) and (3).

$$\hat{y}(x) = \sum_{k=1}^{n} v_k(x)\, y_k \tag{2}$$

$$v_k(x) = \frac{w_k(x)}{\sum_{i=1}^{n} w_i(x)} \tag{3}$$

for $x/\in \{X_{1,\ldots,} X_n\}$, $v_k(X_i) = 1$ if i = k and 0 otherwise. Thus, by definition, $\hat{y}$ interpolates the data. The weighting function $w_k(x)$ is chosen such that the prediction at x is influenced more by the nearby points than the distant points (Alabi & Abubakar, 2023).

2.3 Spatial Statistic Analysis of Risk Areas

The Spatial Autocorrelation (Moran's I method), works not only on feature locations or attribute values individually but simultaneously considers both. Given a set of features and an associated attribute, it evaluates whether the spatial pattern is clustered, dispersed, or random. Moran's I is one of the earliest indicators of global spatial autocorrelation and is still used for determining spatial autocorrelation. It compares the value of a variable at any one location with the value at all other locations and can be expressed as Equation (4).

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1,\, j\neq i}^{n} w_{ij}\,(x - \bar{x})}{s_0 \sum_{i=1}^{n}(x_i - \bar{x})^2} \quad \forall i = 1, \ldots, n \ \forall j = 1, \ldots, n \tag{4}$$

where x_i is the value of the feature on location i, $\bar{x}$ is the mean of the feature, n is the total number of locations, W_{ij} is the spatial weight representing the connectivity between feature i and j, and S_0 is the sum of all spatial weight. The results from the Global Moran's I statistics are interpreted concerning its null hypothesis, which states that the attribute is randomly distributed among the features in the study area. The statistical significance of this test is calculated from a Z-score, assuming a normal distribution with a mean of zero and a variance of one. A positive Z-score implies that the feature is surrounded by similar values, while a negative Z-score shows that neighboring features have different values (Prasannakumar et al., 2011).

3. Results and Discussion

3.1 The Results of Getis-Ord Gi*, IDW, Global Moran's I

From the analysis, it is inferred that statistically significant positive GiZScore (high values) indicates incident hot spots, while statistically significant negative GiZScore (low values) indicates incident cold spots. Identified significant hot spots indicate areas with either high or low values, surrounded by other features exhibiting similar tendencies. Breaks were established at Z-scores of 1.65, 1.96, and 2.58, corresponding to statistical significance levels of 0.10, 0.05, and 0.01, respectively. Three confidence interval levels—90 %, 95 %, and 99 %—were employed, with higher confidence levels indicating more likely hot spot aggregation. This method calculates the Global Moran's I

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statistic at varying distances to assess the intensification of clustering at each distance. Within this study, risk areas were categorized into four groups based on the corresponding densities of stolen motorcycle: low, medium, high, and very high-risk areas.

In 2019, the application of Gi* statistics in the hot spot analysis of Mueang Chonburi Police Station revealed a notable impact of stolen motorcycle occurrences in the Nong Mai Daeng district. This impact is accompanied by a high-risk confidence level of 95%, as depicted in Figure 3(a). The existence of concentrated motorcycle theft crime is shown by areas with high positive Gi* ratings on the map. The value of Gi* in the Nong Mai Daeng districts is 1.96–2.58 as presented in Figure 4(a) (Alkaabi, 2023).

To enhance the visualization of the results obtained from the hot spot analysis. The provided data was utilized to generate a crime hot spot map through the application of Inverse Distance Weight analysis (IDW). The IDW results indicate that the areas with the highest incidence of stolen motorcycle crime are Nong Mai Daeng and Khlong Tamru, while Bang Pla Soi, Ban Khot, Ban Saun, Makham Yong, Samnakbok, Nong Khang Khok, Nong RI, Bang Sai, and Na Pa have a lower risk of stolen motorcycles crime as presented in Figure 3(a).

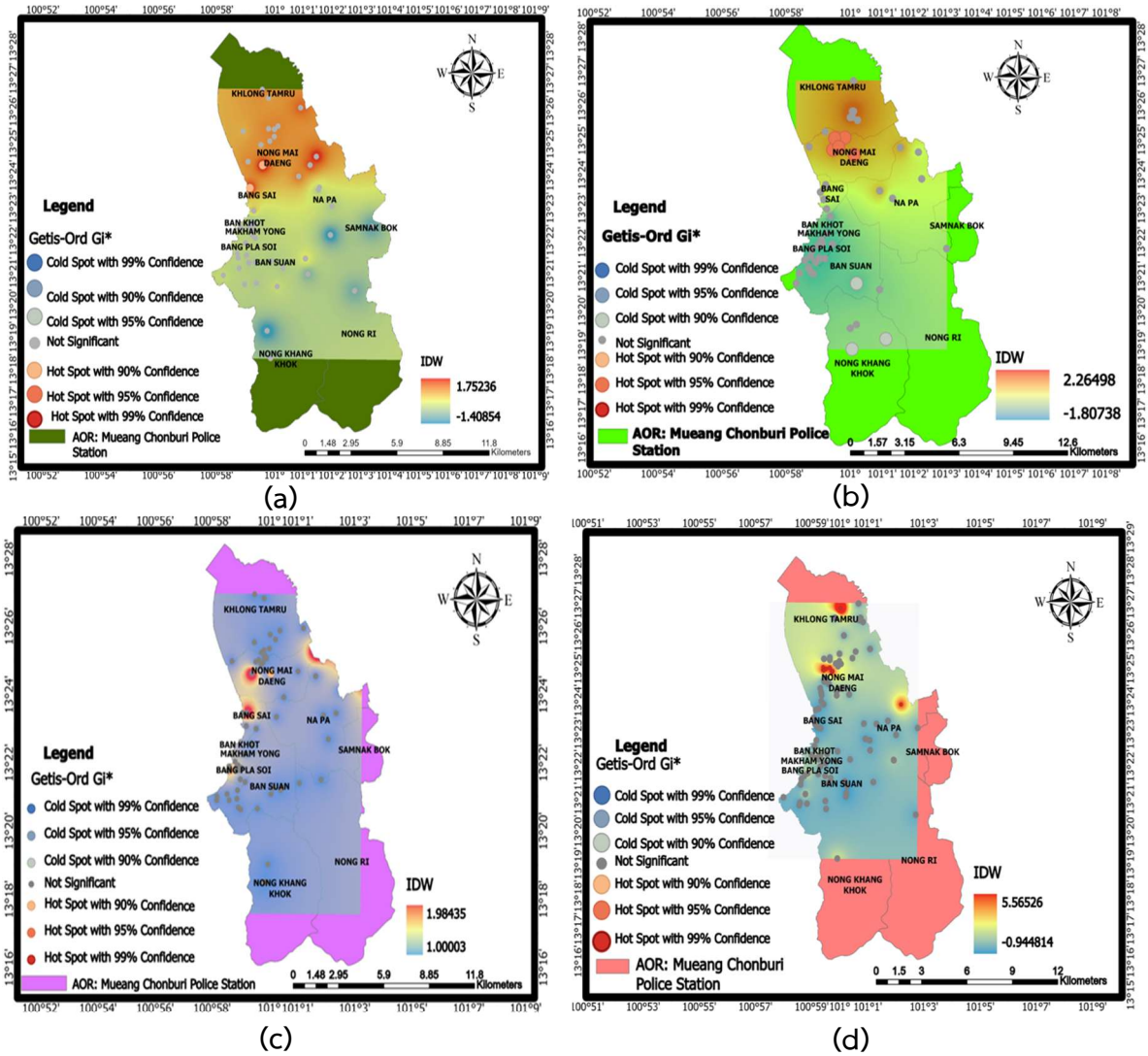

Figure 3 Getis-Ord Gi*/IDW analysis results: (a) 2019, (b) 2021, (c)2022, (d) 2023

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Global Moran's I, this section provides findings for the various hot spot techniques used in analyzing stolen motorcycle crime. To measure the tendency of stolen events to cluster and estimate the overall degree of spatial autocorrelation as shown in Figure 4(a). In the year 2019, the value of Moran's I index was positive as 1.105300, which shows a significant clustering of stolen motorcycles in the study area. The associated z-score was 8.417058, with a p-value of 0.00. The assumption of random distribution for stolen motorcycles was rejected because the z-score of 8.417058 was significantly greater than the threshold for rejection. It means there is less than 1% likelihood that this clustered pattern could be the result of random chance. The high value of absolute z-score indicates significant spatial autocorrelation of stolen motorcycles in the study area (Khan et al., 2023).

The Getis-Ord Gi* and IDW analyses did not yield any significant results in 2020. This may be attributed to the impact of the COVID-19 pandemic, which affected crime patterns nationwide. There was a total of 22 occurrences of motorbike theft in the study area, which influenced the results of the crime analysis.

In 2021, the Getis-Ord Gi* method was applied to conduct hot spot analysis within the Mueang Chonburi Police Station's area of responsibility using Gi* statistic. It becomes evident that the Nong Mai Daeng district area was significantly impacted by stolen motorcycle incidents with medium-risk confidence at the 90% level, as shown in Figure 3(b). Areas with medium positive Gi* scores on the map indicate the presence of concentrated motorcycle theft crime (Gi* = 1.65–1.96) in Nong Mai Daeng areas as presented in Figure 4(b) (Alkaabi, 2023). To enhance the visualization of the results obtained from the hot spot analysis. The provided data were utilized to generate a crime hot spot map through the application of Inverse Distance Weight (IDW) analysis. The IDW results indicate that the high intensity of stolen motorcycle crime is found very high risk at Nong Mai Daeng, Bang Sai, and Khlong Tamru identified as high-risk areas. In contrast, Bang Pla Soi, Ban Khot, Makham Yong, Ban Saun, Samnak Bok, Nong Khang Khok, Nong Ri, and Na Pa were classified as very low-risk crime area, as presented in Figure 3(b).

In 2021, the value of Moran's I index was 0.928155, which that stolen motorcycle incidents were distributed randomly across the study area. The z-score for crashes was 1.410708 and the p-value was 0.158331. The assumption of random distribution was therefore accepted because the z-score did not exceed the threshold for statistical significance. Given the z-score of 1.410708, the pattern does not appear to be significantly different from random, as shown in Figure 4(b) (Khan et al., 2023).

In 2022, the Getis-Ord Gi* method shows the hot spot analysis of the Mueang Chonburi Police Station area of responsibility using Gi* statistics, it becomes evident that Nong Mai Daeng district area is significantly impacted by stolen motorcycle incidents with medium-risk confidence at 90% as shown in Figure 3(c). Areas with medium positive Gi* scores on the map indicate the presence of concentrated motorcycle theft crime Gi* = 1.65–1.96 in Nong Mai Daeng areas as shown in Figure 4(c). To enhance the visualization of the results obtained from the hot spot analysis. The provided data was utilized to generate a crime hot spot map through the application of Inverse Distance Weight analysis (IDW). The IDW (Inverse Distance Weight) results show the high intensity of stolen motorcycle crime is found very high risk at Nong Mai Daeng, Bang Sai, and Bang Pla Soi while Khlong Tamru, Ban Khot, Makham Yong, Ban Saun, Samnak Bok, Nong Khang Khok, Nong RI, Na Pa are very low-risk crime area as presented in Figure 3(c).

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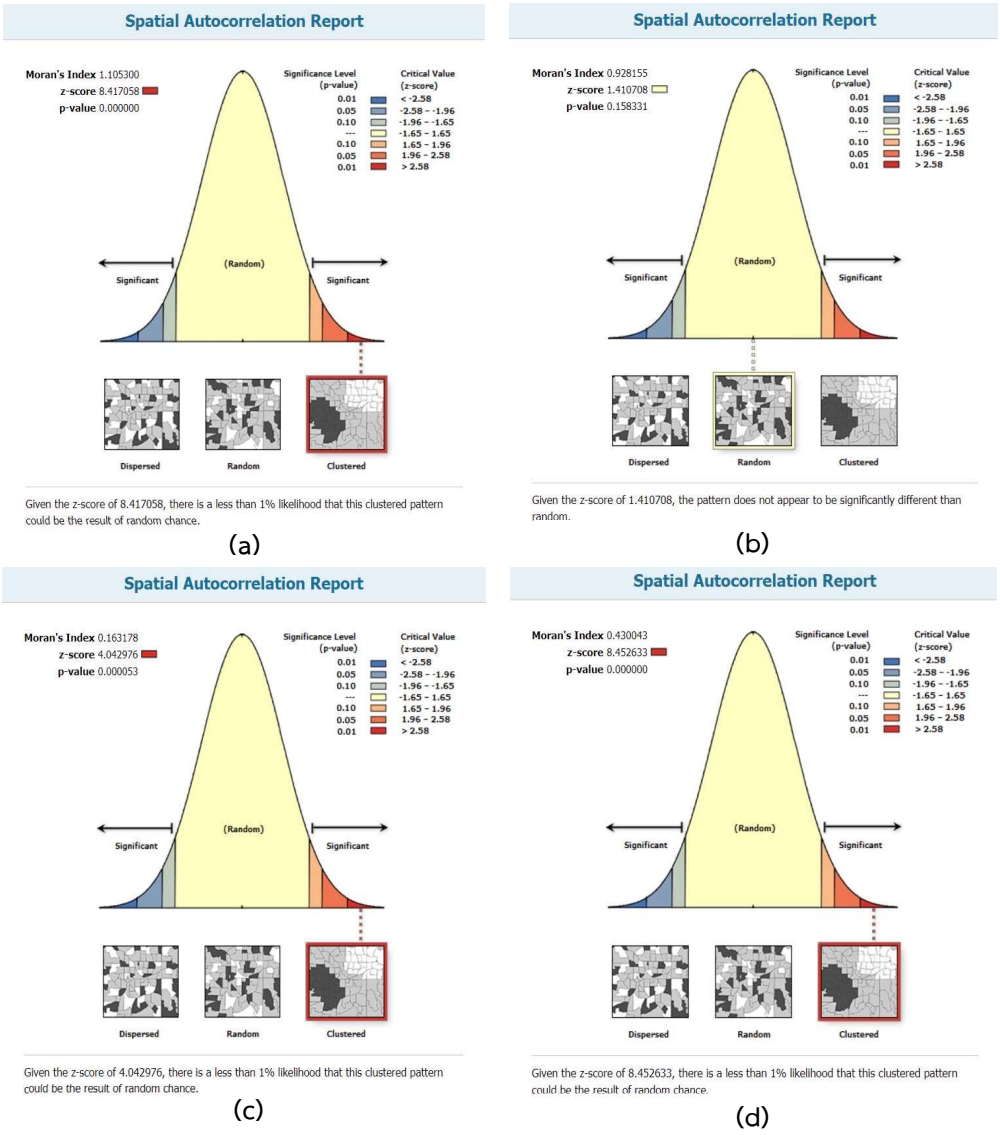

Figure 4 Global Moran's I index analysis results: (a) 2019, (b) 2021, (c)2022, (d) 2023

In 2022, the value of Moran's I index was positive as 0.163178, which shows a significant clustering of stolen motorcycles in the study area. The z-score was 4.042976 and the p-value was 0.000053. The assumption of random distribution for stolen motorcycles was rejected because the z-score of 4.042976 was significantly greater than the threshold for rejection. It means there is less than 1% likelihood that this clustered pattern could be the result of random chance. The high value of absolute z-score indicates significant spatial autocorrelation of stolen motorcycles in the study area Figure 4(c) (Khan et al., 2023).

In 2023, hot spot analysis of the Mueang Chonburi Police Station area of responsibility using Gi* statistics revealed that the Nong Mai Daeng district area was significantly impacted by stolen motorcycle incidents, with very high-risk confidence at 99%, as shown in Figure 3(d). Areas with very high positive Gi* scores on the map indicate the presence of concentrated motorcycle theft crime (Gi*>2.58) in Nong Mai Daeng areas, as shown in Figure 4(d). To enhance the visualization of the hot spot analysis results, the provided data were utilized to generate a crime hot spot map through the application of Inverse Distance Weight (IDW) analysis. The IDW results show that stolen motorcycle crime was classified as very high risk in Nong Mai Daeng, Khlong Tamru,

and Na Pa, while Bang Pla Soi, Ban Khot, Ban Saun, Makham Yong, Samnak Bok, Nong Khang Khok, Nong Ri and Bang Sai were classified as very low-risk crime areas, as shown in Figure 3(d).

Table 1: The results of stolen motorcycle crime risk areas analysis 2019 – 2023

Year	Hot Spot Getis-Ord Gi*	Inverse Distance Weight (IDW)	Global Moran's I index
2019	Nong Mai Daeng (High) Confidence at 95% Gi* = 1.96–2.58	Nong Mai Daeng and Khlong Tamru (Very High)	Moran's Index 1.105300 z-score 8.417058 p-value 0.000000
2020	No result	No result	No result
2021	Nong Mai Daeng and Bang Sai (Medium) Confidence at 90% Gi* = 1.65–1.96	Nong Mai Daeng and Bang Sai (Very High) Khlong Tamru (High)	Moran's Index 0.928155 z-score 1.410708 p-value 0.158331
2022	Nong Mai Daeng (Medium) Confidence at 90% Gi* = 1.65–1.96	Nong Mai Daeng, Bang Sai, and Bang Pla Sroy (Very High)	Moran's Index 0.163178 z-score 4.042976 p-value 0.000053
2023	Nong Mai Daeng, Khlong Tamru, and Napa (Very High) Confidence at 99% Gi* > 2.56	Nong Mai Daeng, Khlong Tamru, and Napa (Very High)	Moran's Index 0.430043 z-score 8.452633 p-value 0.000000

The risk areas classified as stolen motorcycle hot spot under the jurisdiction of Mueang Chonburi Police Station were evaluated using Getis-Ord Gi*, IDW, and Global Moran's I. The findings indicate that the highest spatial clustering crime trend occurred in Nong Mai Daeng, which exhibited the highest risk level, followed by Khlong Tamru, which, located adjacent to Nong Mai Daeng. Police operations in these locations necessitate heightened attention. Police authorities can strategize the crime analysis results to plan the augmentation of police red box checkpoints and police patrols within high-risk areas for crime prevention.

Khlong Tamru was identified as the second high-risk area for motorcycle theft according to the results of all methods each year. Due to its predominantly industrial setting and proximity to Nong Mai Daeng, the lifestyle of employees in Khlong Tamru commonly use motorcycles for daily transportation, and many workers live in Nong Mai Daeng, Khlong Tamru, and Napa. Therefore, the primary determinant contributing to the elevated risk level in Nong Mai Daeng is not solely attributed to land use variables within the area itself, but also to land use elements in the surrounding such as Khlong Tamru and Na Pa, which consequently impact the incidence of stolen motorcycles crime in Nong Mai Daeng.

Based on data from 2019 to 2023, the COVID-19 pandemic significantly changed travel behavior, possibly creating a permanent shift in travel volume, frequency, and destinations. Many countries have implemented mobility restriction measures. On March 10, 2020, the Governor of Thailand declared a state of emergency in Thailand to address the COVID-19 pandemic. All schools were closed, and individuals were required to remain at home. The policy had an impact on both criminals and victims across several spatial and temporal dimensions. In 2019, the number of stolen cases amounted to 55. The majority of criminal incidents occurred

in apartments-type land-use, specifically rooms for rent, with a total of 21 cases. Private dwellings followed closely behind with 13 cases, while marketplaces, shops, and department stores accounted for 7 cases. Four cases involving institutional land. In 2020, during the Covid-19 outbreak, a total of 22 instances of motorcycle theft were documented, a decreasing from the previous year. In 8 occurrences, private residences were the most frequently tageted locations. Subsequently, there were 6 instances of apartments and rooms for rent, followed by 4 insidents in markets, shops, and department stores, and 1 case on institutional land. There were 3 cases involving other land use types, such as roadways and car parks. The majority of crime occurrences took place in private residences.

As a consequence of this Covid 19, many workers returned to their hometowns in other provinces. A smaller number of employees were residing in rented accommodations and individuals were unable to spend time outdoors. Consequently, perpetrators were rendered incapable of pilfering motorcycles from either the market or store.

4. Conclusions

To analyze the risk areas of motorcycle theft under the jurisdiction of Mueang Chonburi Police Station in Thailand, this study evaluated data were evaluated using Getis-Ord Gi*, IDW and Global Moran's I. The findings indicate that Nong Mai Daeng exhibits the highest risk level, followed by Khlong Tamru, which is adjacent to Nong Mai Daeng. The analysis utilizes crime statistics spanning the years 2019 to 2023. The IDW interpolation approach was employed to enhance the visualization of results obtained from the Getis-Ord Gi* hot spot study. The areas of Nong Mai Daeng and Khlong Tamru have been classified as crime hot spots characterized by a significantly high-risk level. Police services in these locations necessitated heightened attention. Nevertheless, it can be inferred that none of the procedures alone exhibit a high level of accuracy and yield consistently precise outcomes for hot spot detection. Each method demonstrates effectiveness in isolation and can be employed according to specific requirements. If law enforcement authorities want to strategize the augmentation of police red box checkpoints and patrols within high-risk areas. It is possible to utilize the outcomes obtained via Gitis-Ord Gi*, IDW and Global Moran's I. This paper presents a proposed method for addressing the issue of stolen motorcycles within the jurisdiction of Mueang Chonburi Police Station, incorporating the principle of Crime Prevention through Environment Design (CPTED).

(1) The identification of risk areas for stolen motorcycles can enhance the CPTED strategy. It is advised that the Mueang Chonburi Police Station consider implementing a heightened presence of police red box checkpoints and police patrols in the high-risk areas of Nong Mai Daeng and Khlong Tamru. A greater presence of police patrols is needed in response to the recurrent criminal activities. Landscape management should improve the lighting and use closed-circuit television (CCTV) in places with a high risk of incidents. It is recommended that the Mueang Chonburi Police Station inform the inhabitants living in high-risk areas of the implementation of fences encircling their residences. The effective management of unoccupied land by local government agencies plays a vital role in reducing the likelihood of hazardous situations. It is recommended that the market increase the number of security staff and implement rigorous supervision of the entrance and exit gates. Each of these measures has the potential to increase perceived risk for offenders.

(2) The theories of criminal behavior presented by Beccaria and Bentham revolve around the concept of rational choice. Bentham's research suggests that the main driving force behind individuals' involvement in illicit activities is the potential for acquiring gains or advantages, whereas the deterrent to such action is the following encounter with pain or punishment. Hence, to effectively tackle the problem of stolen motorcycles, the Thai government should consider supporting the adoption of e-bike as a viable alternative to motorcycles. Smart chips should be used in e-bikes to prevent theft. The cost of e-bikes is comparatively cheaper than that of motorbikes. As a result, the criminals will incur financial losses due to their illegal actions, while the associated punishments for property theft remain unchanged. For example, the Wuhan Municipal Bureau of Public Security recorded a total of 1594 stolen electric bicycles between January 1, 2013, and August 31, 2013 (Yue et al., 2017). In 2018, the municipality of Wuhan, located in Central China, implemented its version of the Internet of Things (IoT) to mitigate theft involving electric bicycles owned by its residents. Wuhan successfully deployed this IoT network, incorporating intelligent chips into a fleet of 560,000 electric bicycles, therefore achieving comprehensive urban coverage. There has been a 40 percent reduction in the number of e-bikes that are currently missing compared to the prior year (Laine, 2018). To safeguard the safety of riders and promote their confidence in using e-bikes, the Thai government must establish a separate bike lane exclusively for e-bikes, apart from the existing car lanes. Nonetheless, the analysis identified a constraint indicating that in 2020, incidents of motorcycle theft were the lowest compared to prior years, attributable to the Covid-19 pandemic.The Getis-Ord Gi* and IDW methods did not produce significant results in 2020. There was a total of 22 occurrences of motorbike theft in the study area, which influenced the results of the crime analysis. Consequently, future research endeavors should employ alternative methodologies, such as Kernel Density Estimation (KDE), to substantiate the findings of risk area analysis

5. References

Alabi, M. O., & Abubakar, E. O. (2023). Sustainable urban form: Socio-demographic and permeability factors as determinants of crime spots in cities, case of Akure, Nigeria. *Urban Planning and Transport Research*, 11(1), 1–22. https://doi.org/10.1080/21650020.2023.2195469

Alkaabi, K. (2023). Identification of hotspot areas for traffic accidents and analyzing drivers' behaviors and road accidents. *Elsevier Ltd Journal*, 1–15. https://doi.org/10.1016/j.trip.2023.100929

Amta Company Limited. (2017). Amta Sustainability Report 2017. AMTA.

International Association of Chiefs of Police. (2017). Auto theft educational awareness report. https://www.theiacp.org/sites/default/files/2018-09/IACP%20VCC%20Auto%20Theft%20Educational%20Awareness %20 Report_ 0.pdf

Khan, I. U., Vachal, K., Ebrahimi, S., & Wadhwa, S. S. (2023). Hotspot analysis of single-vehicle lane departure crashes in North Dakota. *IATSS Research*, 47(1), 25–34. https://doi.org/10.1016/j.iatssr.2022.12.003

Laine, E. (2018). Wuhan make its own Internet of Things for e-bike; theft down nearly 40%. https://www.yicaiglobal.com/news/wuhan-makes-its-own-internet-of-things-for-e-bikes-theft-down-nearly-40

Makrit, A., & Vichuwanich, W. (2021). Crime mapping and spatial analysis of motorcycle thefts in the Thai-Cambodian border in Sa Kaeo Province using the geographic information system. *Research Journal Rajamangala University of Technology Thanyaburi*, 20, 1–15. https://doi.org/10.14456/rj-rmutt.2021.8

Mohammed, A. F., & Baiee, W. R. (2020). Analysis of criminal spatial events in GIS for predicting hotspots. In *Proceedings of the 2nd International Scientific Conference of Al-Ayen University* (pp. 1–9). IOP Publishing Ltd. https://doi.org/10.1088/1757-899X/928/3/032071

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. https://doi.org/10.1016/j.sbspro.2011.07.020

Yue, H., Zhu, X., Ye, X., & Guo, W. (2017). The local colocation patterns of crime and land-use features in Wuhan, China. *ISPRS International Journal of Geo-Information*, *6*(10), 307. https://doi.org/10.3390/ijgi6100307